THE UNIVERSITY OF CHICAGO

TOWARD A SOCIOLOGY OF ECONOMIC ENGINEERING: THE CREATION AND COLLAPSE OF CALIFORNIA'S ELECTRICITY MARKETS BETWEEN 1993 AND 2001

A DISSERTATION SUBMITTED TO

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To my mother,
who has shown me the kind of person one should try to be

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Acknowledgements

The work on this dissertation began in 2017. I first became interested in electricity markets after learning that the Enron scandal was a sideshow in the larger drama of the Western energy crisis. The markets had created systemic opportunities and incentives for manipulative behavior and so it was a pervasive feature of these markets. Reading a literature that was dominated by stories of corporate crime and incompetent politicians, I began to sense that another story might be hidden beneath the frantic search for culprits. This story would have to do with economists' failed attempt to build synthetic electricity markets according to a theoretical ideal, creating a structurally flawed system. More than three years of scholarly work followed this first sense of discovery. The subsequent journey has been longer and more circuitous than I ever imagined. It required me to learn about subjects and methods outside my disciplinary training, and forced me to straddle ideas from sociology, engineering, economics, market design, and philosophy. Thanks to generous funding from the Mellon Foundation, the Sociology Department at the University of Chicago and the Stigler Center at the Booth School of Business, I had the time to do so. These different grants allowed me to dedicate most of my time in the final years of graduate school to this project. I am forever grateful for this opportunity.

First and foremost, I would like to thank my interviewees who took time out of their busy schedules to talk to me. Many of them agreed to meet not just once but several times and patiently answered follow up questions, cleared up confusions, and provided rich background information about the case. Some also shared information and documents from their private archives. Without this otherwise unavailable material several core insights about the intricate workings of California's organizations would have never emerged. Thanks to all of them for their selfless support of my project.

Without funding and the patience of my interviewees, this project would have been materially impossible. But the actual work of analyzing the data and building an argument required more than that. At many points during the last three years, I felt that the wealth of material and the sheer technical complexity of the topic would overwhelm me. Even when I pushed on and finally mastered details of technical blueprints from the late 1990s or flowcharts from long-derelict organizations, I often felt lost. More often than I would like to admit, I had no clear idea how the material would assemble into a larger argument, or how anything of interest could possibly emerge for the larger discipline. Without the support of my advisors and friends, I doubt I would have found my way out of these dead ends.

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While my committee shaped the dissertation, sharpened its analytical focus, and held me to high analytical standards, my colleagues and friends at the sociology department helped me to develop the minutia of the arguments I present in the following pages. Though Timothy Elder, Andrew Swift, and Austin Kozlowski would reliably make fun about my love for 'the condition of the possibility of mah-kets', they were also endlessly willing to listen to my arguments, play devil's advocate, and push back when they thought I had wandered off into the occult regions of technical details. My love for this project and sociology in general owes much to our drunken evenings of mirth and sociology.

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Acronyms and Abbreviations

A/C – Alternating Current

CAISO – California Independent System Operator

CFD – Contract for Differences

CLECA – California Large Energy Consumers Association

CMA – California Manufacturer's Association

CPUC – California Public Utility Commission

CTC – Competitive Transition Charge

D/C – Direct Current

DOJ – Department of Justice

EIA – U.S. Energy Information Administration

EOB – Electricity Oversight Board

EOL – Enron Online

ESP – Energy Service Provider

FERC – Federal Energy Regulatory Commission

FTC – Federal Trade Commission

FTR – Financial Transmission Right

FPA – Federal Power Act, 16 U.S.C.

GPU – General Public Utilities Corporation

HHI – Herfindahl-Hirschman Index

IPP – Independent Power Producer

IOU – Investor Owned Utility

LMP – Locational Marginal Pricing

MOU – Memorandum of Understanding (Submitted to CPUC September 1995)

MW – Megawatt

PECO – Pennsylvania Energy Company

PEPCO - Potomac Electric Power Company

PG&E – Pacific Gas & Electric

PJM – Pennsylvania-New-Jersey-Maryland Independent System Operator

PURPA – Public Utilities Regulatory Policy Act (1978)

PX – Power Exchange

QF – Qualifying Facility

RSI – Residual Supplier Index

SAB – Schedule Adjustment Bid

SC – Scheduling Coordinator

SCE – Southern California Edison

SDG&E – San Diego Gas & Electric

TAC – Trust Advisory Committee

TURN – The Utility Reform Network

UCAN – Utility Consumer Action Network

VOLL – Value of Lost Load

WEPEX – Western Power Exchange Process

Key to Archival Sources

Newspapers:

SFC – San Francisco Chronicle

SF Gate – San Francisco Gate

LAT – Los Angeles Times

WP – The Washington Post

NYT – The New York Times

CEC – California Energy Commission, Report Number, Sacramento, California, accessible under: https://ww2.energy.ca.gov/publications/searchReports_cms.php

Physical Archives:

CSA – California State Archives, Sacramento, CA.

CPUC – Docket R.94-04-031/I.94-04-032, California Public Utility Commission Archive, San Francisco, California.

FERC – Federal Energy Regulatory Commission

Convention for FERC citations:

For Orders: "Order Name," decision number *FERC* paragraph number, (date)

For Cases: *Party Name*, decision number *FERC* paragraph number, (date)

For Evidence and Other Submissions: "Document Title," *FERC* docket number.

Abstract

This dissertation examines the creation and catastrophic failure of California's electricity markets in the period between 1993 and 2001. It looks at this case as an extreme example of failed market design. No longer content to merely describe the world, market designers try to create institutional frameworks that can enforce the idealizing assumptions of economic theory. The dissertation asks why the California markets were built in such a way that they became vulnerable to widespread corporate crime. The first part reconstructs the structural preconditions for the Western energy crisis. It finds that the markets suffered from a self-destructive dynamic that would have pushed the system to the brink of collapse even absent the proximate causes usually stressed by the literature. To understand what prompted the design decisions that triggered this dynamic, I look at three different domains of design work: politics, regulation, and technical implementation. I show that each domain posed unique problems to the realization of the market designers' vision. In political processes, designers struggled to obtain jurisdiction over decisions that violated the principles of market design. In technical contexts, their decisions suffered from "blindspots" that were embedded in the theoretical blueprints they used in their work. Finally, in regulatory contexts, market designers underestimated the oversight requirements of their market mechanisms. Their silence led regulators to create the monitoring protocols on the basis of a flawed imaging of the new markets. Apart from developing a new explanation of the California energy crisis, the dissertation develops a theoretical perspective on market design work as a form of centralized planning. It argues that the practical design problems go back to an unspoken tension between a mechanistic and an emergentist understanding of markets that is implicit in the intellectual project of market design. This tension calls for contradictory design decisions. Since only a control structure can potentially resolve these contradictions, success and failure of market design ultimately hinges on the requirements for effective market oversight. If the allocation problem requires adaptive, interdependent markets with narrow standards of calculative rationality, these requirements become so extensive that they bring classic problems of centralized planning back into the project. The study is based on extensive archival material from three different archives and seventy-five in-depth interviews.

1. Introduction

1.1. A New Form of Social Engineering

The confidence in Western societies' political institutions is declining.[1] Democratic processes seem increasingly ill-equipped to deal with the myriad challenges that emerge from financial crises, global warming, overpopulation, migration, and many other global problems. In a world of "post-truth politics," the political spectrum polarizes, populist movements spread, and demagogues ascend.[2] Perhaps in reaction to the looming crisis of the democratic state, we observe a new fascination with projects of social engineering. Their architects envision technological solutions to social problems that will be implemented by benign groups of experts.[3] A particularly ambitious new vision of technocratic rule emanates from an unlikely corner of the intellectual universe: formal economics.

To the public, economists are usually perceived as stewards of laissez-faire politics and believers in the superior wisdom of the free market. But this perception has been inaccurate for some years. Today, most economists distance themselves from the kind of market enthusiasm that drives political debate. Consider the following quote from the recent *Good Economics for Hard*

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[1] By 2017, Europeans' confidence in political institutions had dropped continuously since the onset of the Euro-crisis in 2009, though the results differed by nation and socio-economic status. Chase Foster and Jeffry Frieden, "Crisis of Trust: Socio-Economic Determinants of Europeans' Confidence in Government," *European Union Politics* 18, no. 4 (2017). In the U.S., trust in governmental institutions has repeatedly declined after moments of crisis, such as the financial meltdown of 2007–08. Donald Trump's election to President of the U.S. has been linked to a prior loss of trust in politics as well. Kenneth Newton, Dietlind Stolle, and Sonja Zmerli, "Social and Political Trust," in *The Oxford Handbook of Social and Political Trust*, ed. Eric M. Uslander (Oxford, UK: Oxford University Press, 2018), 50.

[2] The polarization of political camps has been well documented in the U.S. Pew Research Center, *The Partisan Divide on Political Values Grows Even Wider*, (Washington D.C.: Pew Research Center, 2017), 8. https://www.people-press.org/2017/10/05/8-partisan-animosity-personal-politics-views-of-trump/, last accessed 02/23/2020.

[3] The phenomenon has also been referred to as Silicon Valley's "solutionism," i.e., the tendency to think that all problems are amenable to digital quantification, tracking, and/or gamifying of behavior. Evgeny Morozov, *To Save Everything, Click Here: The Folly of Technological Solutionism* (New York: Public Affairs, 2013). For a particularly drastic proposal for a new technocracy, c.f. Parag Khanna, *Technocracy in America: Rise of the Info-State* (CreateSpace, 2017).

Times. Here, the two most recent recipients of the Bank of Sweden Nobel Memorial Prize in Economic Sciences,[4] Abhijit V. Banerjee and Esther Duflo, write:

> The self-proclaimed economists on TV and in the press—chief economist of Bank X or Firm—are, with important exceptions, primarily spokespersons for their firms' economic interests who often feel free to ignore the weight of the evidence. Moreover, they have a relatively predictable slant toward market optimism at all costs, which is what the public associates with economists in general.[5]

Their wariness reflects a shift in economic thinking that has evolved over several decades. Since the 1970s, various economic subdisciplines gradually refocused economics away from mathematical theories of ideal markets and towards applied, empirical research.[6]

In the course of this reorientation, economists have come to recognize that real market environments rarely meet the idealizing assumptions of economic theory and fail to produce the welfare benefits of perfectly competitive markets. Empirical market settings are riddled with processes that create "market failures" and produce inefficient aggregate outcomes. Equilibria are rare and rarely efficient. By now, the once powerful idea of perfectly competitive markets has dwarfed into a distant star whose light provides guidance on the sea of empirical research, but no one thinks that it reflects how real markets work.

Nonetheless, the Enlightenment legacy of Adam Smith's "invisible hand" continues to influence the discipline. Economists study real markets primarily in terms of deviations from the theoretical ideal. The ideal thus maintains *normative* force, which leads to the impression that the

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[4] Contrary to common belief, this price is not actually awarded by the Alfred Nobel Foundation.

[5] Abhijit V. Banerjee and Esther Duflo, *Good Economics for Hard Times: Better Answers to Our Biggest Problems* (Hachette Book Group, 2019), 5.

[6] Roger E. Backhouse and Béatrice Cherrier, "The Age of the Applied Economist: The Transformation of Economics since the 1970s," *History of Political Economy* 49, no. Supplement (2017). The orthodoxy of pure theory associated with the "neoclassic synthesis" was dominant between 1940 and 1970, but it was never absolute. Economics has always housed heterodox approaches. These often lingered in obscurity before breaking powerfully into the mainstream. Michel Beaud and Gilles Dostaler, *Economic Thought since Keynes: A History and Dictionary of Major Economists* (New York: Routledge, 2005), 92,141-50.

real-world deviations are problems. Behavior that diverges from enlightened self-interest is read as irrational or guided by cognitive bias.

For example, in their book *Animal Spirits*, the renowned economists George Akerlof and Robert Shiller write that the ideal of perfectly competitive markets "fails to take into account the extent to which [actors] are irrational or misguided. It ignores the *animal spirits*."[7] While they reject the ideal, at the same time they affirm its normative power. They point to people's deficient rationality as the reason for the rejection of the ideal. When real markets appear as intransigent and messy deviations from a counterfactually valid ideal, it is only a small step to the question of how one might *resolve* the deficiencies of the real world.

This is where a new form of social engineering enters the stage: market design. A growing number of economists are no longer content describing the shortcomings of real markets. Instead, they seek to create social institutions that can enforce the assumptions of economic theory by design. Such "economic machines" lead individuals to act in ways that mimic the rational utility maximizers of economic theories. Once institutional frameworks coerce people to realize the behavioral prescriptions of economic theory, the equilibria promised by the invisible hand become the constructions of the economist qua engineer.

It is hard to overstate how radical the idea of market design is. It effectively turns economics from an explanatory enterprise into one of construction; from a science into a political project of human self-transcendence. Market designers are less interested in understanding how the social process works and more interested in shaping it. This changes the fundamental, epistemic

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[7] George A. Akerlof and Robert J. Shiller, *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism* (Princeton, NJ: Princeton University Press, 2010), 3. This line of thinking continues in their more recent book *Phishing for Phools* where they show how market pressures encourage manipulative and deceptive strategies that capitalize on peoples' animal spirit. *Phishing for Phools: The Economics of Manipulation and Deception* (Princeton, NJ: Princeton University Press, 2015).

orientation of the discipline and leads to different criteria for the validity of theoretical statements. Whether a given proposition is true no longer depends on its ability to answer a question relative to some standard of measurement and inference. It depends on the ability to create a set of social arrangements that realize the proposition. For example, the assumption that agents act rationally is no longer problematic because it is unrealistic. Whether or not it is problematic now depends on designers' ability to enforce a particular logic of decision-making by means of institutional design. The fundamental shift is visible in the company that market designers keep. They no longer mainly cooperate with other social scientists. Their preferred company are now experts from applied disciplines like computer science, engineering, and operations research. In other words, we are dealing with a completely different beast than economic sociology usually expects.

The significance of economics' transformation has likely been overlooked because designers initially applied their engineering approach to relatively few allocation problems.[8] Early examples include a program to allocate landing slots to airlines and to auction off the Federal Communication Commission's (FCC) spectrum licenses to telecommunication companies.[9] However, in the last two decades, these new "engineers of the human soul" have expanded their work significantly.[10]

Apart from their work in universities, academic market designers have now started private companies that sell custom tailored market solutions to governments and corporations. Other market design companies assemble academics, but train them outside the university.[11] Virtual trading

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[8] Another reason for the lack of attention to this shift is that mechanism design is usually considered to be the core of market design. However, in the university, mechanism design is one of the most theoretical and abstract parts of the discipline. I will define market design more carefully later on.
[9] Alvin E. Roth and Tayfun Sönmez, "A Kidney Exchange Clearinghouse in New England," *American Economic Review* 95, no. 2 (2005).
[10] Philip Mirowski, "Information in Economics: A Fictionalist Account," *Schmollers Jahrbuch* 136 (2016): 17.
[11] Peter Cramon, for example, founded MDI Market Design Inc. Other companies are ECCO Market Design or The Brattle Group Market Design, which specialize in energy markets.

platforms like Uber and Amazon now rely on principles of market design to match buyers and sellers. Governmental agencies employ market designers to tweak the infrastructures of electronic clearing houses. Policy makers debate the use of synthetic markets for problems ranging from refugee allocation and emission reduction to the accessibility of healthcare.[12]

Two technological developments contribute to this trend. On the one hand, the rise of Big Data and its measurement techniques make economic life increasingly visible.[13] As never before, it is possible to track and analyze individual behavior on a granular level and in real time. On the other hand, the *form* of economic interaction becomes amenable to human control. This is perhaps even more important. To the extent that economic interactions take place over software interfaces, designers can quickly change parameters of interactions and use computer algorithms to manipulate how they aggregate. By relocating economic life into virtual worlds of their own making, the engineers can control all parameters of economic interactions, including the complexity of the resulting economic process. The increased visibility and control of market activities multiplies the opportunities for economic engineering. It turns market design into a comprehensive approach for the solution of almost arbitrary allocation problems.

Even though market design proliferates, and many academic observers express sheer boundless optimism for this new technique, the experiences have been mixed.[14] While some "smart markets" continue to operate without major problems, others have failed catastrophically or

[12] Scott D. Kominers, Alexander Teytelboym, and Vincent P. Crawford, "An Invitation to Market Design," *Oxford Review of Economic Policy* 33, no. 4 (2017).
[13] Marion Fourcade and Kieran Healy, "Classification Situations: Life-Chances in the Neoliberal Era," *Accounting, Organizations and Society* 38, no. 8 (2013); "Seeing Like a Market," *Socio-Economic Review* 15, no. 1 (2016); Stefan Timmermans and Steven Epstein, "A World of Standards but Not a Standard World: Toward a Sociology of Standards and Standardization," *Annual Review of Sociology* 36 (2010).
[14] Eric A. Posner and Glen E. Weyl, *Radical Markets: Uprooting Capitalism and Democracy for a Just Society* (Cambridge, MA: Princeton University Press, 2018).

produced ambiguous results.[15] Failure may mean that the markets do not conform to the mechanisms outlined in the economists' blueprints. But failure can also mean that markets do not produce the results promised by the theory. For example, despite being generally celebrated as a success, the FCC auctions to allocate spectrum licenses failed to meet at least one crucial goal: they did not distribute the licenses among a large number of companies.[16] Similarly, despite almost fifteen years of development, the European Union (EU) scheme for trading carbon dioxide emissions continues to generate inefficient allocations of certificates.[17] Yet, other synthetic markets work exactly as advertised. For example, the spot markets for Feeding America have drastically reduced food waste from donations.[18] Given the mixed experiences, it is crucial to ask: How do you explain why some designs work as intended while others fail?

Though there is a relatively developed literature on experiments with market design, economic sociology has not yet asked this question. The existing research on market design falls into two camps. The literature on performativity forms the first camp. It starts with the assumption that all economic theories are complicit in creating the world they purport to describe.[19] Modern markets are suffused with economic knowledge that "formats" the interactions through legal rules,

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[15] Peter Cramton, "Electricity Market Design," *Oxford Review of Economic Policy* 33, no. 4 (2017): 593.
[16] Stephen Labaton and Simon Romero, "Wireless Giants Won F.C.C. Auction Unfairly, Critics Say," *The New York Times* 12 (2001).
[17] Y. H. Chiu et al., "An Efficiency Evaluation of the E.U.'S Allocation of Carbon Emission Allowances," *Energy Sources, Part B: Economics, Planning, and Policy* 10, no. 2 (2015).
[18] Canice Prendergast, "The Allocation of Food to Food Banks," (Chicago, IL: University of Chicago Booth School of Business, 2016).
[19] C.f. Ivan Boldyrev, "After the Turn: How the Performativity of Economics Matters," in *Enacting Dismal Science*, ed. Ivan Boldyrev and Ekaterina Svetlova (New York: Palgrave, 2016); Nicolas Brisset, *Economics and Performativity: Exploring Limits, Theories and Cases* (London, UK: Routledge, 2018); Michel Callon, "What Does It Mean to Say That Economics Is Performative?" in *Do Economists Make Markets? On the Performativity of Economics*, ed. Donald MacKenzie, Fabian Muniesa, and Lucia Siu (Cambridge, MA: Princeton University Press, 2007); Donald MacKenzie, Fabian Muniesa, and Lucia Siu, eds., *Do Economists Make Markets? On the Performativity of Economics* (Cambridge, MA: Princeton University Press, 2007); Trevor Pinch and Richard Swedberg, *Living in a Material World: Economic Sociology Meets Science and Technology Studies*, vol. 1 (Cambridge, MA: MIT Press, 2008), 57-58.

information systems, even the spatial and temporal configuration of the market.[20] But it is historically contingent on what extent economic models shape economic practice. Social factors such as organizational structure, embeddedness, and culture determine whether an economic context "performs" the claims of a theory.[21]

From the perspective of this literature, economic engineering cannot be understood as mechanical, one-step implementation of a theoretical blueprint.[22] Instead, it is a complex, iterative process of slowly creating a social infrastructure that bears resemblance to the model. For example, in his analysis of the FCC spectrum auctions, Guala shows how market designers became progressively aware of the social, technological, and political realities that impacted the correct functioning of their economic machine. Making it work was a slow, iterative process of building, testing, and adapting, and the designers relied on experiments to test the feasibility of their models.[23] In this literature, economists laboriously constructed correspondences between economic theory and markets in the face of practical challenges.[24]

The second line of research takes a somewhat different perspective. This research is informed by a theoretical literature that describes markets as the product of political struggles

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[20] Michel Callon, ed. *The Laws of the Markets*, vol. 6 (Oxford, UK: Blackwell, 1998), 16; "What Does It Mean to Say That Economics Is Performative?" 315.
[21] Donald MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets* (Cambridge, MA: MIT Press, 2006); "Is Economics Performative? Option Theory and the Construction of Derivatives Markes," in *Do Economists Make Markets? On the Performativity of Economics*, ed. Donald MacKenzie, Fabian Muniesa, and Lucia Siu (Cambridge, MA: Princeton University Press, 2007).
[22] Daniel Breslau, "What Do Market Designers Do When They Design Markets?" in *Social Knowledge in the Making*, ed. Charles Camic (Chicago: University of Chicago Press, 2011), 380.
[23] Francesco Guala, "Building Economic Machines: The F.C.C. Auctions," *Studies in History and Philosophy of Science* 32, no. 3 (2001).
[24] Marie-France Garcia-Parpet, "The Social Construction of a Perfect Market: The Strawberry Auction at Fontaines-En-Sologne," in *Do Economists Make Markets? On the Performativity of Economics*, ed. Donald MacKenzie, Fabian Muniesa, and Lucia Siu (Cambridge, MA: Princeton University Press, 2007); Francesco Guala, "How to Do Things with Experimental Economics," in *Do Economists Make Markets*, ed. D Muniesa MacKenzie, Fabian Muniesa, and Lucia Siu (Cambridge, MA: Princeton University Press, 2007).

between stakeholders.[25] Market design experiments are accordingly not neutral processes that follow a logic of progressive, technical mastery. Instead, they are political processes in which economists provide only one voice among many. Economists' blueprints should therefore be treated as rhetorical tools or epistemic frameworks.[26] Different groups of stakeholders use the arguments provided by these frameworks to articulate their interests and shape market rules.

Although research in the political tradition has occasionally criticized the performativity literature as technocratic, the two perspectives are complimentary.[27] Performativity studies agree that practical processes of market creation are suffused with politics.[28] Rather, the two literatures differ mostly in focus. While performativity studies look at the technical and material dimension of processes that give rise to new market infrastructures, the alternative perspective focuses on the political dimension. Bringing the two sides together, the work of economists appears as a kind of "applied Platonism" in which theoretical models for market mechanisms serve as a guiding ideal.[29] The ideal configures and orients the political, social, and technological processes in which the participants identify and resolve practical problems, negotiate interests, and create the new market infrastructure.

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[25] Pierre Bourdieu, *The Social Structures of the Economy* (Cambridge, UK: Polity, 2005), 193-216; Neil Fligstein, "Markets as Politics: A Political-Cultural Approach to Market Institutions," *American Sociological Review* 61, no. 4 (1996); *The Architecture of Markets: An Economic Sociology of Twenty-First-Century Capitalist Societies* (Cambridge, MA: Princeton University Press, 2002).
[26] For the former approach, c.f. Frank Dobbin and Jiwook Jung, "The Misapplication of Mr. Michael Jensen: How Agency Theory Brought Down the Economy and Why It Might Again," in *Markets on Trial: The Economic Sociology of the U.S. Financial Crisis: Part B*, ed. Michael Lounsbury and Paul M. Hirsch (Bingley, UK Emerald Group Publishing Limited, 2010). For the latter: Daniel Breslau, "Designing a Market-Like Entity: Economics in the Politics of Market Formation," *Social Studies of Science* 43, no. 6 (2013): 830.
[27] Philip Mirowski and Edward Nik-Khah, "Markets Made Flesh: Performativity, and a Problem in Science Studies, Augmented with Consideration of the F.C.C. Auctions," in *Do Economists Make Markets?* ed. Donald MacKenzie, Fabian Muniesa, and Lucia Siu (Cambridge, MA: Princeton University Press, 2007); Ana C. Santos and João Rodrigues, "Economics as Social Engineering? Questioning the Performativity Thesis," *Cambridge Journal of Economics* 33, no. 5 (2009).
[28] MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets*, 147-50.
[29] Breslau, "What Do Market Designers Do When They Design Markets?" 382.

Both literatures have produced invaluable insights into the practical reality of market design. Yet, both locate the conditions for success or failure of economic design in the social conditions that determine how designers use the blueprints.[30] There can be no doubt that these conditions are important; since the blueprints are pragmatically undetermined and used in political struggles, the context of implementation is crucial for the resulting market structure.

Yet, the exclusive focus on application has prevented the development of a complimentary, critical perspective on the relationship between the intellectual project and its implementation. Most of the existing studies are descriptive and reject the idea that there is a categorical difference between the intellectual project and its execution. This makes it impossible to evaluate one in terms of the other and defines independent criteria of success and failure. Successful designs are simply those that come to be embedded in stable socio-technical assemblages whereas failed designs are those that are not. The descriptive orientation prevents the generation of critical counterfactuals.

Accordingly, the literature has not yet asked: Are there designs that are more feasible than others? Are there reasons why some models may be impossible to realize? Under what conditions do projects in market design succeed or fail to achieve the goals their designers aimed for? These questions point toward a different kind of critical engagement with economics. Normally, economics sociology evaluates the propositions of economics from an analytical point of view and asks: Is the world really like this?[31] However, the rise of economic engineering requires a different question. We now have to ask: Can the designers *make* the world like this?

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[30] "Designing a Market-Like Entity: Economics in the Politics of Market Formation," 830.
[31] This is the classic perspective economic sociology has taken toward economics. C.f. Mark Granovetter, "The Old and the New Economic Sociology: A History and an Agenda," in *Beyond the Marketplace: Rethinking Economy and Society*, ed. Roger Friedland and A. F. Robertson (New York: Aldine de Gruyter, 1990).

There are several reasons why it is important to answer this question. First, as market designers move to turn collective goods into commodities, the question has important welfare consequences. The social impact of market design failure is obvious: poorly designed markets will produce inefficient allocations and exacerbate inequalities. Before we begin to create synthetic markets for environmental services and refugee allocation, we should first examine the conditions for success and failure of market design.

Second, market design is part of a broader trend. The digitization of social life and the rise of Big Data mean that projects of social engineering permeate our everyday life. Wherever software architects put new communication infrastructures into place, they reshape social life in accordance with normative and instrumental ideas.[32] These projects of social engineering play out under different circumstances compared to historical attempts to control populations through centralized control. The software architectures make it possible to control the form of interaction and collect and process decentralized information in real time. Given that sociology is already complicit with these new projects of social engineering, it is high time we investigate the prospects and dangers of these projects.[33]

The emergence of market design also irritates some central intuitions in economic sociology. Much micro-sociological research views markets as highly variable social systems whose order is emergent and precarious. The stabilization of expectations is always the product of *local* coordination processes, networks, cultural scripts, etc.[34] This is one of the reasons sociologists are

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[32] Fourcade and Healy, "Seeing Like a Market."

[33] The social sciences have long had an affinity to projects of social engineering. It is only with the loss of political influence that sociology has found its main occupation in the appeal to liberal normative principles and the cataloguing of their violation. Peter Wagner, "Social Science and Social Planning During the Twentieth Century," in *The Cambridge History of Science: Volume 7: The Modern Social Sciences*, ed. Dorothy Ross and Theodore M. Porter, The Cambridge History of Science (Cambridge: Cambridge University Press, 2003).

[34] Jens Beckert, "The Social Order of Markets," *Theory and Society* 38, no. 3 (2009).

skeptical about the models that economists develop: their theories seem to overgeneralize to a point where the belief in the self-regulatory capacity of markets becomes ideological. This theme goes back to the beginning of the discipline. Polanyi already wrote laconically: "Laissez-faire was planned, planning was not."[35] The pithy statement encompasses much of the contemporary wisdom on the role of economics in politics. The theories posit mechanisms of self-regulation that are ideological because they depend on institutional foundations they cannot guarantee and do not recognize. But market design promises to lift this ideological veil. If economics provides blueprints to *plan* market processes and force them into alignment with a theoretical model, the standard critique is no longer valid. Economics now seeks to account for the institutional foundations that can guarantee it. Perhaps, this allows them to avoid the kind of contradictions that Polanyi had in mind? At the very least, economists' move to market design challenges micro-sociological ideas about the determinants of market order.[36]

Conversely, market design may also undermine ideas that sociology has taken over from economics. It has long been observed that economic sociology has a curiously indeterminate concept of the market.[37] We usually ask questions on the level of firms or networks of firms, but not on the level of the market as a whole.[38] When the market shows up as an analytical entity, we thus tend to smuggle ideas from economics into our own thinking. For example, sociologists who

[35] Karl Polanyi, *The Great Transformation - the Political and Economic Origins of Our Time*, 2nd ed. (Boston, MA: Beacon Paperback, 2001 [1944]), 147.
[36] In other words, we have to reconsider claims about the emergent nature of order in markets, which are fundamentally based on the role of Knightian uncertainty in economic life. In a way, market design is an attempt to reduce Knightian uncertainty to stochastic uncertainty, i.e., uncertainty about which choice from a set of choices actors will find useful. Of course, this is also where the problems of market design manifest most clearly. Jens Beckert, *Beyond the Market: The Social Foundations of Economic Efficiency* (Princeton, NJ: Princeton University Press, 2002), 286.
[37] Greta R. Krippner, "The Elusive Market: Embeddedness and the Paradigm of Economic Sociology," *Theory and Society* 30, no. 6 (2002).
[38] Neil Fligstein and Luke Dauter, "The Sociology of Markets," *Annual Review of Sociology* 33 (2007); Christine Overdevest, "Towards a More Pragmatic Sociology of Markets," *Theory and Society* 40, no. 5 (2011).

operate with a rational actor framework often assume that market competition does produce allocative efficiency.[39] Here, sociology sometimes echoes the idea that social processes "distort" or enable the theoretical principles of competitive markets. If it turns out that the allocative efficiency of markets depends on highly specific institutional designs that enforce narrow forms of interactions, we may have to revisit these assumptions. Then again, if these assumptions *can* be enforced, we may also have to revisit critical theories that reject them.

In sum, the question about the conditions for the success and failure of market design point to a new research agenda for economic sociology. This research agenda asks, "Under what conditions do economists succeed or fail to build the markets they envision?" As market design proliferates, this question is of theoretical and empirical importance.

1.2. The Research Question

This dissertation seeks to engage this question by studying in-depth an extreme case of failed market design: the creation and subsequent collapse of California's wholesale markets for electricity between 1993 and 2001. By choosing a case that not only posed particularly high barriers to successful design but also failed, I try to reveal a broad range of problems that market designers might confront in their work.[40] The creation of electricity markets is an extreme case because electricity systems have unusual features that pose challenges to designers.

The difficulties begin with the industry structure. Throughout the twentieth century, the industry and its regulatory environment evolved around vertically integrated monopolies. The legal, organizational, and material infrastructures of the industry was thus not built to sustain

[39] This is implicit in much network research on markets, e.g., Mark Granovetter, "The Impact of Social Structure on Economic Outcomes," *The Journal of Economic Perspectives* 19, no. 1 (2005).
[40] See the next section for a more detailed justification of the research design.

competition. Creating new markets required substantial transformations not only to the structures of ownership but also organizational and physical infrastructures.

Further, electricity grids are complex technical systems that obey the laws of physics, are extremely vulnerable to minor disruptions, and provide a service that is foundational to modern societies. Any artificial market has to operate in close and consistent coordination with the complex, technical activities of grid management—that is, these technical activities create specific requirements for the outcomes that market designers must be able to ensure with their mechanisms.

Lastly, electricity itself lacks almost all characteristics of a regular commodity: once generated and fed into the grid, it cannot be individuated or stored (easily). It travels at close to the speed of light, needs to be consumed the second it is produced, and kills people with ease. In sum, almost every aspect of the electricity industry is inconsistent in the way standard markets operate. This makes market design a formidable challenge. Even after twenty years of experience with market design *after* the events in California, a prominent market designer told me, "Any [electricity] market we design is going to have imperfections in it."[41]

And indeed: California's early and ambitious plan to meet these intellectual challenges came to a devastating conclusion. The electricity markets first opened in 1998 after five years of intensive design efforts. In the beginning, the transition from a regulated industry to a system of competitive markets seemed flawless. The markets reduced the price of electricity across the state, and the system operated without major problems. Experts who had built the markets were flown around the country—all expenses paid—to tell the tale of their success. But then, in April and May of 2000, sudden price spikes started to rattle the markets. Before too long, the crisis escalated. Utilities approached bankruptcy, the political and regulatory apparatus fell into paralysis, and the

[41] Interview with Peter J., 04/09/2018.

electricity system teetered at the brink of collapse. Rolling blackouts swept through the state until the state stepped in and took over.

A torrent of journalistic work, congressional investigations, administrative and criminal litigation, as well as legal and economic research followed the Western energy crisis. The question that uniformly motivated these investigations was: What caused the crisis and who is to blame? Following the spectacular collapse of Enron in December of 2001, it gradually became clear that dozens of sellers of electricity had manipulated the markets and driven up the prices. This spurred the development of two fundamentally different explanations for the crisis. While one side attributes the crisis mainly to the interplay of bad political decisions and economic fundamentals, the other side tells a story of greed and corporate conspiracy. Both agree on the basic factors that contributed to the crisis and the succession of the most important events, but they vigorously debate how these factors should be weighed and interpreted.

The existence of two narratives has to do with the fact that almost all academic research on the crisis has been conducted by scholars who are close to the industry. The dominant accounts have been produced by economists, lawyers, engineers, and politicians who were intimately connected with the creation of the markets or the subsequent litigation. Predictably, the energy merchants and their advisers tell the first story of political failure, while the California parties and its government tell variations of the story about corporate greed and crime. However, it is remarkable that even two decades of journalistic investigations and extensive litigation have not been able to move the weight of evidence to one side. Even after twenty years of sustained inquiry, the two narratives continue to coexist in uneasy tension.

Rather than confronting the debate head on, this dissertation is going to take a different analytical approach. Unlike most of the existing literature, it is less interested in the proximate causes of the crisis or how particular events form links in a chain that lead from the actions of a culprit to the crisis. Treating the California markets as an instance of failed market design, the dissertation will instead reconstruct the *structural preconditions* for the crisis and then trace their origin in different contexts of market design work.

From this perspective, the unsettled state of the empirical literature itself becomes part of the puzzle. The persistence of the two narratives suggests that some of the evidence that would be necessary to settle the score is fundamentally ambiguous or missing. Accordingly, the question becomes: Why did the designers not ensure that the markets were legible? Why did they not produce the information required to decide about the nature and prevalence of manipulative behavior? The fundamental ambiguity of the crisis is thus itself part of the market design failure and needs to be explained.

To understand the origin of the structural features that enabled the crisis, we must then focus not on the events during the crisis, but on the design processes in the period between 1993 and 1998. While much research has acknowledged that the markets were "designed," almost no studies explore their creation as an instance of market design, i.e., as the intentional attempt by a group of market designers to realize a particular intellectual vision of how these markets should operate.[42] Studies usually assume that the design process was an example of the 1990s misguided obsession with "deregulation" and focus on the political processes that led to the creation of AB1890, the law that put restructuring into effect. Accordingly, they describe California's market

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[42] See, for example, the summary of the crisis in California's "green book," which analyzes the current challenges the electricity markets face against the background of the historical experience. CPUC, Policy and Planning Division: *California Customer Choice – An Evaluation of Regulatory Framework Options for an Evolving Electricity Market*, (San Francisco, CA: CPUC, 2018), 3. https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/Cal%20Customer%20Choice%20Report%208-7-18%20rm.pdf, last accessed 03/05/20.

design as the consequence of “naïve” political compromises or as the product of a corporate conspiracy by cunning power marketers who tried to design a system that they could game.

But the unusual technical characteristics of the industry required substantial efforts to create new institutions, organizations, computer infrastructures, and software. This, in turn, required the sustained work of experts. Not only did many of these experts track to California from some of the most prestigious institutions in the country; they also followed a comprehensive intellectual vision that had first been developed in workshops at MIT and Harvard during the late 1970s. This dissertation focuses on these processes.

Treating the California case as one of failed market design has not just a theoretical and an empirical justification; it is also a timely enterprise. In 2019, the headlines once again described an energy crisis in California. Rolling blackouts swept through the state, the government was stepping in to take over the provision of electricity, and the biggest utilities are once again facing bankruptcy. Despite twenty years of experience with market design, it seems that the markets are once again unable to sustain the financial structure of the industry, affecting the basic ability to deliver reliable energy. The markets did not generate the incentives to implement crucial transmission updates and seem unable to price the necessary mix of generation assets as the industry is flooded with renewable energy. These shortcomings suggest that electricity markets allow us to study some challenges to market design that are fundamental to the project itself *and* relevant for the current energy crisis in California.

In pursuit of deeper theoretical insights, my empirical analysis asks three questions about the creation of California’s energy markets in the 1990s: How did the markets deviate from the intellectual vision of market design? How did this create structural preconditions for the crisis? And, what processes led to the decisions that gave rise to the preconditions of the crisis? The answers to these questions reveal conditions that must be met for successful market design and explain why the experts were unable to meet these requirements in specific contexts of decision-making. This allows a final question: Given the shape of the requirements, could the markets have been realized or was the intellectual project logically and/or practically infeasible?

1.3. Overview of the Argument

The dissertation proceeds in two large steps that are subdivided into several chapters. The first part (chapters 3–6) introduces the case, reconstructs the intellectual vision of market design, shows how the California system worked as a response to the various design challenges, and then discusses how the system fell short of the ideal. This reveals the structural preconditions for the crisis and prepares the ground for the second half of the dissertation. The second part (chapters 7–10) traces the decisions that led to the preconditions for the crisis in three contexts of market design work: political debates before the California Public Utility Commission (CPUC), technical work in processes of implementation in the Western Power Exchange (WEPEX) working groups and their successors, and regulatory debates before the Federal Energy Regulatory Commission (FERC). The conclusion summarizes the argument, generates some general propositions about the conditions for the success and failure of market design, and then sketches a research agenda for a new sociology of economic engineering.

Analytically, the dissertation takes a hybrid approach. The first part reconstructs basic criteria for successful market design. It asks what the intellectual project of market design entails, what would be required for its success, and in what way California failed to meet these requirements. To this end, I engage in a *conceptual* analysis of the intellectual history of market design. In other words, I reconstruct the internal logic of market design as a formal body of thought to uncover hidden assumptions. In conjunction with sociological theory, these assumptions provide basic requirements that must be met for market design to succeed. I then apply this framework to the case and show how California markets violated these requirements, gaining a new explanation of the California crisis. Crucially, the first part reconstructs a standard for the evaluation of market design that is *independent* from particular practices of market design. It compares the intellectual vision with reality and diagnoses where reality fell short. The second part, then, seeks to reconstruct the reasons why designers made decisions that led to the discrepancy between plan and reality. This involves an approach to market design as a social practice in which specific market designers tried to solve specific design problems. Here, I switch to a more classically sociological analysis and reconstruct the epistemic, organizational, and cultural conditions of design work on the basis of interviews and archival material. This leads to insights about the various difficulties that stand in the way of successful market design as a technique of social engineering. While the first part is thus a conceptual and structural analysis, the second part is a processual analysis of design work. Both complement each other as they develop increasingly refined criteria for the success of market design. I will now provide a more detailed overview of the argument.

After a brief section on research design, the argument begins with the third chapter, which introduces the case and the empirical questions that guide this dissertation. It outlines the progression of the Western energy crisis and reconstructs the two dominant narratives of the crisis from the secondary literature, the history of litigation, and quantitative datasets from the California Energy Institute. Against this background, I then introduce my own analytical approach to treat the California crisis as an instance of failed market design.

Having set up the trajectory of empirical questions that guides the different chapters, the fourth chapter reconstructs the intellectual vision of market design from the professional and intellectual history of economics. The central claim is that market design is a form of centralized planning that is able to respond to standard objections against similar experiments with social engineering. This sharpens the theoretical puzzle because it shows that market design ingeniously combines the advantages of centralized and decentralized decision-making. The question then becomes: How and under what conditions can market designers realize this division of labor?

The chapter begins by reconstructing the intellectual project of market design. Tracing the project back to the Socialist Calculation Debate of the 1930s, I show that market design conceptualizes markets as information processors. Market mechanisms appear as algorithms that solve constrained optimization problems. If the market participants follow the logic that the designers specify, their trades will execute a part of the algorithm. Software interfaces process the results from these interactions to complete the algorithm. Synthetic markets are thus hybrids of humans and software. To succeed, market designers have to enforce the logic of interaction as described by their theoretical mechanism. To this end, they develop institutions that configure the incentive market players face and allow the designers to monitor and control the resulting process.

While market designers seek to control the basic logic of interaction in the market, they leave it up to actors to make substantial decisions about trade, production, and consumption. The decisions of decentralized individuals become the inputs for the larger search algorithm, which is executed by their distributed activities. In this way, market design promises to combine decentralized and centralized planning. This promises to resolve the main problem with centralized planning.

As a brief survey of historical experiments with centralized planning shows, centralized bureaucracies face substantial problems in collecting, processing, and disseminating information from highly dynamic, distributed economic contexts. The division of labor in bureaucracies prevents the dynamic adjustments that are necessary to respond to unexpected needs and problems that decentralized economic processes may encounter. Since market designers try to offload most decisions onto individual actors, they might be able to avoid the problems of centralized planning.

However, the promise to combine centralized with decentralized decision-making is both the biggest asset and the Achilles heel of market design. There is an inherent tension between the need to allow substantive decisions by individuals and the need to enforce the interactional logic of the blueprint. The more freedom market participants have, the more likely they are to deviate from the model. But the more likely they are to deviate from the model, the more watchful and discerning the oversight regime has to become.

This generates the following hypothesis: If the requirements to enforce consistency with the blueprint grow to the point where they overwhelm decentralized decision-making, market design will fail for the same reasons that centralized planning failed—that is, if the difference between the form (logic of interaction) and substance of market action (decisions about production, consumption, and trade) collapses, market design will likely fail.

This hypothesis sets up the analytical trajectory of the dissertation. The analysis has to establish what kind of design decisions create room for deviations from the market mechanism and how this increases control requirements. It then has to explain what prompts these decisions and establish the limits for feasible control.

After establishing this analytical program, we move into the analysis of the case. Chapter five shows how California's system can be understood as an attempt to realize the intellectual vision of electricity market design. Specifically, I argue that the system resolved the central design challenges that the technological and organizational characteristics of the electricity system presented, but only under a set of normal operating conditions.

Chapter six then tells us how the markets fell short of the intellectual ideal of market design. This reveals the structural preconditions for the crisis and provides a novel account of the energy crisis. Most existing research identifies three design features that caused the crisis. These factors combined in such a way that California's three utilities had to buy energy at disadvantageous prices, which ultimately drove them to the brink of bankruptcy and led to the destabilization of the industry as a whole. First, the absence of forward contracts exposed utilities to the volatility of short-term spot markets. This rendered them vulnerable to sudden price increases. Second, fixed electricity rates in the retail markets rendered the demand of end users inelastic. Utilities who had an obligation to serve these end users thus had no way to reduce their purchases in response to higher prices. Third, the so-called "must-buy" requirement forced the utilities to buy nearly all the energy from an auction market with notoriously high prices. Together, these conditions put the utilities in a bind that undermined their financial viability and, since they were the ultimate provider of electricity, endangered the reliability of the electricity system.

While I agree that the three factors *precipitated* the onset of the crisis, I argue that the structural preconditions for the crisis lie elsewhere. I show that the markets were designed in such a way that they produced the incentives required by the blueprint only some of the time. Only under a narrow band of operating conditions did sellers of electricity have the incentive to sell their output at marginal cost and thus contribute to desired equilibrium outcomes. As soon as these conditions were no longer given, incentives emerged to exercise market power and play a variety of manipulative games that undermined the reliability of the system. Crucially, the markets undermined these normal operating conditions in the long run. Even with forward contracts, a deregulated retail market, and no must-buy requirements, the markets would have eventually ended up at the point where the existing incentives inverted and derailed the market mechanism.

The only way to circumvent this self-destructive logic would have been a highly capable control structure. But the fragmentation of the markets, the insufficient standardization of market action, and features of the monitoring regimes rendered the existing control structure inefficient. This made it impossible to observe and prevent the occurrence of problematic behavior that ultimately undermined the system and caused the crisis. These structural problems explain not just the crisis, but also the opposing narratives: the oversight regimes did not collect the data that would have enabled them to detect the problematic behavior. Accordingly, the problems had to be reconstructed ex post and from insufficient evidence. This created room for significant ambiguity in the interpretation of the Western energy crisis.

Having identified the structural preconditions that triggered the self-destructive logic in California's markets, I move to the second part of the dissertation (chapters 7–10). After a brief interlude that gives a broad overview of the design process, I begin to reconstruct the expertise that market designers brought to this process. I identify who the market designers were and how their ideas about electricity market design evolved in a nexus between Harvard/MIT, industry, and California research institutes.

Academics in engineering workshops at Harvard and MIT during the 1970s conceived the original project of electricity market design. The participants speculated how they could use markets to introduce *homeostatic*—self-regulating—control mechanisms into electricity systems. In the initial vision, the actors would simply be the machines that made up the electricity system. Spot markets would be used to organize the autonomous communication between meters and generators, allowing a process of mutual adjustment to make the use of resources more efficient. The markets here appeared as subsystems of the larger electricity system of a utility, viewed as a cybernetic structure with feedback- and homeostatic-control loops.

In subsequent years, this original vision quickly fragmented into an engineering and an economic version. These two separate approaches left behind crucial elements of the theory that guided the original vision. Specifically, I argue that economists developed mechanisms for electricity markets by reasoning, from static equilibria to the incentives that would produce the necessary behavior. This approach suggested that market design is primarily an exercise in "getting the incentives" right, i.e., creating institutions that set the market process up in a way that will push all activities toward the desired equilibria. This approach also lost the basic concern with feedback-control loops of the original formulations.

Engineers, in contrast, continued to rely on basic cybernetic imagination. This included awareness of the dynamic adjustments necessary to keep a system in check. But they largely ignored the potentially antagonistic position of market players who seek to deviate from the rules of the system to make profits. So they neglected an important source of behavioral variation over time: systems of incentives. Both sides thus lost crucial elements of the original vision (chapter 7).

The next three chapters then reconstruct in detail how the market designers contributed to problematic decisions in three contexts of market design work. In each case, I ask how the nature of work led to decisions that created the structural preconditions for the crisis. I establish what kind of decisions would have been necessary to realize the intellectual project and how the conditions of work prevented these decisions.

My basic contention in these chapters is that we need to understand the California debacle as a crisis of *expertise*. Not only were market designers unable to assume jurisdiction over issues that were central for successful market design, but the fragmented nature of their expertise and the blindspots in their theoretical blueprints also obscured the true requirements for success. Their decisions exacerbated the mismatches between the market mechanism and allocation problem.

This heightened the need for an oversight regime that could have sanctioned deviations from the desired market logic. But these requirements, too, fell through the cracks of designers' fragmented expertise. Overall, the design process failed because the designers followed an impossible plan. They wanted to maximize market participants' room for innovation and choice, but they also wanted to create a market that could solve a clearly specified optimization problem. This required that market participants follow highly specific sets of rules. To reconcile this tension, they would have required a potent oversight structure. But this requirement, as well as the tension itself, got lost in the fragmentation of the designers' intellectual project.

Chapter eight analyzes the first context of market design work: political discussions before the CPUC. In this context, stakeholders made the decision to segment the market into several independent organizations. The market designers rejected this proposal almost unanimously because it violated basic principles of market design. But the stakeholders ignored their advice. I investigate why they were ignored by comparing the situation with parallel processes at PJM Interconnection (the Pennsylvania, Jersey, Maryland region), where market designers were able to persuade political actors to follow their expert opinion. This analysis reveals a central problem of market design expertise: the core conceptual tools of market design are not in the exclusive possession of market designers.

Lawyers, politicians, and nonacademic economists have absorbed ideas about efficiency, competition, markets, comparative advantage, invisible hand, etc. into their own domain of expertise. In these other domains of knowledge, the concepts often take on meanings that diverge from the economic definition. In addition, even to outside professional expertise, many concepts of economists involve common sense interpretations that are close to an "Econ 101" vision of the world. Since market design is a highly technical subfield of economics, the designers' view of these concepts was inconsistent with the common sense understanding. Accordingly, market designers' arguments were not immediately intuitive to political actors.

At PJM, the designers faced the same problem, but they were able to establish jurisdiction by appealing to a shared standard of proof to demonstrate the validity of their claims. This was possible because the PJM context was dominated by political actors who were also engineers and shared a common framework for evaluating technical claims. In California, such a common frame of reference was not available. This made it impossible for market designers to establish jurisdiction over central issues by demonstrating the validity of their claims.

In this chapter, we thus encounter the problem that market design is, at certain moments, incompatible with democratic compromises. In principle, the methodology is relatively flexible, and designers can adjust blueprints to a variety of democratic compromises. But this is not the case when the very possibility of applying the tools of market design is at stake. In these moments, experts need to be able to reclaim the decision from the democratic process. Market designers have a hard time doing so because they do not have exclusive jurisdiction over the knowledge that makes up their expertise.

In chapter nine I explore the technical processes involved in implementing the WEPEX processes. I first reconstruct how the fragmentation of expertise impacted the organization of design work. Engineers who worked for the three major utilities in California presided over the division of labor. They assumed that work on the different submarkets could be modularized, and implemented a strict division of labor between teams that worked independently. This did not leave room for teams to systematically evaluate the interdependencies between their design decisions. Though economists who worked in these teams noted that problematic incentives might derive from the interplay between these markets, the division of labor prevented them from addressing these problems. The engineers did not anticipate the need to sort out in advance how the incentives would interact because they viewed markets in mechanistic terms. Accordingly, they assumed that people would play according to the rules and that links between markets would have to be designed explicitly. Some of the problematic mismatches between the protocols for the submarkets thus fell through the cracks in the division of labor.

In the next step, I look at the design work in the small teams itself. Here, designers tried to realize the explicit assumptions of their theoretical blueprints. They tried to develop an institutional framework that would create a market process in line with the assumptions of the model. However, these blueprints also relied on implicit assumptions that were embedded in the structure of the mathematical models (blindspots). In the analysis, I show how the economic perspective on market design made the teams liable to the blindspots embedded in their blueprints. In the attempt to build institutions that could enforce the explicit assumptions, the designers created conditions for a market process that violated these implicit assumptions. Specifically, they created incentives for a variety of manipulative games.

Chapter ten explores the creation of the flawed oversight structure in the regulatory processes before FERC. I argue, first, that the market designers should have had a comprehensive theory for the oversight regime that would complement their market design. This follows from the problematic temporal dynamic of electricity markets. As outlined in chapter six, electricity markets gradually undermine the conditions for their operation. This problem does not have a market-based solution because the required excess capacity is never fully known in advance, which means that it needs to be estimated by a regulatory actor. Even today, there is no fully functional, market-based solution to the so-called "missing money problem." Accordingly, even a perfect implementation of the blueprints would have required an extensive control structure.

But despite this basic design requirement, the designers did not develop a plan for a capable oversight structure and left the issue to utility officials and regulators. Again, this problem can be traced back to the fragmentation of expertise. Since the economists did not systematically think about the required oversight regimes, they yielded decisions about the creation of the regulatory infrastructure to utility officials and regulators. The utilities' engineers underestimated the need to control incentives and did not design the oversight structures in line with the rest of the market system. They focused on the creation of local oversight units, but did not contribute to the larger architecture of control.

Since the designers left the issue to the regulators and their lawyers, the monitoring protocols and tools followed a legal dogma that informed work at FERC. This legal dogma was based on an understanding of markets as physical "marketplaces." This analogy obscured several fundamental features of electricity systems and thus misconstrued how electricity markets operated. Accordingly, the resulting standards of oversight were poorly adjusted to the opportunities for manipulative and destructive behavior in the new markets. Due to the discrepancies between the intellectual vision and their fragmented expertise, economists recused themselves from an issue of central importance for the success of market design. And since their expertise did not have exclusive jurisdiction over design questions, the void was filled by legal knowledge that was inconsistent with the larger project.

Having established how the different contexts of design work led to California's flawed market structure, a last step remains. Up to this point, the analysis assumes that the blueprints for the markets are fundamentally sound. The California crisis appears mainly as the consequence of social processes that led to flawed design decisions. However, the blueprints may themselves have been inconsistent. The problematic design decisions created mismatches between the logic of the market mechanism and the requirements of grid management. Such mismatches could in principle be resolved by a control structure. Whether or not designers could put such a structure into place thus determines whether a market design project is fundamentally sound or not. If the mechanism creates control requirements that could never be met, it is logically infeasible. If it creates exceedingly high control requirements, it becomes practically infeasible. In the last part of the chapter, I show how the blueprints for California generated impossible control requirements even apart from the specific decisions about their implementation. I provide two illustrative examples.

First, I show that the blueprint for the creation of California's transmission capacity markets was *logically* infeasible. To implement it, a control structure would have needed to evaluate each transaction in the market relative to an ideal dispatch structure. But the information about the ideal dispatch was supposed to be produced by the market, which was affected by the game. This rendered the blueprint logically infeasible: it could not have been implemented as stated.

Second, I demonstrate how the combination of market complexity and innovation made the decentralized market design for California practically infeasible. I approach this problem by exploring how the monitoring units in California managed to detect problems with their metric for market power, developed a new monitoring approach, and tried (unsuccessfully) to convince FERC to adjust their approach as well. The analysis suggests that dynamic adjustments to the oversight regime depend on regulators' proximity to market data and their willingness to discover deviant patterns. If the regulatory hierarchy is too large to transmit these insights, the dynamic adjustments fail. Far away from the observation of anomalous patterns of behavior, FERC saw no reason to change its approach to the markets. This suggests that the acceptable limit for the complexity of synthetic markets is at the point where all permutations of possible behavior can be observed by a highly centralized group of regulators. Since this was not the case in California, where a decentralized structure of many interdependent markets would have required a substantial division of labor, the blueprints were infeasible. This concludes the analysis of the creation of California's markets as a form of market design failure.

In sum, I argue that the California crisis can be understood as a crisis of expertise: After the intellectual vision fragmented, economists and engineers came to the creation of California's markets with approaches that suffered from blindspots. They relied on implicit assumptions that would have had to be realized for the markets to work, but were not explicitly reflected on by the experts. This led to a problematic division of labor, flawed blueprints, and decisions to ignore questions of central importance to the design project. At the same time, the expertise did not command the necessary authority to sway the political process at decisive moments: it was not just flawed, but also insufficiently powerful and thus at odds with the democratic process.

1.4. Theoretical Argument

The nature of the design problems in California leads to a larger theoretical argument. The problems go back to the fact that the economists, engineers, and the various political actors had an incomplete understanding of the intellectual vision that stood behind electricity market design. This led them to underestimate the amount of centralization, oversight, and control that was required to realize the blueprints for the markets. From a theoretical perspective, we can therefore understand the conditions for the success and failure of electricity market design by recovering these requirements. We can then ask: At what point does it become impossible or too costly to meet them?

Since market designers perceive markets as information processors that execute algorithms, they aim to create closed systems of interactions between players who follow a prespecified logic of action. Based on an institutional structure that configures the incentives people face, the agents take in particular types of information, calculate the best response, and then act on it by choosing from a menu of predefined options. Economists who participated in the creation of the market operated under the assumption that it suffices to set up these institutional structures and make sure that economic action does not violate the constraints these structures impose. Hence only the form, not the substance, of economic decisions needs to be monitored and controlled. As long as generators act within the confines of the institutions that the designers created, the equilibrium follows as a matter of course. But this underestimates the requirements for dynamic adjustments.

Just as Hayek observed in the 1940s, equilibrium models of economic action are static in a particular way. They prove that a particular logic of interaction leads to an efficient aggregate outcome. This ignores the fact that each time point before the equilibrium is obtained, dynamic interactions between different participants, perturbations, or unexpected events can change the landscape of incentives. The coordination of plans that takes place in a dynamic system of constant adjustments can therefore deviate off course from equilibrium in a variety of ways. In other words, the theoretical mechanisms that economists propose are not normally *dynamically* robust. Even the highly simplified Arrow-Debreu model for general equilibria has long been shown to be unstable. Despite using convenient assumptions and unrealistic idealizations like the Walrasian *tâtonnement* for price adjustments, the model does not reliably lead to a convergence of prices. Under some sets of individual preferences and initial endowments, even the simple model leads to chaotic price swings, infinite fluctuation at suboptimal levels, etc. before equilibria can be achieved.[43] In the absence of models whose equilibrium conditions are dynamically robust, the economists are likely to underestimate the amount of oversight that is required for the markets to function efficiently.[44]

Because of the need to ensure that transformation of positions in the market over time remain stable, an oversight regime is necessary to evaluate whether the transactions remain on the path toward equilibrium or have deviated in a problematic way. The only way to determine whether this is the case is to evaluate the substance of individual transactions in terms of the theoretical ideal. In that way, the market process is like a nuclear chain reaction. It follows a relatively straightforward logic, but needs to be carefully controlled in order to remain within tolerable parameters—it can constantly veer off course if the dynamic interactions between parts are not carefully monitored and controlled. In electricity markets, the oversight regime needs to decide if a trade actually corresponds to a marginal cost transaction or if the trade is informed by calculations that violate the blueprint. The claim that market designers only need to control the form but not the content of economic decisions is therefore deceptive.[45]

This requirements for oversight and control are compounded by a second, even more important element of cybernetic systems: evolution. One of the central justifications for the use of markets is that competition leads to innovation. Innovation and "creative destruction" are

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[43] Frank Ackerman, "Still Dead after All These Years: Interpreting the Failure of General Equilibrium Theory," *Journal of Economic Methodology* 9, no. 2 (2002): 122.

[44] Whether there is a form of market design that creates models that reach stable equilibria under a variety of different logics of action is an open question. To my knowledge, there are only very few approaches that seek to broaden the blueprints in contrast to those that seek to impose more effective control on the social process. On the fledgling search for more robust market mechanisms, c.f. Gabriel Carroll, "Robustness in Mechanism Design and Contracting," *Annual Review of Economics* 11, no. 1 (2019).

[45] The instability of the form/content distinction has been known since nominalists criticized Aristotle's hylomorphism in the Middle Ages. The problems in establishing a stable distinction between (universal) form and (particular) content is also foundational to cybernetic system theory, which takes form to be the unity of a distinction made by an observer (rather than anything context-transcendent). Niklas Luhmann, *Theory of Society*, vol. 1 (Palo Alto, CA: Stanford University Press, 2012), 113-20.

necessary for the long-term efficiency of the markets. In contrast to the mathematical models used by designers, this argument relies on an evolutionary, dynamic, and chaotic vision of the market system that is conceptually at odds with the methodological tools of economists and engineers. Market designers thus need to leave room for behavior that has not been anticipated by the blueprint that structures the market institutions. This is dangerous because markets are volatile processes that can create antagonistic relations between market participants and regulatory agencies.

Since competition at marginal cost is extremely costly to companies, they always have an incentive to search for ways to circumvent it. This means that players in markets not only have an incentive to innovate cheaper and better ways to produce and sell their outputs, but they have an incentive to discover loopholes in the market system itself. Since individuals never just act in one domain of social life (i.e., the synthetic market), they can identify such gaming opportunities in the dynamic combination of different market settings. Such interdependencies and the need to allow some room for creative action constantly create room to deviate from the logic of the model and act against the system itself. While economists know this—it is a fundamental premise of game theory—they underestimate the degree to which this heightens the requirements for oversight: the control structure most be able to *recognize* innovative behavior and co-evolve with the market structure. It must be able to discover systematic deviations from the regular logic of market activities, and it must then be able to distinguish productive innovations from destructive behavior. If the new logic of action is productive, the designers must be able to adjust the blueprints and the corresponding oversight regime to the new market logic. If the innovation is problematic, it must be able to curb the behavior. Of course, all these changes must follow a technical rationale and remain free of influence from powerful industry players who will try to shape the market rules in their interest.[46]

These considerations suggest that the hard limits for market design (and criteria for success) are defined by the requirements of effective oversight and control. But as soon as the rules of the mechanism become sufficiently flexible to allow many different trajectories through the state-space of the market system, even allowing shifts in the basic logic of the mechanism, these requirements explode. This brings some of the most severe problems of centralized planning back into the picture. These problems are well documented in organizational sociology. As bureaucracies seek to collect and process all relevant information from a dynamic process, they run up against the static, slow-moving division of labor in which divergent departmental goals, operating protocols, informal structures, and cultural traditions incite organizational deviance and structural secrecy.

Thus, not only do market designers have to wield the authority necessary to bound market settings from external influences to prevent the runaway complexities from interactions between various market settings, they have to be able to impose a centralized and comprehensive oversight to these market processes. This oversight needs to be able to analyze all dynamic combinations of possible behavior on an ongoing basis, detect deviations from the model, evaluate them, and either coerce them back into line or adjust the model to accommodate them.

It is questionable under what conditions market designers can gain the required authority to design such systems and fend off influence from powerful market players. It is also questionable

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[46] This is the most basic insight of the "market as politics" approach. C.f. Fligstein, "Markets as Politics: A Political-Cultural Approach to Market Institutions."

how quickly the complexity of market processes exceeds the capacity for comprehensive oversight with even the highest computational abilities.

However, this is not to say that market design has to fail; it merely suggests that the complexity of market processes and the ability to create oversight regimes are likely the decisive factors for the success and failure of market design. How these can be reflected within the practical world of fragmented market design expertise is an interesting question for the sociology of economic engineering and promises new fields of application for sociological knowledge. In the conclusion, I will draw out these considerations to arrive at some hypotheses about the conditions for successful market design, hypotheses about limits and dangers of market design, and a research agenda for a new sociology of economic engineering.

2. Research Design

2.1. Analytical Approach

This dissertation investigates an illustrative case in-depth to ask a larger question about the conditions for the success and failure of market design.[1] In the course of the study, I make two separate analytical moves to arrive at a specific class of theoretical statements. The first part of the dissertation compares the intellectual vision of market design as articulated in the academy with the actual markets as they were built in California between 1994 and 1998. This analysis is based on conceptual work that engages market design as a formal body of thought, relates it to sociological theory, and then recovers basic, hidden requirements for the success of market design. The implicit assumptions reveal a set of basic requirements for the success of market design, which allows us to evaluate the California energy markets as a project of market design. By tracing the disparities between intellectual vision and real markets, the structural preconditions for the energy crisis become apparent. This reveals an internal contradiction at the heart of the markets. Yet it also reveals how economists could have avoided this contradiction with a different market design, which provides the puzzle for the second part of the dissertation: Why did the designers settle on a market design that necessarily failed to realize the requirements of the intellectual project? In the second part, I analyze how the activities of market designers in different contexts of work led to that fateful decision. In other words, I explain the structural flaws of the California markets by looking at the tension between the intellectual project and practical design work.

In developing this argument, I pursue two distinct analytical aims: (1) I seek to identify conditions for successful market design by exploring the tensions between the intellectual project

[1] Bruce Lawrence Berg and Howard Lune, *Qualitative Research Methods for the Social Sciences*, 9th ed. (Boston, MA: Pearson 2017), 17.

and the practices of its implementation in California. (2) I then try to develop a theoretical generalization from this empirical argument to identify conditions for the possibility of successful market design. In this section, I will discuss these two goals in turn. I begin with a description of the analytical strategy. Then, I will discuss the question of whether and to what extent it is appropriate to use a single, failed case of market design to arrive at more general conclusions about the conditions for the success and failure of market design.[2]

I will begin by explaining the analytical strategy I use to investigate the design process in California. Though the dissertation follows methodological guidelines for the qualitative analysis of archival materials and in-depth interviews, the general analytical approach can be described as one of immanent critique.[3] I am referring here to a broadly Marxist notion that has developed in the later generations of the Frankfurt School. [4] In this tradition, immanent critique is the attempt to develop a critical stance toward social practices based on the norms that constitute a practice. The basic idea is to draw out the implicit norms that guide the activities of the participants and then compare them to the norms they profess to follow. Immanent critique aims to find contradictions between these two sides of the practice, which then explain why the practice fails to achieve its goals as intended.[5]

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[2] A long tradition in social history, starting with Eric Hobsbawm and continued by Charles Tilly, used conflict episodes as a way to discover peoples and issues otherwise invisible to standard historical methods. Eric J. Hobsbawm, "Karl Marx's Contribution to Historiography," *Diogenes* 16, no. 64 (1968); Charles Tilly, *The Contentious French* (Cambridge, MA: Harvard University Press, 2013). This is the same principle—to see the constituents of order, one has to look to chaotic events where these constituents are absent. I thank Prof. Abbott for pointing this out to me. The deeper philosophical roots of this position lie in Hegelian dialectics and its materialist inversion by Marx. In order to understand the constituents of the present, we must follow the history of dialectical struggles that have brought it—and our perception of it—about.
[3] I am here following an approach for a “social practice of critique” that I tried to develop when I first moved from philosophy into sociology. Georg Rilinger, "Methodenprobleme Immanenter Kritik: Das Beispiel Der Entfremdung," *Leviathan* (2015): 90.
[4] Titus Stahl, *Immanente Kritik: Elemente Einer Theorie Sozialer Praktiken*, vol. 78 (Campus Verlag, 2013), 43-49.
[5] Usually, immanent critique requires a normative foundation that transcends the practice itself. For example, different versions ground the critique in universal presuppositions of the object of critique, which ensures that the critical discourse does not become conservative, i.e., entirely beholden to the values of those who engage in the practice.

The dissertation approaches this task in several steps. First, it has to generate an understanding of the problems that the practices of market design work generated. The first step of the dissertation can be understood as a reconstruction of the intellectual vision that stands behind practices of market design. The second step is to spell out how the market design experiment failed to live up to the vision. By comparing the two sides, we can recover the presuppositions of success—what would have been necessary for the markets to work. Since we now know where the markets fell short of these presuppositions, we can investigate the reasons for this problem.

This is the task in the second part of the dissertation. I explain the structural flaws of the market by showing that the practical forms of expertise fall short of the intellectual vision. This reveals the contradictions that are implicit in market design as the *empirical practice* of design work.[6] In other words, we can use the tension between the intellectual project and the practical work of market design to reveal how the practices were flawed. With this information about the problems of market design work, we can then turn around and ask whether there are ways in which the intellectual project is itself internally inconsistent. So if the intellectual project has requirements that can never be realized in practices of design work, we discover limiting conditions for

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However, such universal presuppositions are either too weak or not defensible. One option to solve the problem is to justify the critique on the basis of the self-transformation of the practice *through* the act of critique, conceived as a mutual, hermeneutical process. Precisely this is my goal for a sociology of economic engineering: by helping market designers to discover flaws in their approach and pointing to limits that derive from the true requirements of market design, the critical discourse helps designers to transform the practice toward the realization of a shared normative framework. Here, the implicit normative background that provides direction to this transformation is, of course, my liberal concerns over the totalizing tendencies of technocratic rule, their erosion of deliberative democracy, and their overestimation of human ability to control the future—held in balance by a fascination with radical attempts to resolve the malaise of the democratic governance. Rilinger, "Methodenprobleme Immanenter Kritik: Das Beispiel Der Entfremdung," 92-94.

[6] This type of exploration is closely related to the meaning of hermeneutics as proposed by Dilthey and Heidegger. By exploring the relationship between question and answer, the presuppositions of both become clearer and translate the practice within which the question arose. C.f. Josef Bleicher, *Contemporary Hermeneutics: Hermeneutics as Method, Philosophy and Critique*, vol. 2 (New York: Routledge, 2017).

the success of market design.[7] The dissertation thus moves in a hermeneutic circle between the intellectual project and the practices that seek to realize it. In the course of this movement, conditions for the success and failure become visible as we probe the reasons why the project failed in California. This reveals conditions for successful market design work and conditions for conceptually consistent market design projects.

Now, the question is what we can learn from this exercise. Specifically, the question is whether we can learn anything more general from a single case study of *failed* market design. Of course, as with any case study, all theoretical generalizations have to be understood as analytical rather than statistical propositions.[8] But this still leaves open the possibility that the case might lead to a biased theory of market design.

The most obvious version of this problem is the hindsight bias. By looking at a failed case, I may be predisposed to conclude that market design must fail more generally. Retrospectively, that which happened seems inevitable. It happened, so it *was* inevitable. However, just because something did happen does not mean that it was *likely* to happen. Unlikely things happen all the time, and assuming a probabilistic universe of social events, everything could have very well have happened differently. It is therefore a fatal flaw to generalize from a single study. The "links" in the analytical framework that we derive from a single case may be the product of chance rather than necessary connections. This objection stands even if we acknowledge that case study generalizations have an analytical rather than a statistical meaning. Arguments about the enabling

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[7] A more sociological way to put the same idea is to say that this dissertation compares aspirations of the intellectual project with the culture and practices of those who try to bring it about. The toolkit approach to culture fits well with this idea because it argues that unsettled times alone draw the repertoire into question, requiring revision and innovation. C.f. Ann Swidler, "Culture in Action: Symbols and Strategies," *American Sociological Review* 51, no. 2 (1986).
[8] Robert K. Yin, *Case Study Research and Applications: Design and Methods*, 4th ed. (New York: Sage publications, 2017), 43.

condition of successful market design will posit strong relations between analytical entities. A single case study may overvalue the strength of these connections.[9]

The key for a response to this objection can be found in the nature of the analytical claims I seek to make. My dissertation does not try to specify causal arguments in the way sociology usually thinks about causality. Though the meta-theoretical accounts often differ and are often murky, the broadly Durkheimian vision of causal inference as spelled out by Rubin and Pearle probably captures the sociological imagination of causality best.

Here, causal effects are defined as comparisons of potential outcomes under different treatments on a common set of units.[10] The imagination is closely based on the logic of experiments. Since we cannot conduct experiments most of the time, we build counterfactuals by imagining an alternative universe without the factor of interest. If the observed regularity were to disappear in that universe, the factor is causal. Aristotle would probably call this "efficient causality," i.e., the factor that actually brought a situation about.

The *theoretical* claims this dissertation wants to make are not causal in this way. Statements about the condition for successful market design have this shape: if x is the desired market process with features 1…n, then y is a *condition for the possibility* that this process can be realized as

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[9] Generally, sociology suffers from an inconsistent stance on analytical entities. On the one hand, we view them as ideal typical heuristics (i.e., nominalism). On the other hand, in our theories we treat them as if they were real entities (e.g., we easily talk about what states *do).* C.f. John Levi Martin, *Thinking through Statistics* (Chicago, IL: Chicago University Press, 2018), 37.

[10] C.f. Donald B. Rubin, "Causal Inference Using Potential Outcomes: Design, Modeling, Decisions," *Journal of the American Statistical Association* 100, no. 469 (2005). Of course, not everyone relies on the causal inference framework that Rubin/Pearle develop. I am referring only to the conceptual framework. This framework itself goes back to Hume's notion of causality as "constant conjunction" between events. The development of this concept of causality and its principal problems are a broad topic in philosophy. For the analytical tradition, c.f. J.L. Mackie, *The Cement of the Universe: A Study in Causation* (Oxford, UK: Oxford University Press, 1980); Herbert Lionel Adolphus Hart and Tony Honoré, *Causation in the Law* (Oxford, UK: Oxford University Press, 1985 [1959]). For everything that is wrong with counterfactuals, c.f. David Lewis, *Counterfactuals* (New York: John Wiley & Sons, 2013). More recently, Martin reconstructs the standard account of causality in sociology and analyzes the various ways that it is inconsistent and problematic, c.f. Chapter 2 of John L. Martin, *The Explanation of Social Action* (New York: Oxford University Press, 2011), 24-73.

envisioned. Sometimes, the conditions are that market designers can play a certain role or recognize a particular implication of their project. At other times, the conditions refer to the conceptual project itself. They might suggest that a social process would have to be changed in a particular way to bring about the market mechanism or that economists need to put particular structures of control into place to prevent market design failure.

At first sight, these claims may seem similar to counterfactual causal statements. After all, we are specifying a reason why a market design may *not* work as intended. Accordingly, we can imagine an alternative universe without the condition and then the observed regularity (the intended process) will disappear. However, this impression is inaccurate because the presence or absence of condition y does not affect the occurrence of market process x *directly*. If an enabling condition of successful market design is absent, a variety of different behaviors become available that can derail the market mechanism. The condition is compatible with an indeterminate number of possible ways the design can succeed or fail. So, the counterfactual that animates the claim does not have to be stable in the way causal explanations require.

Further, the condition y is not jointly necessary and sufficient for the occurrence of process x. A market mechanism that meets the enabling condition can *still* go wrong in a variety of ways. So, you can imagine the alternative universe with the enabling condition present (if it is absent) and find no difference in the observed regularity. Finally, the statement applies only to a subset of market design experiments that have the features 1…n. Since these features are *theoretical* rather than empirical, the condition refers to the components of a theoretical statement, not an empirical process. This means that the counterfactual refers to a *logical* connection between elements rather than some sort of force that pushes down on social life.[11]

In sum, the theoretical statements of this dissertation are not causal in the sense of standard sociological accounts. They do not explain observable regularities by exploring the causal relations between components. Instead, they establish logical entailment relations based on the use of theory in practice. If you want to do x, then you necessarily also have to do y and z. The question is then whether it is possible to do any of these things individually or in combination and what the cost of doing these things are. Since my analysis establishes *conditions* for the realization of theoretical propositions, the argument does not hinge on probabilities—it does not concern the question of how likely particular elements of the California system were to fail. This means that the hindsight objection does not apply. The theoretical argument neither establishes that the market necessarily fails nor does it identify the immediate causes of failure. It establishes the prerequisites of success, which leaves open how exactly failure occurs if they are not met.

Incidentally, this goal makes it not just convenient but necessary to look at a failed experiment of market design. As classic pragmatist philosophy would suggest, it is only in the breakdown of activities that their complex presuppositions become visible.[12] This renders the choice of the California case valid in two different ways. First, as a case of particularly difficult market design, the choice maximizes the number of problems we can observe. If we assume that there are some similarities between different types of market design (as we know there are), we are thus likely to pick up problems that may apply elsewhere or even more generally.

[11] In that way, they are causal in the sense that Aristotle would call "formal," the conditions explain what the end product is going to be without specifying the path that gets us there.
[12] Arguably, that idea is first fully developed in Heidegger's *Being and Time*, where it becomes the basic premise of philosophical investigation into the constituent elements of Dasein's Being.

Second, studying failures is a basic requirement for understanding the conditions for the possibility of successful market design. This has to do with the fact that market design is an enterprise not to explain but to *change* the social world. This means it cannot be evaluated in terms of some analytical purpose that we would use to evaluate explanatory theories.

Instead, the condition for the possibility of successful market design must be evaluated in terms of its *practical feasibility*. Any theoretical account about social phenomena—regardless of whether it is explanatory or constructive—involves simplifying abstractions. To know is to simplify. This means that the theories' referents necessarily include features that are outside the scope of the explanation. For explanations, these features only matter if they prevent an answer to an analytical question relative to criteria of success as derived from the relevant methodological paradigm. We never evaluate explanatory theories in terms of their ability to capture every facet of a given phenomenon, but in terms of their ability to answer a question within particular standards of what a valid answer is.

Since constructive theories are not meant to explain, but to shape the world, they must be evaluated differently. The decisive question is whether the features the theory picks out are sufficient for the user of the theory to create a working realization of that theory. This, however, *cannot* be known with certainty before someone has tried to realize the theory.

An analogy to material artifacts makes this clearer. Any specific material artefact, say an airplane door, contains features that are not represented in the theories and models used to create it. There will be features of the concrete material object (such as interactions on the molecular level) that influence the durability of the door beyond what has been anticipated by the model used to build it. Now, to tell whether the model is accurate and a good template for the creation of additional artifacts, we cannot look at the model alone. We have to look to see if they capture everything about the door that is relevant to know in order to know that it will fulfill its purpose. But whether or not that is the case can only be determined by looking at whether the doors cause accidents. Accidents are crucial to determine whether the model was adequate because the model itself would never have revealed its inadequacy on its own terms. The accident reveals a problem that could not become visible in the model.[13] To understand the conditions for the possibility of success of practical theories that aim to change the world, it is therefore *necessary* to look at failures as they reveal the hidden preconditions for successful engineering and allow a critical assessment.

Incidentally, market designers have thought so too. The California crisis provided a powerful learning experience for market designers who have changed their practices significantly since the crisis in 2000–2001.[14] Yet, despite two decades of sustained efforts, electricity market design still has not solved all challenges. The current energy crisis in California suggests that sociologists might study electricity market design to unearth fundamental problems and limiting conditions of market design.[15] In sum, to learn about the conditions for the possibility of successful market design more generally, it is prudent to study in-depth a single case of extreme market design failure.

That being said, I am going to engage in occasional comparisons to evaluate specific *empirical* hypotheses about mechanisms in the standard sense in the course of my analysis. The wholesale markets for electricity in the PJM Interconnect (the Pennsylvania, Jersey, Maryland

[13] C.f. John Downer, "“737-Cabriolet”: The Limits of Knowledge and the Sociology of Inevitable Failure," *American Journal of Sociology* 117, no. 3 (2011). He argues that any technical artifact contains features that cannot be known because all knowledge operates with abstractions. To know which abstractions are justified and which ones are not, we need to explore the practical failures.

[14] C.f. Richard O’Neill et al., "Independent System Operators in the U.S.A.: History, Lessons Learned, and Prospects," in *Electricity Market Reform: An International Perspective*, ed. Fereidoon P. Sioshansi and Wolfgang Pfaffenberger (Kidlington, UK: Elsevier, 2006); Cramton, "Electricity Market Design."

[15] Kotkin, Joel, “California’s Self-Created Future Energy Crisis,” *Los Angeles Daily News*, March 30, 2019, https://www.dailynews.com/2019/03/30/californias-self-created-future-energy-crisis/, last accessed 03/04/2020.

region) were developed at the same time as the California markets and confronted many of the same problems. But in contrast to California, the designers managed to address these problems and get the system back under control. The similarities render the case ideal for a comparative approach. Yet this approach has to be limited. This follows from the central challenge of small-n comparisons. When there are more relevant variables than data points, it becomes impossible to rule out competing explanations because it is impossible to "control" for all variations in other variables. The Eastern markets were built under different circumstances and with different assumptions than the California markets. This makes a global comparison impractical. To mitigate this problem, the study uses evidence from the Eastern states to evaluate *local* hypotheses about the California case—that is, it breaks the focal case into small empirical puzzles, develops hypotheses about the factors that might explain these local puzzles, and then evaluates them by finding similar, limited constellations in the contrast cases. This mitigates the methodological problem since only a few factors will have to be held constant for these local hypotheses.[16] I thus draw on the PJM experience at crucial points in the *empirical* analysis to gain leverage by comparison. Having outlined the analytical strategy, I will now discuss the different sources of data I use in the analysis as well as the methods I employ.

2.2. Data and Methods

The study relies on two types of data: archival material from various sources and in-depth interviews with market designers, stakeholders, and regulators. Most of the archival materials stem from three archives: the archive of the California Public Utility Commission (CPUC) in San Francisco, the California State Archives in Sacramento, and the online filing system of the Federal

[16] John L. Martin, *Thinking through Methods* (Chicago, IL: University of Chicago Press, 2017).

Energy Regulatory Commission. These three archives contain materials that document the work of the organizations that were tasked to design, implement, and monitor the electricity markets in California. They also contain the voluminous record of litigation on the California energy crisis.

The CPUC archive in San Francisco houses sixty-three boxes of filings, transcripts, and submittals in a docket that chronicles the entire period of deregulation. Early files contain transcripts and filings from the negotiations between regulators and stakeholders after the CPUC published the decision to deregulate in 1994. Boxes from later dates contain various filings that document the technical process of implementation during the WEPEX (later Trust Advisory Committee, or TAC) process between 1994 and 1998. The last folders chronicle state actions dealing with the unfolding crisis between 2000 and 2001. I visited the archive in the summer of 2018 and digitized over 10,000 pages of transcripts and filings, primarily documenting the period of market design between 1994 and 1997.[17]

The California State Archive contains documents that chronicle the political processes leading to the creation of AB1890 and business documents that were preserved from the California Energy Crisis. Of particular importance were the business documents of the Power Exchange and the California System Operator, which chronicle the initial design, operation, adjustment, and monitoring of these markets in great detail (1997–2002). The archive also contains transcripts from the hearings before the Electricity Oversight Board (EOB). The EOB was a California institution that formally oversaw the design process, though its importance was eclipsed by the steering committee of the WEPEX and TAC meetings. The hearings give insight into some of the debates about technical design challenges and issues of governance over CAISO/PX. Lastly, the archives contain

[17] In 1997, design efforts moved from the WEPEX process that was associated with the CPCU into the TAC groups that were associated with the California Independent System Operator and the PX.

material that pertains to the Senate Select Committee's investigation of fraudulent behavior during the energy crisis, a highly political investigation of power marketers' behavior. I visited the state archives twice, once in the winter of 2017 and once in the summer of 2018. Here, I digitized about 7,000 pages of material, focusing on the business documents from the PX and CAISO as well as EOB transcripts and the material from the Senate Select Committee.

Finally, the online archives at FERC contain an abundance of materials on all aspects of restructuring in California as well as the market design process at PJM. Since FERC had to sanction all design decisions as well as decisions about changes to the tariffs governing the operation of the markets, the archival record gives a close overview of the initial design process and the adjustments to both California's and PJM's markets between 1998 and 2001. Since FERC was also the main regulatory entity of the California wholesale markets, most of the litigation took place at FERC, and the dockets contain a vast paper trail of filings, evidence, hearing transcripts, technical statements, expert analyses, and affidavits that allow us to dive into any aspect of the crisis. Throughout the period of data collection between January of 2017 and the summer of 2018, I scraped all substantial filings from the dockets.[18] Transcripts of hearings and dockets associated with the standards of legal oversight were relevant to my reconstruction of how the monitoring regimes were developed.

I supplement the sources from the three archives with a variety of other archival material. I retrieved transcripts from fifteen congressional hearings on the Western energy crisis, the Enron collapse, and FERC's oversight of the energy markets. I added four reports from the United States Accounting Office on different aspects of the regulatory structure. Further, for descriptive

[18] For larger dockets, I wrote a python script to scrape all submissions. It circumvented the cumbersome interface of the FERC ebrary and eased the analysis by standardizing file names.

purposes I used a quantitative dataset from the California Energy Institute that captures key metrics of the California energy markets for the period from 1998 to 2002. To reconstruct the intellectual history of market design, I relied on a variety of working papers and publications from the Energy Institute in Palo Alto, the Working Paper Series of the California Center for the Study of Energy, William Hogan's working paper archive, and the working paper series of the MIT/Harvard workshop on homeostatic systems. Finally, I supplemented these sources, with the dominant trade publications: *The Electricity Journal*, *the Energy Law Journal* and the *Public Utility Fortnightly* for the years between 1993 and 2000. To reconstruct the crisis, I also drew on general newspapers like the *Los Angeles Times* and the *San Francisco Chronicle*. Lastly, I made use of the WEPEX coordination website that was stored in the Internet ArchiveX (1996–98). Table 1-4 summarize the main sources by archive, leaving out newspapers, working papers, trade publications, and materials from ArchiveX. These were used more selectively and will be cited in full in the analysis.

Table 2-1 – Archival Material (Congressional Investigations)

Congressional Investigations	Description & Date
Electric Utility Industry Restructuring: The California Market California's Electricity Crisis	Subcommittee on Energy and Power, Committee on Commerce, House of the Representatives, One Hundredth and Seventh Congress, First Session, September 11th, 2000 Committee on Energy and Natural Resources, House of the Representatives, One Hundredth and Seventh Congress, First Session, January 31st, 2001
Electricity markets: Lessons learned from California	Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, House of the Representatives, One Hundredth and Seventh Congress, First Session, February, 15th 2001
Congressional Perspectives on Electricity Markets in California and the West and National Energy Policy	Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, House of the Representatives, One Hundredth and Seventh Congress, First Session, March 6th 2001
Electricity Markets: California	Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, House of the Representatives, One Hundredth and Seventh Congress, First Session, March 20 and 22, 2001
Assessing the California energy crisis: How did we get to this point, and Where do we go from here?	Joint Hearings, Subcommittee on Energy Policy, Natural Resources, and Regulatory Affairs and the Committee on Government Reform, House of the Representatives, One Hundredth and Seventh Congress, First Session, April 10, 11 AND 12, 2001
Wholesale Electricity Prices in California and the Western United States	Committee on Energy and Natural Resources, U.S. Senate, One Hundredth and Seventh Congress, First Session, May 3rd, 2001
The California Energy Crisis: Impacts, Causes and Remedies	Committee on Financial Services, House of the Representatives, One Hundredth and Seventh Congress, First Session, June 20th, 2001
FERC: Regulators in Deregulated Electricity Markets	Committee on Government Reform, House of the Representatives, One Hundredth and Seventh Congress, First Session, August 2, 2001
The Effect of the Bankruptcy of Enron on the Functioning of Energy Markets	Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, House of the Representatives, One Hundredth and Seventh Congress, Second Session, February 13 2002
California Independent System Operator: Governance and Design of California's Electricity Market	Subcommittee on Energy Policy, Natural Resources, and Regulatory Affairs, Committee on Government Reform, House of the Representatives, One Hundredth and Seventh Congress, Second Session, February 22, 2002
Examining Enron: electricity market Manipulation and the effect on the Western states	Subcommittee on Consumer Affairs, Foreign Commerce, and Tourism, Committee on Commerce, Science, and Transportation, House of the Representatives, One Hundredth and Seventh Congress, Second Session, April 11, 2002
Examining Enron: Developments Regarding Electricity Price Manipulation in California; Energy Market Manipulation	Subcommittee on Consumer Affairs, Foreign Commerce, and Tourism, Committee on Commerce, Science, and Transportation, House of the Representatives, One Hundredth and Seventh Congress, Second Session, May 15th, 2002
The Role of Enron Energy Service Inc (EESI), Played in the Manipulation of Western Energy Markets	Committee on Commerce, Science and Transportation, House of the Representatives, One Hundredth and Seventh Congress, Second Session, July 18th, 2002
California's electricity market: the case Of Perot systems	Committee on Government Reform, House of the Representatives, One Hundredth and Seventh Congress, Second Session, July 22, 2002
Asleep at the Switch: FERC's Oversight of Enron Corporation Vol. I – IV.	Committee on Governmental Affairs, United States Senate, One Hundredth and Seventh Congress, Second Session, November 12th 2002

Table 2-2 – Archival Material (CPUC)

California Public Utility Commission (CPUC)	**Archival Material**	**Description**
California Public Utility Commission Order Instituting Rulemaking and Order Instituting Investigation	CPUC Archives San Francisco, R.94-04-031 / I.94-04-132, Box 10 – 50	All filings responding to the Blue Book that formally started the process of restructuring in 1994. Contains information on the political processes before the CPUC and reports about / filings from to technical WEPEX processes of implementation.
Ibid.	CPUC Archives San Francisco, R.94-04-031 / I.94-04-132, Box 50 – 53	CPUC's attempts to cope with the Energy Crisis (consolidated docket)
Ibid.	CPUC Archives San Francisco, R.94-04-031 / I.94-04-132, Box 69 – 71	Transcripts from Hearings during the Design Process (1994 – 1997).

Table 2-3 - Archival Material (California State Archives)

California Independent System Operator (CAISO)	**Archival Material**	**Description**
Market Surveillance Committee, Reports (1998 – 2001)	California State Archive, R400.007, Box 12 – 14	Material (academic papers, analyses, data charts, etc.) related to the problems in the Ancillary Markets
Electricity Oversight Board, Subject Files (related to market power analysis at ISO, 1997-2001)	California State Archive, R400.005, Box 4 & 5. R400.010, Box 18 & 19	Background material pertaining to specific issues, (including market power in Ancillary Markets)
ISO Market Surveillance Committee and Board of Governor Meeting Files (1998 – 2000)	California State Archive, R400.006, Box 6, folder 1- Box 9, folder 6	All materials used during Board Meetings, including all material presented to the Sub-Committees, Contains memos, memoranda and status reports on problems with ancillary markets
Other		
Sheila J. Kuehl Papers: Sen. Select Committee to Investigate Price Manipulation of the Wholesale Energy Markets	California State Archive, LP402:338-353, Box 17 – 18	Personal Files, documenting work for the Senate Select Committee to Investigate Price Manipulation in Wholesale Markets
Power Exchange	**Archival Material**	
Teaching Material (Market Primer, etc.) for Board of Governors	2 Reports (available online)	Background information on how the interface of the market works
Electricity Oversight Board, Subject Files	California State Archive, R400.005, Box 5, folders 10-25, R400.010, Box 18, folder 1 - Box 19, folder 14	Background material related to market power analysis at PX, 1997-2001
Board of Governor's Meeting Files (1998-2000)	California State Archive, R400.008, Box 13, folder 15 - Box 14, folder 9	Agenda, Minutes and Background Materials presented during meetings of the Stakeholder Board, including material of committee meetings, here: Compliance
PX Compliance Filings	George Sladoje's, PX CEO, Personal Archive	I received a DVD that contains detailed documents chronicling the PX's investigation of Enron's early gaming activities.

Table 2-4 – Archival Material (FERC)

Federal Energy Regulatory Commission	**Docket Number (accessible via Ebrary)**	**Notes**
Contract Path Methodology	ER93-706-000	Docket that first develops the legal standards for market oversight in a case against Indiana MI Power Co. Subsequently used until after the Western energy crisis.
Merger Applications and Technical Conferences regarding market power methodology	PL98-6 RM98-4 RM98-6	FERC's early, fruitless attempts to revise their market power standard in the context of mergers (1998).
California Parties' Application for establishment of ISO / PX	ER96-1663 EC96-19	All material related to the design of the markets. In particular, WEPEX hearings that debate the correct approach to measuring market power and overseeing the California markets (1996-99) Contains all formal filings pertaining to the design and implementation of the California markets.
Development of orders concerning deregulation and market power analysis (592, 888, 2000)	RM96-6 RM95-8 RM99-2	Landmark decisions to open the transmission system in order to prepare the ground for deregulation (Order 888 in 1996) and the subsequent development of Regional Transmission Organizations (Order 2000 in 1999). Contains transcripts that debate market power and methodology in energy markets.
Ancillary Market Crisis	ER98-2843	Crisis in Ancillary Markets at CAISO, consolidated docket. Contains all filings relevant to crisis and redesign of the markets.
Gaming Case	EL03-180	Case that investigates the various manipulative games first discovered through the Enron Memos
Enron Investigation	PA02-2	Contains all material relevant to the investigation of manipulation of Western Energy Markets through Enron and Others. In particular: evidence of transactions from all sellers in the Western Energy Markets.
Refund Case	EL00-95 EL00-98	Investigation of Market Power Abuses in the California Energy Markets between 2000 / 2001. Contains all settlements regarding market power abuses as well as the evolution of the oversight standards during the crises. Cross references to all individual cases involving the Western energy crisis.
PJM Companies / Atlantic City et al.	ER96-2516 EC96-28 EL96-69	Chronicles PJM's market design process. Contains filings, transcripts of hearings, memoranda, expert analyses and competing statements from PECO, the company that proposed a design similar to that of California.

Given the wealth of archival material, the primary analytical challenge was to subdivide and filter the data. After sorting the material into big chunks by tying data to timelines of events and charts of the different organizations, I developed an evolving filing system. Initially, it reflected the origin of the material in the different archives. As the analysis progressed, I increasingly reorganized the material to reflect its relevance for different parts of the analysis. Throughout, I wrote memos to summarize data, remember where important evidence was located, and what material belonged together. I then followed the general strategy to break the larger research question into smaller empirical "mini-analyses," selected archival material for these more specific tasks, and then wrote memos summarizing the results of these analyses.[19] Since the central task was to reconstruct the decision-making processes during the design period as well as the operation of the resulting system, the dissertation builds primarily on archival records from this period.

But since all archives collect primary sources for their own purposes, they introduce a selection bias into the data. In addition, most of the available material reflects only formal procedures and not the informal practices surrounding them (excluding certain transcripts and internal reports). The archival sources therefore offer only a fragmented view of the social processes that generated it. Besides relying on more than one archive, the best strategy to deal with this problem is to triangulate archival data with semi-structured, in-depth interviews. I therefore added a series of semi-structured, qualitative interviews to the material for this dissertation.

Interviewing elites like politicians and business leaders harbors particular challenges that have to do with their professional skills, like the ability to dodge questions and generate convincing yet misleading accounts. But the biggest challenge was access.[20] To deal with this problem, I relied on a mixture of quota and snowball sampling. Engaging with the archival material, I drew up lists of relevant actors from several different parts of the design process. In particular, I tried to interview regulators (state/federal), stakeholders, engineers, and economists who participated in the political, regulatory, or technical processes of market design and oversight. After identifying key players in each group and convincing a few to participate, I used their contacts to find new interviewees.

The interviews followed a semi-structured format that was based on an interview guide with modifications for each group. The guide was approved by the IRB in November of 2017. It asks several

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[19] I followed the methodological principles outlined in Andrew Abbott's *Digital Paper.* Andrew Abbott, *Digital Paper: A Manual for Research and Writing with Library and Internet Materials* (Chicago: University of Chicago Press, 2014), 110-29; 49-201.
[20] Rosanna Hertz and Jonathan B. Imber, *Studying Elites Using Qualitative Methods*, vol. 175 (New York: Sage Publications, 1995).

questions about the person's role in the restructuring effort and the internal processes at the organizations they worked at. The questions were meant to elicit narratives about their experiences during the crisis. Apart from asking simple, factual questions not well supported by the archival data (e.g., how many people worked in the departments, etc.), I used the interviews to get information on the culture of market design, the narratives of the crisis, and the texture of everyday life in the organizations that ran the markets. I stopped conducting further interviews when the answers to my questions started to become redundant. Upon completion of the interviews, I took notes about my observations. Over the course of about 1.5 years, I conducted seventy-five interviews with sixty-two individuals. While several of the market designers I talked to contributed to the creation of both the PJM and the California markets, eight of the interviewees worked on PJM exclusively. See table 2-5 and 2.-6 for a detailed overview of the coverage of the different aspects of the design process. Since many interviewees participated in a variety of different parts of the design process, the numbers do not reflect discrete interviews, but rather how many interviews contributed to an understanding of the processes in question. Table 2-6 lists the actual number of interviews and participants by profession. The third column identifies the number of market designers in each category.

To transcribe the interviews, I either paid for transcription services by REV.com with money from a Henderson Grant, or I transcribed the interviews by hand. The seventy-five interviews amount to approximately 900–1,000 pages of transcripts. Relying on grounded theory guidelines, I analyzed these transcripts by building primary and secondary codes, refining them in a process of constant comparison.[21]

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[21] Anselm Strauss and Juliet M. Corbin, *Basics of Qualitative Research: Grounded Theory Procedures and Techniques* (New York: Sage 1990); Johnny Saldaña, *The Coding Manual for Qualitative Researchers* (New York: Sage, 2015).

Table 2-5 – Expert Interviews by Organizational Affiliation and Profession

	Economists / Designers	Engineers / Designers	Stakeholders	Lawyer / Politician / Other
Technical Process / Implementation (WEPEX/TAC)	9	8	9	6
Political Design Process: CPUC / CA Assembly	8	6	10	5
Regulatory Design Process: FERC	11	7	8	6
Affiliation After Market Started				
CAISO/PX	10	6	7	9
FERC	12	5	3	5
CA Government	3	2	4	5
Market	2	1	4	1
PJM	2	7	3	4

Table 2-6 – Number of Interviews and Interviewees by Profession

	Interviews	Interviewees	Market Designers
Economist	23	19	12
Engineer	17	16	13
Stakeholders	10	6	-
Lawyer/Politicians	25	21	-
Total	75	62	25

Since the transcripts were used in combination with archival material, I never used the entire corpus, but selected interviews with participants whose experiences were relevant to the analytical question at hand. This approach yielded themes and patterns that helped to elaborate the archival analysis. Since the interviews were retrospective and dealt with events that lie twenty years in the past, I only used them to corroborate or elaborate on evidence that I found in the archival materials. However, in some cases, I do report statements of interviews that are not covered by archival material. This usually refers to *evaluative* judgments about the crisis. In these cases, at least three interviews contain statements that make similar claims. Some of my interviewees preferred to be quoted anonymously. To these quotes, I have assigned an alias. Aliases can be distinguished from real names since aliases only have abbreviated last names.

In sum, this dissertation is mainly based on the rich archival materials from the organizations that built and oversaw the California markets. To enrich the analysis, it draws on in-depth interviews with key stakeholders and market designers. For comparative arguments, it relies on material from the FERC online archives and several interviews with experts who contributed to the creation of the PJM markets. I will now start the analysis, beginning with an introduction to the case as well as the storied history of attempts to shape the narratives that explain it.

PART I. A Failed Market Design Project

3. Two Tales of a Crisis

3.1. The Crisis Unfolds

The unthinkable happened at 11:40 AM on January 17, 2001. The control room of California's Independent System Operator (CAISO) had grown silent over the last few hours. One after the other, all the little signs of slack in the organizational machinery had died down. People no longer moved to and fro, bantered, or cracked jokes. They sat at their control stations and worked. Occasionally, a telephone call punctuated the silence. Hunched over their desks, operators picked up, stated terse requests, hung up, and dialed again, all the while observing signals from a variety of screens that covered the surfaces of the large room.[1]

The operators sat at semi-circular stations in CAISO's control room, lovingly called the "fish bowl" by the employees. The stations were organized around a large map-board that covered the entire front wall. It provided a schematic overview of California's high-voltage electricity grid. Hundreds of small red and green lights represented every major generation facility and electric switchyard in California. Lines of varying thickness represented transmission links, and LED digits indicated the amount of power presently flowing on each link. The workstations were dedicated to specialized tasks. Each station provided the operators with specialized information, such as voltage support levels, path protection, and generation balance. Glancing up from their individual screens, operators could check the real-time status of the grid on the board.[2] This way, the map

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[1] Arthur O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator* (Lincoln, NE: iUniverse, Inc., 2003), 165-68.
[2] Emery Roe and Paul R. Schulman, *High Reliability Management: Operating on the Edge*, High Reliability and Crisis Management (Stanford, CA: Stanford Business Books, 2008), 25-29.

focused on the dispersed activities in the large room and provided a common reference point. What the operators saw on the wall was not good.

The complex setup of screens, dials, and control panels served a singular purpose. CAISO managed the network of high transmission lines that delivered energy from generators to local distribution networks and from there to end users. At first sight, the technical sophistication of the control room may seem surprising. The blinking LEDs, the large map-board, and the control stations evoke images of interstellar travel rather than the mundane task of moving electricity from a generator to the toaster in someone's kitchen. But the veneer of the mundane often belies great and fragile complexity.[3] The production and delivery of electricity is such a case: it depends on a complex process of adjustments, unparalleled by other infrastructures. As soon as a generator releases energy into the grid, it travels at nearly the speed of light through a vast network of transmission lines. Following Kirchhoff's laws, energy takes all available paths in this network. This means that the inputs from different generators combine and interact with each other. In 2000, the California network had about 3,500 buses and 25,526 miles of circuit power lines. This network was tied into the larger framework of the Western Interconnection, which had over 20,000 nodes and connected parts of Mexico, Canada, and eleven states in the western United States. For energy to traverse this system reliably, frequency and voltage must always be kept within a tight band of error in all parts of the system. Even just minor differences between components of the system can lead to equipment failure and cascading blackouts with potentially devastating effects on people's lives. Maintaining this precarious balance is complicated further by the characteristics of energy production.

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[3] Much of our cognition relies on automatization: processing information without much review is crucial for getting things done efficiently. Unless elements of our environment do not pose obstacles to our practices, they disappear from consciousness into the taken for granted background of our life—this is particularly true for technology. Karen A Cerulo, "Mining the Intersections of Cognitive Sociology and Neuroscience," *Poetics* 38, no. 2 (2010): 117.

Since it is not feasible to store large quantities of electricity (yet), production and consumption of electricity need to be adjusted to each other nearly *instantaneously*. If someone switches a light on in San Francisco, a generator somewhere in the service territory of Pacific Gas & Electric (PG&E) needs to produce that energy just a fraction of a second earlier. These characteristics require that the central system operator constantly adjust the production of energy to be in balance with changes in consumption, all the while maintaining the security standards required for reliability. Since each change in input can influence the available transmission capacity, voltage, and frequency anywhere else in the system, even just one change in one part of the system can require wide-ranging adjustments in all other parts. To get a feeling for this complexity, you can imagine electricity as a concert of light pulses in which each generator influences the pattern and rhythm of the whole—an infinitely complex performance that may collapse with little more than a single node falling out of rhythm. The technical complexity of this constant coordination explains the futuristic look of the control room.

Since about 5:00 AM, the operators had been fighting to keep the system going. Many of the crucial indicators on the board had been worrisome. Now they suggested an impending disaster. Information from a dozen different feeds added up to one simple message: there was not enough capacity. Californians were using a lot more electricity to heat their buildings than usual. Meanwhile, the supply to satisfy the growing demand had virtually disappeared. Many generators inside California had produced in excess of their ideal operating conditions during the summer and were now shut down for maintenance. Generators in adjacent states that normally sold to California did not offer their energy. Even pumped-storage facilities, whose water could usually be relied on to deal with bottleneck situations, were depleted. "We could see that we were at the ragged edge," said CEO Terry Winter to the reporters who had gathered in the "blue box" area of the control room.[4]

Increasingly desperate, the operators relied on informal channels to cope with their task. They had long stopped relying on just CAISO's official imbalance markets, which could be used to adjust supply to sudden fluctuations in demand. Rather than trusting the numbers on their screens, they called friends at other utilities, asked for favors, and begged them to send whatever they had at whatever price. "Everybody around here was doing everything they possibly could," said Jim McIntosh, the director of grid operations. But at 11:00 AM, the balance of forces shifted against the team. A large generating plant in the central coast area declared an engine failure and went offline. In the little time that remained until the impact would materialize, it was impossible to find sufficient energy. "We begged. We borrowed. We tried to steal, but there wasn't anything to steal," remembered Ed Riley.[5] At 11:40 AM, the operators gave up.

The system operator had to institute rolling blackouts in California. Despondent, McIntosh said: "That one day, there wasn't anything left."[6] Then, about 320,000 customers in the San Francisco area lost electricity. After two hours, the blackouts moved up north into central and northern California. Traffic lights, refrigerators, and ATM's stopped working.[7] Images went around the world of mechanics opening elevator doors with crowbars. It seemed absurd that widespread blackouts would affect the state of the computer revolution, the world's fifth largest economy. And

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[4] David Lazarus, "LIGHTS OUT - Juice Cut Again; S.F. Sues Power Firms," *SFC*, January 18, 2001, A1.
[5] O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 167.
[6] Ibid.
[7] Chuck Squatriglia; Justino Aguila, Patrick Hoge; Matthew Stannard,"Rolling Blackouts Hit - Power Cut to Parts of Bay Area at Midday … PG&E Defaults on Debt" *SFC*, January 18, 2001, A1.

yet, it had happened—the system operator had failed in its mission to provide reliability at all cost. "We all just stood there, kind of shocked," said Riley.[8]

But the operators did not have much time to catch their breath. On January 18, the drama repeated itself, and they had to cut twice as much electricity as the day before. After that, the system teetered on the brink of collapse for another thirty days. Pulling together everything they could and working sleepless nights, the operators managed to improve the situation slightly. But despite their combined efforts, blackouts rolled across the state on three more days, affecting millions of Californians. As of May of 2001, the system operator had declared thirty-eight Stage Three emergencies necessitating rolling blackouts.[9] Nonetheless, the operators largely succeeded in preventing blackouts in residential areas, ingeniously pulling the system back from collapse. For several months, the nation stood by in astonishment as California's electrical infrastructure struggled at the brink of system failure.[10]

The dramatic fight to keep the lights on formed the climax of a crisis that had begun about a year earlier, in April of 2000. The crisis followed a familiar pattern: a problematic development was left unrecognized for long enough to turn into a self-sustaining process that escalated as its effects spilled over into adjacent domains. Everything began with problems in the energy markets. These problems quickly spiraled out of control and led to a financial crisis of the most important utilities. Political paralysis allowed the financial crisis to spill over into the operation of the grid, which led to reliability problems that dragged the electricity system as a whole to the brink of collapse. Desperate attempts to bring things back under control eventually required that the state

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[8] O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 168.
[9] EIA, "Subsequent Events-California's Energy Crisis," https://www.eia.gov/electricity/policies/legislation/california/subsequentevents.html, last accessed 03/07/2020.
[10] This is the reason CAISO has been studied as an instance of "high reliability management." Roe and Schulman, *High Reliability Management: Operating on the Edge*.

get involved. The government took over the procurement of electricity and ultimately socialized the problem. This, finally, turned the reliability problems into a (temporary) budget crisis for the state of California. By the time the crisis went into remission, the state had spent more than $7 billion to avert a disaster, committing dozens of billions more for long-term contracts to ensure the delivery of reliable energy in the future.[11]

This dissertation traces the structural preconditions for the crisis. In this chapter, I am going to lay the ground for this investigation by introducing the case as well as the analytical orientation of the study. Specifically, I pursue three goals. First, I will expand on the brief sketch just given and reconstruct the progression of the California crisis blow by blow. This will give a sense of how a complex interplay of factors drove the crisis to its logical conclusion in 2002. Against this background, I will then develop the two dominant explanations of the crisis and show why their disagreements remain intractable. This will also reveal the analytical structure of the dominant explanations. In a third and last step, I will argue that we should analyze the California crisis as a case of failed market design, which calls for a different analytical approach.

To appreciate the logic of the crisis and its rapid escalation, it is necessary to zoom in from the 10,000-meter view just presented. Everything began in California's brand-new energy markets. In 1996, the California legislature had decided to restructure the industry. Two years after the Assembly passed law AB1890, the state placed competitive markets on top of the electricity system. While the operators in the control room managed the physical flow of electricity from

[11] Contrary to common belief, the electricity crisis did not have a lasting effect on the state budget, though. The state had to pay for electricity through 2001 and used its general fund to do so. But it repaid the general fund by selling $6.2 billion in electricity bonds. These were financed by ratepayers, not taxpayers. Accordingly, the crisis was largely paid for by the customers of the utilities—the crisis was socialized by state intervention but not with tax revenues. Steven M. Sheffrin, "State Budget Deficit Dynamics and the California Debacle," *Journal of Economic Perspectives* 2, no. 18 (2004): 215-16. The long-term contracts were renegotiated during the litigation of the crisis.

generators to customers, a series of forward markets created the financial obligations that stood behind the production and consumption of energy. The most important of these markets were operated by the Power Exchange (PX), a public interest organization that matched buyers and sellers in centralized auctions. In these auctions, a variety of sellers offered to deliver energy at different locations in California. Most of these bids specified delivery for the next day or the next hour. The most important buyers of this energy were California's three big utilities: Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E). They served between 75 and 80 percent of California's end users and bought wholesale energy on the basis of estimations about the real-time use of their customers.[12] The trade in the forward markets generated anticipated schedules of generation and consumption. In real time, CAISO's control room then executed these schedules as closely as possible, using imbalance markets to adjust for real-time fluctuations. The structure of these markets was much more complicated than this, but right now it suffices to understand that the three big utilities accounted for most of the demand in California and that they had to buy their energy in markets with very short time horizons, i.e., for delivery during the next day or hour.[13]

For about two years, this structure worked seemingly well and produced low prices. But in April of 2000, the prices for wholesale electricity began to fluctuate dangerously: they first spiked to unprecedented heights, then fell drastically only to jump back up and remain high for several months. Initially, the utilities, regulators, and politicians thought the price spikes were just a minor

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[12] The remaining end users were largely served by municipalities (22 percent), who had been excluded from restructuring. James L. Sweeney, *The California Electricity Crisis* (Stanford, CA: Hoover Institution Press, 2002), 78.
[13] In the electricity industry, day- and hour-ahead markets are often referred to as "spot" markets. This is not technically correct because they also refer to future points of delivery. I will refer to the energy imbalance markets in the ISO as spot markets because their results were not open to revision. Darryl R. Biggar and Mohammad R. Hesamzadeh, *The Economics of Electricity Markets* (Chichester, UK: John Wiley & Sons, 2014), 73.

hiccup, growing pains of competitive markets that were caused by minor supply shortages during unusual weather. Small spikes had occurred at the end of 1999 and were generally expected in a new market environment.

But the new markets defied these hopeful expectations. The spikes kept disrupting the markets and rapidly pushed the average price up. Between the second half of 1999 and the second half of 2000, the average price increased by 500 percent. During the first four months of 2001, it increased to over 300$/MWh, which represented a 1,000 percent increase in comparison to 1998 and 1999.[14] Figure 3-1 shows monthly average prices in the PX day-ahead market and the ISO imbalance markets for the time between 1998 and 2001 in northern and southern California. Since the figure reports averages, it hides significant fluctuations: for certain hours, the prices would spike as high as $1,400 dollars, while at other times they would be as low as before the crisis.[15]

The increases in average prices were bad news for all buyers of electricity, but they posed an existential threat to the three utilities.[16] As part of the restructuring, the utilities had divested about 60 percent of their generation assets.[17] In addition, they had very few long-term contracts from the time before restructuring. Fearing a lack of competition in the new markets, the California Public Utility Commission (CPUC) instituted a rule that required the utilities to buy all their energy in the short-term spot markets of the PX.

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[14] Paul L. Joskow, "California's Electricity Crisis," *Oxford Review of Economic Policy* 17, no. 3 (2001): 1. The quantity of energy that generators deliver is measured in MW/h, while the capacity is measured in MW. The capacity is the *rate* at which energy flows over a line. It describes the maximum output rate of the generator under ideal operating conditions. Since the rate is a relative term, energy is sold and priced in MW/h. To get a certain job done, you need a specific *amount* of energy. Any specific power level gets a job done relative to how *long* the power continues to flow. A megawatt flowing for one hour is a MW/h. For example, to boil some water you need about 30 watt-hours, i.e., a generator needs to supply energy at a rate of 0,000,03 MW for one hour. Biggar and Hesamzadeh, *The Economics of Electricity Markets*, 34.

[15] The data for the PX ends in February of 2001 because the organization declared bankruptcy and stopped operating auction markets.

[16] Sweeney, *The California Electricity Crisis*, 145.

[17] They sold mainly their natural gas plants, which had constituted over 50 percent of their operational capacity in 1999. These plants were important to serve peak periods, when the prices were particularly high, ibid., 67, 134.

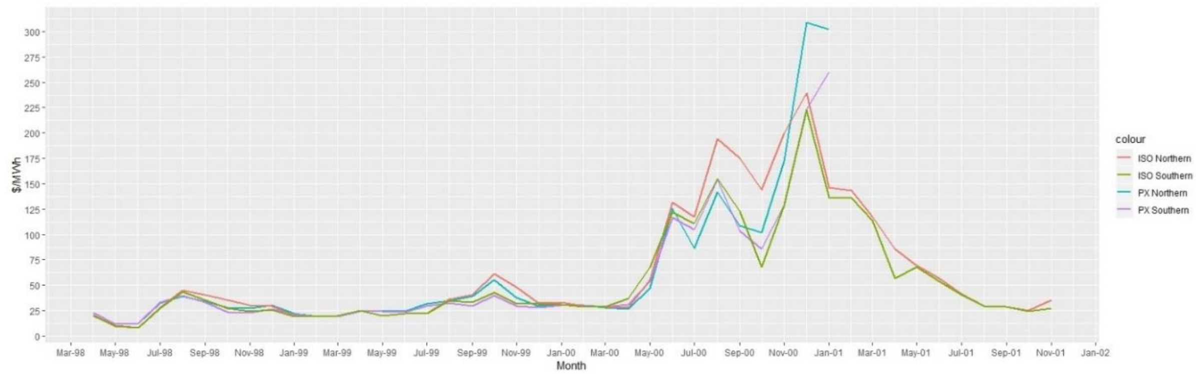

Figure 3-1 – Average Prices in the PX Day Ahead Market and CAISO Real Time Market

This was meant to secure the liquidity of the new markets. But without long-term contracts or independent generation assets, the utilities were unable to protect themselves against the volatility of the spot markets, and the price spikes hit them with full force. Normally, the utilities would have recovered these high costs of wholesale energy by increasing the rates they charged to retail customers. Basic economic theory suggested that this would have led to a decline in demand, which would then have led to downward pressure on wholesale prices. But the utilities did not have recourse to such rate hikes. A state law had imposed a retail-price freeze for the first years after restructuring.[18] This freeze had been a product of political negotiations between the utilities and the CPUC.

During the political negotiations about restructuring between 1994 and 1996, the utilities had fought for the right to recover "stranded costs." Such stranded costs were investments into generation assets that had been approved by regulators but would become uneconomical in the context of a competitive market.[19] The utilities now argued that they wanted compensation for these investments. Their point was straightforward: they had made these investments under a

[18] The details of this arrangement will be discussed later, ibid.
[19] The stranded costs were calculated as the asset's market value in a competitive setting minus the book value that would still have to be paid by ratepayers under the regulated structure. Current net book values of utility assets are the allowable costs that have not yet been recovered. Carl Blumstein, Lee S. Friedman, and Richard Green, "The History of Electricity Restructuring in California," *Journal of Industry, Competition and Trade* 2, no. 1-2 (2002): 8.

regulated system. This meant that the CPUC and the California Energy Commission (CEC) had approved the decisions and granted the right to recover the costs from rate payers. Given that the utilities had made these investments in good faith, they felt that it would only be fair to recover their "stranded costs" under the new system as well. The CPUC, which spearheaded the development of the new markets, decided to honor the commitments of the old regulatory consensus. They designed a Competitive Transition Charge (CTC) that enabled the utilities to recover their costs. This charge would be derived from the difference between the spot prices in the PX and the retail price of electricity.[20] Since everyone assumed that wholesale prices would be lower than retail rates, the regulators froze the retail rate at the level established on January 1, 1996. At low wholesale prices, the utilities would then quickly recover their stranded costs from the difference between wholesale and retail price. After that period, the freeze would be lifted and consumers would be exposed to the price risk of the wholesale markets. Of course, the entire mechanism would only work if the wholesale costs actually remained low.

And lo and behold: when the crisis began in May of 2000, the logic quickly turned on its head. Since wholesale prices were suddenly far above the retail price, the utilities no longer made profits from the difference. Instead, the price freeze prevented utilities from charging their customers the wholesale price. Not only were they barred from charging their customers the true costs of energy, but they were also unable to cut demand because they had a legal obligation to serve all

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[20] The actual structure of this agreement was more complicated because AB1890 also required utilities to lower the retail prices for certain customers. To make sure that they would be able to recover their stranded costs despite these reductions, a financial instrument (rate reduction bond) was used. Essentially, the utilities subsidized the lowered rates with these bonds and would, in later years, recover the bonds after the transition charge was no longer in effect. This simply means that the rate reductions consumers experienced were actually loans on later rate payments. Sweeney, *The California Electricity Crisis*, 72.

customers.[21] In this situation, they had no choice but to buy the required energy at any cost and without ways to recuperate their losses.

The utilities' vulnerability created the foundation for the next phase of the crisis: with no means to defend themselves, the utilities would quickly bleed out. Since they were the crucial intermediary between most of California's end users and the wholesale markets for energy, their demise would undermine not only the markets but also the reliability of the electricity system. This chain of events played out because the crisis paralyzed the regulatory and political apparatus. Recognizing the danger of their exposure to the spot markets as early as March of 2000, the utility executives pleaded politicians and regulators to help. But during the early months, it was neither clear how long the price spikes would last nor what exactly was driving them. Trying to navigate a murky and increasingly dangerous situation, utilities, regulators, and politicians commenced a complicated dance that left the crisis unresolved. As early as May of 2000, the utilities petitioned the CPUC and Governor Davis to lift the existing limitations on forward contracting outside the PX. In May, several independent generation companies were offering forward contracts for 50 $/MWh, which would have reduced the utilities' reliance on the spot markets. But since the price was still in excess of pre-crisis levels, the CPUC was hesitant to heed the utilities' requests. They were worried the utilities might lock themselves into expensive forward contracts, which would then lead to unnecessary rate increases later on. After a month, the CPUC commissioners realized that the price spikes were there to stay and changed their minds. They now allowed the utilities to

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[21] This problem was exacerbated by a regulatory imbalance in the new retail markets. The utilities had to serve all customers and even had to take them back after they had switched to a different supplier. Alternative retail suppliers, however, did not have such an obligation and had no regulatory limitations for their retail prices. When the crisis hit, retail customers thus came back to utilities who had to charge low prices and could not turn them away. Charles J. Cicchetti, Jeffrey A. Dubin, and Colin M. Long, *The California Electricity Crisis: What, Why, and What's Next* (Norwell, MA: Kluwer Academic Publishers, 2004); Timothy P. Duane, "Regulation's Rationale: Learning from the California Energy Crisis," *Yale Journal on Regulation* 19 (2002).

buy power outside the CAISO and PX, thus opening the path to enter into cheaper contracts. However, the California legislature immediately overrode the decision and requested that the CPUC demonstrate that allowing utilities to purchase energy was in the public interest. The CPUC never provided the demonstration.[22]

In August of 2000, the CPUC then decided to lift restrictions on forward contracts that the utilities could enter through the PX markets themselves. Since the end of 1999, the organization had started to offer so-called block-forward contracts, but the CPUC had severely limited the conditions under which those contracts could be used. Even after the commissioners decided to remove restrictions on the conditions of these contracts, the agency withheld the guarantee that the prices for these hedges would count as "reasonable." This meant that the utilities could not be sure that they would be allowed to recuperate the costs from their customers when the crisis was over. Perhaps because the reasonableness standard was unclear and utilities wanted to protect their investors, they decided against hedging. Perhaps they counted on the state to bail them out. Perhaps they thought other recourses would be cheaper. [23] The record is ambiguous, but one thing is clear: when it finally became obvious that forward contracts were the only way to avoid a financial disaster, the cheap options disappeared from the markets.

Without the ability to hedge their position, the utility executives now began to hope that the regulators might eventually release them from the rate freezes. But the political establishment in California tried to avoid such increases with all its might. The first place where the issue came

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[22] Steve Isser, *Electricity Restructuring in the United States: Markets and Policy from the 1978 Energy Act to the Present* (Cambridge, MA: Cambridge University Press, 2015), 256.
[23] This issue is more complicated than presented here and will be discussed later in greater detail. Essentially, there were other ways for the utilities to hedge, and it contested why they did not do this. Frank A. Wolak, "Diagnosing the California Electricity Crisis," *The Electricity Journal* 16, no. 7 (2003): 17; Cicchetti, Dubin, and Long, *The California Electricity Crisis: What, Why, and What's Next*, 67-68. Later, I will argue that the restriction on forward contracts was less relevant to the emergence of the crisis than has usually been claimed.

to the fore was San Diego, which was being served by the smallest of the three big utilities that served California's retail customers, San Diego Gas & Electric (SDG&E). The company had sold most of their generation assets before restructuring. Since they now had very low stranded costs, they managed to recover their money through the spot markets by 1999. No longer beholden to the rate freeze, the utility started to charge customers in San Diego the price of the wholesale markets. When the crisis hit, the results were spectacular. In August, consumer electricity bills suddenly doubled. One interviewee put it like this: "The prices in San Diego went crazy, and the small businesses were affected. San Diego is a very small part of our big state, but it was sort of a canary in a coal mine."[24] The prices were so high that some restaurants could not stay open in the evening. In San Diego, the crisis burst from the obscure world of utility experts who traded in wholesale markets onto the stage of everyday life. The public was outraged. "There were demonstrations in the streets," one of the CAISO board members recalls. "FERC came out to meetings in San Diego that were surrounded by protestors."[25] The promise of restructuring had always been for lower rates. For the most part, people did not want to think about electricity markets or the best way to incent long-term efficiencies in energy production. They wanted cheap, reliable energy.[26] When the prices suddenly skyrocketed, the outrage was commensurate with the desire not to be bothered with issues surrounding a simple and taken-for-granted thing like electricity.

The situation in San Diego first put the crisis into the center of public attention and created significant political pressure to reign in the markets. As the CEO of the PX remembered, "The

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[24] Interview with Thomas K., 03/15/18.
[25] Interview with Andrew F., 01/25/2018.
[26] To prepare for deregulation, the CPUC started a $90 million publicity campaign to alert end users of their ability to choose their own provider. Even though "retail choice" had been one of the leading issues during the debates about restructuring, these efforts largely evaporated without effect. Less than 3 percent small commercial and residential customers decided to switch their provider, c.f. CEC data cited in Christopher Weare, *The California Electricity Crisis: Causes and Policy Options* (San Francisco, CA: Public Policy Institute of California, 2003), 41.

howling, and the crying, and the screams, the hearings, the everything. This just blew up, this whole political fiasco, and created a situation in which there was panic, and at which price caps were put on that we didn't have before. The state legislative branch had several hearings on this problem caused by San Diego in May and June."[27] SDG&E filed a complaint at the Federal Energy Regulatory Commission (FERC), which was responsible for "just and reasonable" prices in the wholesale markets. Steve Peace, the senator who had spearheaded the efforts to pass the legislation for restructuring, started a crusade against the system operator. The California legislature re-imposed the retail price controls and closed off the utilities' route to cost recovery.[28] From then on, it was clear to politicians that it would be political suicide to allow the rate increases that would be necessary to reflect the cost of wholesale energy at the level of the end users. Accordingly, they rejected the requests of the utilities as the crisis got worse.

In addition to the political reasons for not helping the utilities with rate increases, the CPUC and the governor's office became increasingly convinced that the wholesale markets were not working properly. Until about August of 2000, the dominant narrative had been that California suffered from a shortage of supply and that the high prices would eventually attract new generation assets that would drive down the high prices. In the service of this belief, various task forces had tried to find new generation that might stabilize the system. But bringing a new power plant into the system is a long process. Before the plant can be constructed, the California Energy Commission (CEC) has to conduct a review process that included public hearings. This process alone could take two years. If the plant gets approved, it needed to be built. For bigger plants, construction

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[27] Interview with George Sladoje, 03/30/2018.
[28] Will McNamara, *The California Electricity Crisis* (Tulsa, OH: PennWell Corp., 2002), 40-43.

could take several years. Peaker plants could be built quicker, within a year.[29] Once the plant is complete, it needed to be tested. First it had to operate offline, and then it had to run at a low level of power output. After the tests are completed, it is finally certified for operation. The entire process could take three to four years, though for small plants it might have taken as little as one year.[30] Either way, in the face of constant price spikes, the new supply was needed within days or weeks. There were no easy solutions, and the task forces were getting creative. For example, the head of CAISO's governing board, Jan Smutny Jones, entertained the possibility of hooking up the on-board generators of two U.S. Navy aircraft carriers in the San Diego harbor. For a brief moment, there had even been a plan to float a diesel power plant on a barge from Brazil to San Francisco. Yet both plans proved infeasible, and the people in charge of the system's reliability became increasingly desperate for a new supply.[31] While the frantic search for new generation was underway, the narrative of the crisis suddenly changed.

Based on an investigation by the CPUC and another regulatory organization, the Electricity Oversight Board (EOB), the governor became convinced that the crisis was not primarily due to supply shortages, but reflected the exercise of market power.[32] Market power is a company's ability to influence the prices unilaterally, either by physically withholding generation capacity or by influencing the clearing prices in auctions (economic withholding). In a written statement to the

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[29] These are relatively simple and inefficient plants that only come online when the system experiences high demand for short periods of time (peak demand).
[30] Peter Navarro and Michael Shames, "Electricity Deregulation: Lessons Learned from California," *Energy Law Journal* 24, no. 1 (2003).
[31] The plan to bring the barge to San Francisco had first been entertained during the summer of 1999. It belonged to a PG&E subsidiary. Interview with Jan Smutny Jones, 08/17/2017.
[32] This opinion can be found in a joint report by the president of the Electricity Oversight Board and the CPUC to Gray Davis: Kahn, Michael; Lynch Loretta, "EOB-CPUC Report" submitted in: "Joint Informational Hearing," Senate Committee on Energy, Utilities And Communications And Assembly Committee On Utilities And Commerce, California Senate Archive, State Capitol, Sacramento, California, August 10, 2000. The core claim that the markets may be manipulated appeared prior to the release of the report.

press from July 2000, Governor Davis declared that the current situation was "unjust and totally unacceptable" and said there was not yet sufficient competition among electricity suppliers to strip away regulation without hurting consumers.[33] Effectively, the state government claimed that generators and energy companies were manipulating the markets to exploit customers. Davis called the state attorney general Bill Lockyer to investigate the "possible price manipulation in the wholesale electricity marketplace." This implied that the solution was not to be found mainly in the balance of supply and demand. Rather, the best way to improve the situation would be to double down on price controls and freeze the prices not just in the retail, but also in the wholesale markets.

Despite their determination to end price gouging in the wholesale markets, the CPUC and governor's office were unable to curb what they perceived to be problematic behavior—they did not have the requisite jurisdiction. Since the markets had a regional structure that transcended state lines, it was the federal regulator, FERC, that did have the authority. However, FERC's leadership was committed to restructuring and had close ties with companies like Enron, which heavily lobbied for energy deregulation in Washington. Accordingly, FERC did not agree with California's allegations. Not only did they react extremely slowly to events that were unfolding at a rapid pace, a staff investigation in August 2000 responding to the problems in San Diego came to the conclusion that the crisis was mainly a problem of supply and demand imbalances.[34] Accordingly, the commissioners were hesitant to curb the high prices in the wholesale markets too much or remove sellers that might be driving up prices. They thought that the best way to resolve the crisis would be to incent new generation and change the market protocols. The staff report therefore led to

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[33] Vogel, Nancy (2000): "Davis Seeks Price Ceiling on Soaring Electricity Rates," *LAT*, July 28, 2000.
[34] This part of the crisis played out in response to SDG&E's complaint from August of 2000. They were asking for restrictions to seller's behavior and price caps of $250. The other utilities and the CPUC joined the complaint in support. Gary Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present* (Utilities Report Inc., 2015), 72.

various suggestions for gradual reform of the market protocols and the creation of incentives for new generation.[35]

Ideologically, politically, and historically at odds with each other, the agencies at the federal and state level had increasing difficulties agreeing on a joint course of action, and the atmosphere between California and Washington turned sour. The tug-of-war between the state and the federal level played out not just before FERC, but also at CAISO. The organization had a governing stakeholder board that decided the best strategy to deal with the crisis. The twenty-six representatives came from all branches of the energy industry. Prior to the crisis, this board was usually able to agree on the development of the energy markets, but when the crisis began, most of those who made money began to disagree with most of those who were losing it. Technical issues rendered unclear whether price caps would help with the crisis and, if they would help, how high they should be. Soon, the California government leaned on the board to apply lower price caps. FERC insisted that any price caps could only be remedial. Torn between the different political pressures and divided amongst its members, the board could no longer reach majority decisions. The conflicting demands from the political apparatus combined with the internal interest conflicts turned the atmosphere toxic, and the board became dysfunctional.

When the situation continued to worsen, FERC eventually sanctioned price caps in CAISO's imbalance markets. But it mandated that the prices had to be high enough to attract new entrants. Even after they finally became convinced that the markets were not workably competitive in November of 2000, they did not implement strong behavioral constraints for sellers of energy.

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[35] Richard O'Neill and Udi Helman, "Regulatory Reform of the U.S. Wholesale Electricity Markets," in *Creating Competitive Markets - the Politics of Regulatory Reform*, ed. Marc Karnis Landy, Martin A. Levin, and Martin M. Shapiro (Washington, D.C.: Brookings Institution Press, 2007), 144. "Order Accepting for Filing in Part and Rejecting in Part Proposed Tariff Amendment and Directing Reevaluation of Approach to Addressing Intrazonal Congestion" 90 FERC 61,0006 (January 7, 2000).

Since the California system was tied to regional markets that were also facing supply shortages, the moderate price caps did not lead to improvements. Instead, they reduced the available supply in the wholesale markets further, pushed the prices to the allowed limit, and did nothing to relieve the utilities even though the resulting market prices were still far above the retail price. In December of 2000, SCE sued FERC for failing to ensure reasonable wholesale prices, and on January 2, Governor Davis joined the lawsuit. Paul Joskow, an MIT economics professor who analyzed the California markets during the crisis, summarized the situation like this: "When it became clear it was not just a supply problem, the state and feds stared at it for months, pointing fingers at each other."[36]

With no authority to regulate wholesale prices, a very limited ability to reduce demand, no affordable forward contracts, and infeasible rate increases, there were seemingly no good options. Boxed into an impossible situation, the governor and the CPUC commissioners put their heads down, accused generators of market manipulations, and denied requests for rate increases. Various attempts to implement demand response programs and expedite the approval of new generation facilities did not do much to improve the situation.[37] To the state actors, this only proved to show the dysfunctionality of the markets, and they dug their heels in further. In 2003, after the crisis had cost him his political career, Davis recapitulated his experience in a speech at UCLA: "I inherited the energy deregulation scheme, which put us all at the mercy of the big energy producers. We got no help from the federal government."[38]

A minor episode in December of 2000 captures how helplessly the government stood by as the crisis raged on. Davis attended a traditional ceremony to celebrate the beginning of the

[36] Quoted in Peter Behr, "Calif.'s Davis Lacked Legal Ability to Solve Energy Crisis," *WP*, August 24, 2003.
[37] Weare, *The California Electricity Crisis: Causes and Policy Options*, 44-46.
[38] Quoted in Carla Marinucci, "Contentious Davis Blasts GOP 'Power Grab'" *SF Gate*, August 20, 2003.

Christmas season and presided over the lighting of the state's Christmas tree in Sacramento. After the 4,000 bulbs lit up in festive colors to the "ohs" and "ahs" of a cheering crowd, he waited a few minutes and then switched the tree off. The utilities had begged Californians to forgo Christmas decorations in order to save energy, and the governor was trying to set a precedent with a symbolic gesture. Davis closed his speech with bitter words that stood in contrast to the season's spirit: "We're going to send FERC a picture of the tree going dark."[39]

Since the crisis had paralyzed the political and regulatory apparatus, the utilities approached insolvency after a few months. The retail price remained fixed, the wholesale price remained high, supply remained scarce. In December of 2000, the utilities' credit became so poor that the sellers of energy were not sure that they would get paid.[40] Accordingly, generators became increasingly unwilling to sell energy into California and chose other Western states that offered better conditions. Some of the independent energy producers had not been paid in such a long time that they could not afford to buy fuel anymore or risked bankruptcy themselves.[41] The prices at hours of peak demand are indicative: in one hour on January 17, 2001, the PX hour-ahead market price exceeded 1000$ per MW/h. Yet, despite this extraordinary price, only 70MW of bids were submitted. In other words, even if operators promised to pay arbitrary prices, it became almost impossible to find enough energy to keep the system going. This, of course, drove prices up further, made the crisis worse, and increased the risk of selling energy in California as no one knew how long the system would last before it broke or what the regulatory response might be. Would the

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[39] Nancy Vogel, "Crisis Darkens State Christmas Tree.," *LAT*, Dec. 6, 2000.
[40] In January and March of 2001, the CPUC finally granted utilities rate increases, but these measures were too little too late and could not resolve the utilities financial troubles.
[41] Laurens J. de Vries, "The California Electiricty Crisis: A Unique Combination of Circumstances or a Symptom of a Structural Flaw," in *Institutional Reform, Regulation and Privatization - Process and Outcomes in Infrastructure Industries*, ed. Rolf W. Kuenneke, Aad F. Correlje, and John P.M. Groenewegen (Chelenham, UK: Edward Elgar, 2007), 96.

generators be paid for their energy? No one knew with certainty. Around the turn of the year, the financial crisis of the utility companies therefore turned into the reliability crisis we encountered in the control room on January 17, 2001.

Since the PX markets increasingly came up short of needed supplies, CAISO's operators were desperately trying to make up the shortfall of scheduled supply in the imbalance markets—sometimes within a few hours, sometimes within minutes before dispatch. As the need to find energy concentrated in the control room, the danger of system emergencies greatly increased. Figure 3-2 shows the dramatic increase of stage 1, 2, and 3 emergencies in 2000 and 2001. Stage 1 refers to a situation in which the operating reserves are forecast to fall below seven percent. It merely requires voluntary conservation efforts. The system operator declares stage 2 when the anticipated operating reserves fall below 5 percent. This leads to the curtailment of interruptible loads and demand relief programs.[42] Stage 3 is declared when the actual operating reserves fall below 1.5 percent. In that case, emergency resources are drawn on and rolling blackouts are implemented.

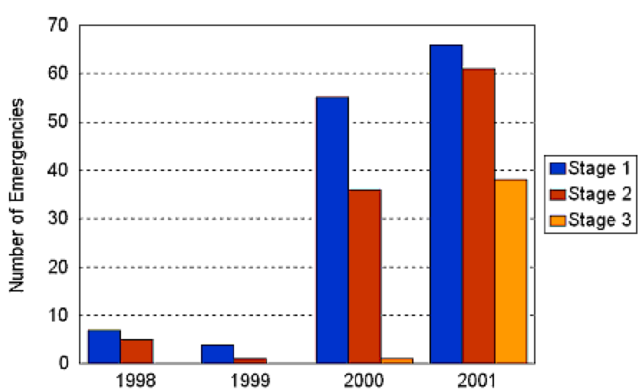

Figure 3-2 – System Emergencies in California Over Time
Source: California Independent System Operator

[42] Interruptible loads refer to energy that was sold with the caveat that it may be interrupted should the need occur. This energy is usually purchased by users who can reduce their use of energy flexibly.

Under immense pressure, the CPUC finally approved a 10 percent rate increase in January of 2001. But this was too little too late. Shortly after the events of January 17, the utilities became unable to pay their bills, and central pieces of the market collapsed. Without utilities or willing sellers, the PX markets became illiquid, and the organization declared bankruptcy in February of 2001. Shortly after, it ceased operations. In April, PG&E declared bankruptcy.[43] SCE had been at the verge of bankruptcy since November 2000.[44] Amidst rolling blackouts and system emergencies, it was increasingly unclear how the majority of end users could be served, and a system collapse seemed possible.

To prevent a disaster and guarantee the demand for energy would be served, the state finally took over and vouched for the utilities. As a first step, the Davis administration took over control of the CAISO, whose stakeholder board had become dysfunctional. In a dramatic move, the governor disbanded the board in January of 2001 and replaced it with five persons loyal to him. One of the former board members recalls how suddenly this move came. She was on her way to the board meeting, when "a process server came to my door and served me with a legal summons, and said that if I didn't resign from the California ISO board, I would be prosecuted as impersonating a board member."[45] Faced with the possibility of the entire state grinding to a halt, the administration then took over the procurement of power.

On February 1, the governor signed into law AB1X authorizing the Department of Water Resources (DPWR) to purchase power under long term contracts for sale to PG&E and SCE. The employees moved into the CAISO headquarters, and their actions largely replaced the market

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[43] Pacific Gas & Electric Company, Press Release April 6, 2001, http://www.pgecorp.com/corp/news/press-releases.page, last accessed 03/07/2020.
[44] Southern California Edison, Press Release, November 17, 2000, https://newsroom.edison.com/releases/sce-proposes-plan-to-stabilize-rates-protect-customers-from-san-diego-type-rate-shock, last accessed 03/07/2020.
[45] Interview with Barbara Barkovich, 10/14/17.

mechanisms of the auction markets with a centralized purchasing program. This move finally turned the financial crisis of the utilities into a budgetary crisis of the state. Since these contracts were signed at the climax of the crisis, their terms were unforgiving and three to four times the national average. Through August 31, 2001, the state paid $10 billion for electricity, which was then sold back to the utilities at the regulated price for about $3 billion. When all was said and done, the state lost about $7 billion from the state budget.

But the implied costs of the crisis were much higher. The long-term contracts committed the state to purchase $42 billion worth of electricity over the next ten years. This represented about 3.5 percent of the yearly total economic output of California at the time. In comparison, the Savings and Loan debacle of the 1980s amounted to a total cost of $100 billion, but that represented just one half of 1 percent of the total U.S. economy.[46]

During the subsequent litigation, California managed to renegotiate many of the long-term contracts and recovered $7.5 billion of the money they had paid to sellers of energy in 2001. So, from today's perspective, the total cost of the crisis remains somewhere below $5 billion. These costs were ultimately shifted onto rate payers. But before two decades of litigation commenced, it looked like the crisis had cost the state somewhere between $40 and $47 billion dollars. The market crisis had morphed from a financial crisis to a system one, and finally a state budgetary crisis.[47] It prematurely ended Gray Davis's career as governor in 2003 and paved the way for Arnold Schwarzenegger. It also led to a second restructuring of California's energy industry in the years to follow. Seven states that had prepared to follow in California's footsteps canceled their plans for restructuring. On September 20, 2001, the five members of the CPUC voted to end power

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[46] Weare, *The California Electricity Crisis: Causes and Policy Options*, 4.
[47] James L. Sweeney, "The California Electricity Crisis: Lessons for the Future," *The Bridge* 32, no. 2: 29.

competition in California. The grand experiment to create competitive markets for electricity to bring reliable electricity at low prices to California's customers had failed.

3.2. Two Narratives of the Crisis

Long before the crisis was over and many years after the dust had settled, the stakeholders fought to take control of the narrative that would explain what had happened. Amidst blackouts and a mounting state deficit, the search for the culprits had begun. Politicians, regulators, utilities, and power marketers released economic analyses, ran advertisement campaigns, and published legal statements that explained what had happened and why they were blameless. In the almost two decades that have elapsed since the crisis ended, a complex tableau of court cases, congressional hearings, and regulatory investigations has unfolded. The legal and economic scholarship that has tried to explain the crisis cannot be understood in isolation from these processes. Perhaps due to the vast complexity of the electricity system, most of those who commented on the crisis were insiders. They were closely related to the court proceedings or wrote about matters whose relevance only emerged in these proceedings. To provide some orientation, table 3-1 has a timeline on the most important stations in the litigation history. Initially, the core questions about the crisis were negotiated before a variety of legal bodies at the federal and local level. But as time progressed, the search for an explanation concentrated in FERC's courts, with the academic literature mirroring the central positions in the court cases.

Table 3-1 – Timeline Litigation / Congressional Hearings

Date	At	Action	Details	Narrative
July 26, 2000	FERC	Fact-finding investigation begins	Internal investigation, trying to understand what was driving the price spikes	Economic fundamentals
August 2, 2000	CPUC/EOB	Report on Price Spikes	Informs the governor that price spikes might have to do with the manipulation of prices by sellers of energy.	Corporate Crime
August 2, 2000	FERC	SDG&E files a complaint, seeking price controls for the wholesale markets, EL00-95-00, EL00-98-0000	Proceeding is joined by other utilities and California government, claim that markets are being manipulated. FERC rejects the request for price controls and starts independent investigation in that docket.	Corporate Crime

Table 3-1 – Timeline Litigation / Congressional Hearings (continued)

October 26th, 2000	FERC	Puget Sound Energy Inc. files complaint that seeks price cap on markets in the Pacific Northwest, EL01-10	Initially denied, but was picked up in 2001, after the 9th Court of Appeal remanded FERC.	Economic fundamentals
November 1st, 2000	FERC	Report of investigation complete	Finds that supply/demand imbalances in combination with flawed CAISO/PX market design is to blame for crisis, potentially market power as well.	Economic Fundamentals
November 9th, 2000	FERC	Technical conference with all California Parties	Public discussion between state and federal regulators about crisis and possible ways to mitigate it	Division between narratives
December 15th, 2000	FERC	Orders to address crisis in California, 93 FERC61,294 in Docket EL00-95-000	Commission eliminates the mandatory PX buy-sell requirement, sets a benchmark price for wholesale bilateral contracts, orders market monitoring, adds a penalty charge for under-scheduling of power, orders the establishment of independent, non-stakeholder Governing Boards for the PX and the ISO, and orders generation interconnection procedure. These measures were largely unsuccessful	Economic Fundamentals
January 31st, 2001	Congress	California's Electricity Crisis	First attempt to come to terms with the crisis in Congress. The focus is on the relation between the problems in California and the other Western states. Congress is concerned the crisis will spread.	Economic Fundamentals
February, 15th 2001	Congress	Electricity markets: Lessons learned from California	Considers the issues in California to develop better legislative approaches in other states.	Economic Fundamentals
March 6th 2001	Congress	Congressional Perspectives on Electricity Markets in California and the West and National Energy Policy	Investigates wholesale and retail market structure in California and supply/demand management to determine a course for national energy proposals regarding restructuring	Economic Fundamentals
March 20 and 22, 2001	Congress	Electricity Markets: California	Restructuring and the danger of blackouts. Considers what the reasons for the recurring blackouts in California are and what they have to do with market structure.	Economic Fundamentals
April 10, 11 AND 12, 2001	Congress	Assessing the California energy crisis: How did we get to this point, and Where do we go from here?	The Crisis is seen as a major problem for economic growth in California and senators are trying to figure out if the state and federal regulators are getting things under control. Curt Hebert at FERC still argues for explanation that focuses on economic fundamentals, CPUC under Loretta Lynch presents CA view of corporate conspiracy + FERC inaction.	Economic Fundamentals / Corporate Crime
April 18th, 2001	CA Senate Select Committee to Investigate Price Manipulation	Hearing	First results are presented, continues to work until 2003. Crucial part of California's attempt to stabilize the alternative narrative. Cooperation with State Attorney.	Corporate Crime
April 26th 2001	FERC	Order establishing prospective mitigation and monitoring plan and establishing investigation of public utility rates in wholesale western energy markets, 95 FERC ¶ 61,115	Measures that addressed concerns over the exercise of market power.	Corporate Crime (structural)
May 3rd, 2001	Congress	Wholesale Electricity Prices in California and the Western United States	Discusses shortages and price spikes across the western states. Critical examination of FERC's response to the crisis.	Economic Fundamentals
June 19th 2001	FERC	Commission issues orders calming market volatility by requiring generators to run and capping prices. Order's price-control limits on wholesale electricity prices in California ISO and PX markets are never triggered. 95FERC61,418	Further measures meant to mitigate market power in the Western Energy Markets. They take effect and the price spikes continue to abate.	Corporate Crime (structural)

Table 3-1 – Timeline Litigation / Congressional Hearings (continued)

Date	At	Action	Details	Narrative
June 20th, 2001	Congress	The California Energy Crisis: Impacts, Causes and Remedies	As the crisis starts to affect the larger economy, the corporate conspiracy story gains currency. Expert testimony from market designers and CAISO market monitoring committee. Considers how legal foundation may be created to reestablish control over the marketplace (including new rules for holding companies), as well as a national energy plan.	Corporate Crime (Structural)
July 25th, 2001	FERC	Order establishing rules for refunds.	Establishes the approach for determining refunds to buyers of energy at inflated prices. The refund period is set for the time from October of 2000 to June 20th of 2001 (based on limits to refund authority granted under FPA, section 206. Only the transactions in the PX/CAISO are subject to refund	Corporate Crime
August 2, 2001	Congress	FERC: Regulators in Deregulated Electricity Markets	Considers the bad record of FERC's attempts to deal with the crisis, FERC's efforts to reform its approach, and what needs to be done for effective oversight.	Corporate Crime (Structural) + Economic Fundamentals
September 2001	FERC	Hearing in Puget Sound case	No refunds for the Pacific Northwest, but later reopened.	Economic Fundamentals
February 13, 2002	FERC	Commission institutes staff level investigation into Enron and the Western energy crisis. Docket PA02-2-000	This started the investigation of seller's behavior for the period between January 1st, 2000 and forward.	Corporate Crime (behavioral)
February 13 2002	Congress	The Effect of the Bankruptcy of Enron on the Functioning of Energy Markets	Contains testimony that shows that generators were run far below output level (thermal plants at 50.3 % of capacity).	Corporate Crime (behavioral)
February 22, 2002	Congress	California Independent System Operator: Governance and Design of California's Electricity Market	Investigates the political and regulatory context of California's energy markets, focusing on the role of the CAISO governing board in the face of the crisis. No testimony from market designers.	Corporate Crime (behavioral) + Economic Fundamentals
April 11, 2002	Congress	Examining Enron: electricity market Manipulation and the effect on the Western states	Discusses the implications of the Enron Scandal and its impact on the energy crisis. The final form of the second narrative assumes its form.	Corporate Crime (behavioral)
May 15th, 2002	Congress	Examining Enron: Developments Regarding Electricity Price Manipulation in California; Energy Market Manipulation	Ibid.	Corporate Crime (behavioral)
June 2002,	U.S. General Accounting Office	California Market Design Enabled Exercise of Market Power: GAO-02-828,	Shows that Suppliers Exercised Market Power during Periods of Tight Demand and Supply Balances; that Market Design in California Enabled Exercise of Market Power:	Corporate Crime (behavioral) + Economic Fundamentals
June 5, 2002	9th Circuit Court of Appeals	e Motion of the Cal. Parties for Leave to Adduce Additional Evidence Before FERC, Case No. 01-71051	Directs FERC to permit the California Parties to obtain and introduce into the record of the Refund Proceeding evidence concerning sellers' market manipulation, so that all such evidence could be considering in evaluating the appeals by the California Parties	Corporate Crime (behavioral)
July 18th, 2002	Congress	The Role of Enron Energy Service Inc (EESI), Played in the Manipulation of Western Energy Markets	Investigates the details of behavior by one of Enron's trading subsidiaries.	Corporate Crime (behavioral)
July 22, 2002	Congress	California's electricity market: the case Of Perot systems	Following up allegation's of California's Select Senate Committee this hearing follows up on the claim that Perot System's sold insider information to traders about loopholes in California's market software.	Corporate Crime (behavioral)
November 12th 2002	Congress	Asleep at the Switch: FERC's Oversight of Enron Corporation Vol. I – IV.	Investigates the various failures at FERC, considers regulatory capture, and ways to move forward.	Corporate Crime (behavioral)

Table 3-1 – Timeline Litigation / Congressional Hearings (continued)

Date	At	Action	Details	Narrative
	FERC	100 days of evidence , 93 FERC ¶61,186	In respond to 9th Circuit Court of Appeal Remand, FERC asks buyers of energy to submit evidence of market manipulation under EL00-95	Corporate Crime (behavioral)
March 26th, 2003	FERC	Final Report on Price Manipulation in Western Energy Markets	Concludes that certain supplier behavior violated the Market Monitoring and Information Protocol (MMIP) provisions of the PX and CAISO tariffs. -> Gaming provisions.	Corporate Crime (behavioral)
June 25th 2003	FERC	Based on the investigation, the FERC issues four orders that establish the structure of subsequent litigation Gaming Order, Partnership Order (103FERC61,346), Enron Order, Order establishing investigation in non-competitive bidding behavior (103FERC61,347)	Gaming Order: Defines manipulation and gaming in line with the strategies from the Enron memos and determines that they violated PX/CAISO tariffs. Required a variety of sellers to show cause why they should not be found to have engaged in Enron type manipulation strategies. 22 entities were accused of having played the Ricochet strategy. 65 were accused of congestion games 26 were alleged to have misrepresented their capabilities to sell ancillary services (Get Shorty). Each allegation is addressed in a separate docket. Profit disgorgement is the punishment of choice. Partnership Order: 10 companies should show cause why they should not to be found to have been in league with Enron in executing its manipulative schemes. Enron Order: Revokes market based rates for Enron	Corporate Crime (behavioral)
2006	9th Circuit Court of Appeals	Pub. Util. Com'n of the State of Cal. V. FERC, 462 F.3d 1027	Allowed sellers to seek refunds for the summer of 2000 and opened the door to potential relief for manipulative strategies other than those that had been defined by the Commission. Leads to re-hearings for cases where there had not been a settlement yet.	Corporate Crime (behavioral)
2007	9th Circuit Court of Appeals	City of Seattle v. FERC, 499, F. 3rd	Puts the long-term contracts back onto the table for investigation that CERS signed with companies in the Pacific Northwest to end the crisis in 2001. Leads to r-hearings for cases without settlements	Corporate Crime (behavioral)
2009	FERC	129 FERC ¶ 61,147 (2009)	the Commission expanded the Refund Proceeding to include spot market sales that occurred during that part of the Crisis Period that predated October 2, 2000, and certain other types of transactions	Corporate Crime (behavioral)
2011	FERC	135 FERC ¶ 61,183 (2011)	Reahearing on decision to expand refund proccedings…	Corporate Crime (behavioral)
2013	FERC	142 FERC 63,011 (February 15, 2013)	Based on evidence by 31 witnesses, submitted over 60 days. The judge decided, on a transaction by transaction basis that sellers had violated the market tariff in over 30,000 transactions. Administrative Law Judge Philip Baten determined in 2013 that forward market and energy exchange sellers collectively owed an additional $90.9 million in payments exceeding MMCP for the original Refund Period.2	Corporate Crime (behavioral)
2014	FERC	149 FERC ¶ 61,116 (2014) (Opinion No. 536)	In 2014, the Commission affirmed the ALJ's findings in the expanded Refund Proceeding in SDG&E. In 2014, the Commission affirmed the ALJ's findings in the expanded Refund Proceeding in SDG&E. However, all respondents that engaged in energy exchange transactions, and all respondents that engaged in forward market transactions except Constellation, had already settled with the Complainants by that time.	Corporate Crime (behavioral)
2014	FERC	146 FERC ¶ 63,028, pp. 1413-1414	In Puget Sound case, judge decided that complainants had made a prima facie showing that sellers (including Shell) had engaged in manipulative schemes (false exports)	Corporate Crime (behavioral)
April 12, 2016	FERC	155 FERC ¶ 63,004	ALJ judge decides that Shell and Iberdrola defrauded California during the negotiation of long-term contracts (the 22 other contracting parties had previously settled with FERC)	Corporate Crime (behavioral)

When reading the literature on the crisis and examining the voluminous body of litigation, one overarching theme becomes visible: everyone is looking for a culprit with overarching responsibility and everyone is trying to show that this culprit has to be located in a corner of the universe that is far away from them. At the core of the attempts to understand the crisis thus stands one central question: who is to blame for the high prices?[48]

This question necessitates narratives not unlike those in the first part of this chapter: one event causes another event, which makes it possible to isolate culprits at the end of the event chain. While some accounts tell straightforward narratives that trace an actor of significance through time and show how they react to a variety of causal pressures, the other side provides more a mechanistic account of the relation between events. Either way, significant efforts were directed at the search for the right counterfactuals that would establish a clear narrative with clear culprits. But despite enormous efforts and a good understanding of the different elements that played together to produce the crisis, a single answer has never materialized. There continue to be at least two explanations that coexist in uneasy tension. One is the narrative of those who made money during the crisis, and the other is that of those who lost it. Each party blames the other side and the existing scholarship divides relatively neatly into the two camps.[49] The last column of table 3-1 presents a rough grouping of hearings and investigations into narratives. While the column suggests that the

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[48] McNamara, *The California Electricity Crisis*, xv.
[49] More recent, cursory treatments of the crisis sometimes bring the sides together and claim that *both* are true. Particularly Isser's recent recounting in his monumental history of electricity restructuring in the U.S. takes this route. C.f. Isser, *Electricity Restructuring in the United States: Markets and Policy from the 1978 Energy Act to the Present*. Other examples are short overviews in collected editions, like Jerry Taylor and Peter VanDoren, "California's Electricity Crisis," in *Electricity Pricing in Transition*, ed. Ahmad B. Faruqui and Kelly Eakin (New York: Springer, 2002); Timothy J. Considine and Andrew N. Kleit, "Can Electricity Restrucuturing Survive? Lessons from California and Pennsylvania," in *Electric Choices*, ed. Andrew N. Kleit (Oakland, CA: Rowman & Littlefield Publishers Inc., 2007). Usually these treatments simply report the facts that are not in dispute. Accordingly, they do not contribute to a resolution of the debate: neither side denies the existence of the factors the other side focuses on (supply, market power, manipulation, demand, political errors). What is in dispute is the relative weight of these factors in causing the train of events outlined in the first section.

narrative of corporate crime dominates over time, this is not the case: the table simply captures that the court proceedings and congressional hearings increasingly considered the case in terms of corporate crime. It does not mean that they arrived at definitive conclusions about which side is correct. The table thus reflects the dominant terms under which the crisis was debated, not the substantial positions they ended up with. In what follows, I will reconstruct these two narratives. Not only do they show clearly how the two sides tried to position themselves in relation to the public and the crisis itself; they also provide the basis for the puzzle that animates this dissertation.

3.3. The First Narrative: It's the Economy, Stupid.

The first narrative traces its roots as far back as 1999 when a reporter from the San Diego Union Tribune came across a report by the CEC. The report considered the impact of extreme weather conditions on California's generation capacity. Under certain conditions, the report warned, there might not be enough installed capacity to serve demand.[50] The CAISO staff had also begun to warn of supply shortages during a hot summer and was considering ways to speed up the process to bring new plants into the system. Though the CEC had not anticipated problems for at least another five years, journalists and economists invoked this explanation when the crisis started.[51] It offered a compelling narrative: the rise of Silicon Valley and a general boom in industry, population growth, as well as unusually hot weather during the summer months caused rapid and unprecedented growth in demand. In relation to this increased need for electricity, not enough

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[50] CEC, *High Temperatures & Electricity Demand: An Assessment of Supply Adequacy in California - Trends & Outlook*, P300-99-004, (Sacramento, CA: CEC, 1999).
[51] An important part of the story is the fact that the CEC's biennial resource plan reflected the belief that demand management can be counted as gains in supply, i.e., by reducing demand, they reduced the requirements for new capacity. These reductions or "negawatts" were then counted positively in the report. This contributed to an overly optimistic view of existing supply in the 1990s. William Marcus and Jan Hamrin, "How We Got into the California Energy Crisis," (Sacramento, CA: JBS Energy, Inc., 2001), 2-3. For the general planning process see Duane, "Regulation's Rationale: Learning from the California Energy Crisis," 486-87.

additional generation capacity had been developed. Practically no capacity had been added to California during the 1990s. Now, the prices in the PX markets were so low that it was not profitable to develop new generation assets. This was particularly true in light of the high environmental standards, which were expensive to meet. In the summer of 2000, another factor reduced the available supply further: hot weather and a prolonged draught had reduced the hydro-reserves that were one of California's most important energy sources. A reporter summarized the implications of this development: "Its Economics 101. Essentially, when you have a commodity in short supply, the price goes up."[52]

Particularly owners of generation assets tried to convince the public of this narrative. The 21st Century Energy Project, a coalition of these generating companies, relied on numbers by the Edison Electric Institute (EEI) to claim that a surprising growth in demand had caused the crisis. According to the EEI, consumption of energy in California had grown by over 20 percent in the time between 1992 and 2002. At its core the story was optimistic: California is doing better than anyone expected, and so demand increased far above expectations. The best way to solve this problem would be to encourage the construction of new energy plants. This could be done by simply sustaining high prices, slashing environmental standards, and increasing the commitment to deregulation.[53] Key executives at Enron told this story repeatedly to journalists and governmental officials.[54]

Relatively quickly, however, politicians in California and economists pointed out that core pieces of this story were not supported by the facts. Over the entire decade, energy consumption

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[52] O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 133.
[53] EEI advertisement, "Believe It or Not There is Light at the End of the Tunnel," quoted in Sharon Beder, *Power Play: The Fight for Control of the World's Electricity* (New York: Scribe Publications, 2003), 138.
[54] Unknown, "Enron Sees New Plants, Increased Access Helping California," *Megawatt Daily*, Vol. 5, Issue 171 (Sept. 7, 2000).

did not increase by more than 16 percent. During 1997–2000, it grew slightly faster than during the years before at an annual rate of 2.3 percent. This faster pace accounts for the rise of Silicon Valley and general economic growth. But it did by no means exceed 20 percent. And, more importantly, neither of these growth rates very much exceeded the official expectations that guided the planning of new generation facilities. In 1996, the CEC had projected a 11.7 percent of total growth in demand between 1995 and 2000. The real growth rate was 14.5 percent, only 3 percent higher than had been generally anticipated by the regulators.[55] California has a temperate climate, which generally leads to low demand for air conditioning and heating. Demand management programs had kept the energy consumption in the state relatively low. In 1999, the average consumption per capita was 37 percent below the national average. Accordingly, the story of a surprising surge in demand did not work as well as many commentators claimed. Demand was growing, yes, but it was growing much slower than the sellers of energy suggested, only slightly above expectations, and far below the national average.

The other side of the story also did not quite add up. It was true that between 1990 and 1996, annual applications for certification averaged about 250 MW per year while annual retirements averaged about 450 MW. This imbalance reduced the available capacity by about 1400 MW over the decade. But in anticipation of restructuring, the applications for the construction of new power plants went up significantly after 1997. Between the years 1997 and 2000, sellers of energy applied for additions that averaged a net increase of about 3300 MW per year.[56] Since these resources had not come online by the time the crisis started, another fact is more important. The seven-year slump of the 1990s was preceded by a long period during which the growth of capacity

[55] CEC, *Gas Prices: Gouging or Supply and Demand*, CEC-999-1996-002, (Sacramento, CA: CEC, 1996); Sweeney, *The California Electricity Crisis*, 94.
[56] Though these plants had not come online by the end of 2000 (and by 2001, only 1400 MW had), ibid., 103.

had been in excess of growth in demand. Though the utilities only added 28 percent of new capacity between 1977 and 1998, independent producers had added another 10,000 MW of capacity in the form of so-called “Qualifying Facilities.” In total, this represented a 57 percent increase in installed capacity. Compared with the total growth of consumption of 44 percent, it was clear that California did add enough generation to keep in step with the growth in demand.[57] The alleged failure to add insufficient generation capacity was thus a myth.

When the price spikes hit the customers of San Diego, one of the leading architects of restructuring, Senator Steve Peace started an angry campaign against sellers of energy. In a letter to the governing board of the CAISO dated June 22, 2000, he wrote: “The market is not workably competitive. Sadly, last week’s market performance confirmed my worst fears. Electricity prices and electricity costs reached grossly unreasonable levels considering that from a statewide perspective, there were ample supplies.”[58]

To rescue the narrative of supply and demand problems, the analysis needed to be expanded.[59] Apart from pointing out that nameplate capacity of generators is rarely indicative of true available capacity, economists took a regional perspective. California’s electricity system was embedded into Western Interconnection, the larger grid managed by the Western States Coordinating Council (WSCC). Generation facilities in eleven western states, Northern Mexico, and the

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[57] Jolanka V. Fisher and Timothy P. Duane, "Trends in Electricity Consumption, Peak Demand, and Generating Capacity in California and the Western Grid," in *Program on Workable Energy Regulation (POWER)*, ed. University of California Energy Institute (Berkeley, California2001), 1-2.

[58] O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 141. Steve Peace, “Letter to CAISO board June 22, 2001,” R400.006, Box 8, Folder 9, Independent System Operator Board of Gov. and Committee Meeting Files 2000/01, *CSA*.

[59] The account largely follows Sweeney, *The California Electricity Crisis*. Occasionally, I supplement the account with information from less expansive treatments that take the same position. I also reconstructed his account with original datasets from the California Energy Institute (CEI) and EIA to determine where the story is borne out by the available facts and where it relies on theoretical plausibility arguments that leave room for interpretation. See the footnotes for details.

Canadian provinces of British Columbia and Alberta were connected through high voltage transmission lines. In the absence of transmission constraints, demand anywhere in the West could be served with generation from anywhere else in the West.

In an interconnected system, prices quickly adjust to each other if transmission is available. If there is a price increase in one region, it quickly leads to price increases elsewhere.[60] Accordingly, the supply and demand conditions in any of these states could affect the *prices* in any other region. This dynamic was exacerbated by the financial structure of the industry. Since the other states had not restructured their industries, most energy outside California was committed in long-term and medium-term contracts, i.e., utilities sold most of their supply for fixed prices over long, pre-arranged time periods. This meant that less energy was available for short-term spot trading.

This type of short-term trading was, of course, what the utilities in California relied on to get their energy. With lower volumes available for trade, the volatility of the markets increased: even minor changes in demand and supply in parts of one region could deplete the markets in other regions or flush them with excess energy. Since the energy committed under long-term contracts would not quickly become available, supply in the spot markets was slow to adjust to price increases. So, the first step of the narrative is to point out that "supply and demand changes occurring either inside or outside of California could translate into very tight supply and demand conditions throughout the West, including slow supply and demand adjustment throughout the region and rapid and profound changes in wholesale spot markets."[61]

California was one of the few net importers of energy in the region. In particular, it was dependent on imports from the Pacific Northwest and the U.S. Southwest. In the summer,

[60] Fisher and Duane, "Trends in Electricity Consumption, Peak Demand, and Generating Capacity in California and the Western Grid," 1.
[61] Sweeney, *The California Electricity Crisis*, 88.

California imported roughly 25 percent of its total energy from (primarily) hydro sources in the Pacific Northwest and coal plants in the Southwest. In the winter, it exported to the Pacific Northwest, where temperatures were lower.[62] California and Idaho in the Western states were the only states that sold, on average, more energy than they produced, i.e., their average energy sales to end users exceeded their average net generation.[63]

This meant that they were dependent on imports from other regions. Reductions in supply outside of California therefore had a direct effect on the composition of its energy production. After the 1980s, not much generation capacity was added throughout the West.[64] In other words, even if demand did not grow particularly fast in California, it grew rapidly in the other states of the WSCC. This was not just average demand, but also peak demand, which increased by approximately 13,000 MW throughout the west from 1995 to 1999.

Peak demand describes the maximum demand that the system needs to serve at some point in time.[65] Given the relatively low growth in supply, this led to tighter and tighter reserve margins.[66] If these are low, even minor increases in peak demand beyond anticipation can threaten the reliability of the system. Like California, the entire Pacific Northwest was vulnerable to such fluctuations because it relied heavily on hydro reserves. This type of power depends on the annual level of rainfall. A drought can therefore severely reduce the available capacity. Recognizing the

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[62] This, of course, reduces the net imports and thus leads us to underestimate its dependency on the Pacific northwest in the summer.
[63] The is supported by data that documents the EIA annual sales and net generation capacity statistics for the years of 1983–2000.
[64] Between 1977 and 1988, the eleven states added capacity at an annual growth rate of 4.5 percent. In the decade between 1988 and 1998, this rate reduced to 0.5 percent. This did not correspond to the growth in demand. Between 1977 and 1998, consumption grew by 2.4 percent per year, with an increase of just below 10 percent in the decade between 1988 and 1998. Fisher and Duane, "Trends in Electricity Consumption, Peak Demand, and Generating Capacity in California and the Western Grid," 4.
[65] Ibid., 2.
[66] Reserve margin is calculated as (installed capacity minus peak demand) divided by demand. It is a measure for how much capacity exists in excess of demand. About 15 percent is necessary for a reliable operation of the system.

thinning reserve margins, the utilities of other states committed more and more of their energy in long-term contracts, which reduced the available supplies in the spot markets further.

So, while California was experiencing moderate demand growth and moderate growth in supply, the supply in the West as a whole was in danger of being overtaken by growth in demand.[67] In California, this led to a decline of net imports. Between 1992 and 1996, strong rainfall kept the hydro reserves in the Northwest full and counterbalanced declining imports of electricity from the Southwest. But in 2000, a drought reduced the hydro reserves and led to decreased imports from both regions. See figure 3-3.

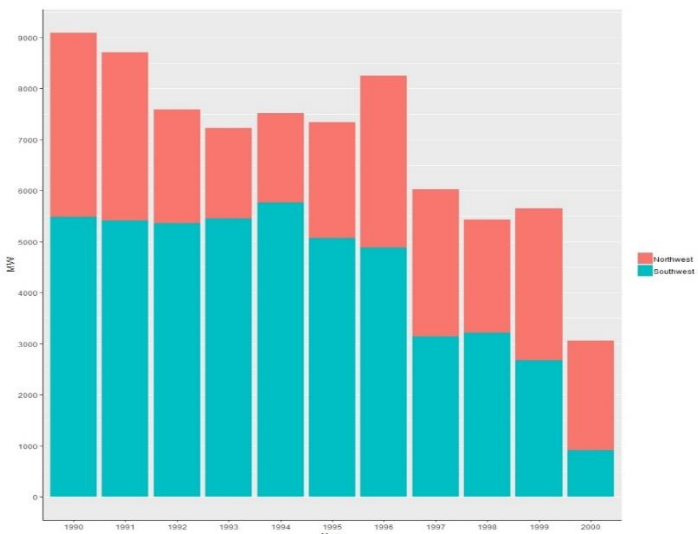

Figure 3-3 – California Imports Northwest / Southwest, Average MW per Year

With dwindling imports and increasing demand, the power plants in California now had to increase their output. Citing data from the CEC, proponents of this narrative claim that the increase in domestic production was significant. From 1997 to 1998, the increase was an average of 3000 MW of domestic production, and from 1999 to 2000 it was 3100 MW, an increase of 12

[67] Cicchetti, Dubin, and Long, *The California Electricity Crisis: What, Why, and What's Next*, 56-57.

percent for that year.[68] Importantly, the increase in domestic production pushed almost all existing generators to their capacity limits. Since 1400 MW of generation had been removed between 1990 and 1997, the remaining generators needed to increase their output. These were, supposedly, gas-fired steam and peaking units.[69] (See figure 3-4, which shows that the output of natural gas power plants steadily increased between 1996 and 1999—of course not above the levels of 1994.)

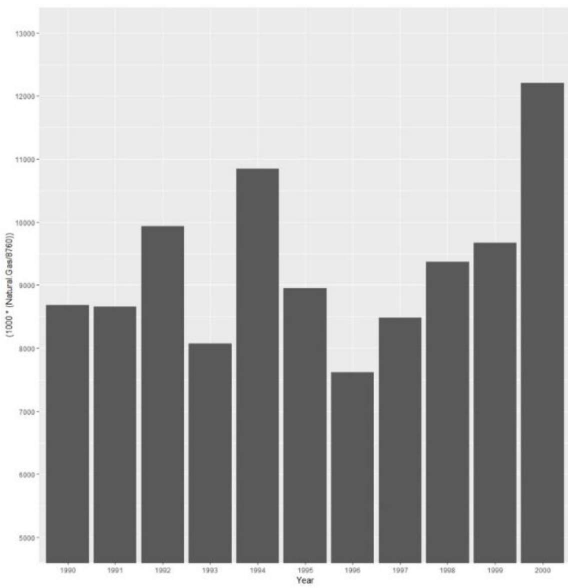

Figure 3-4 – Energy from Natural Gas

Either way, the increasing proportion of energy from natural gas meant that older, less efficient natural plants had to be used more. Units meant to supply peak demand are generally more expensive to run, and they are also less efficient when they have to operate for longer periods

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[68] Sweeney, *The California Electricity Crisis*, 97. The analysis includes coal plants outside California into the calculation because they are owned or controlled by the three utilities in California. If we exclude those plants, the situation looks somewhat different. The claim that the output of the natural gas plants increases massively in 2000 is not borne out by the data. Nonetheless, the output did increase during the time of interest, which supports Sweeney's argument until 2000.

[69] While several sources note this, I have not found any direct evidence of this statement, beyond the output of Natural Gas plants, which used to be higher in the past.

of time. This impacted the efficiency of the overall electricity system as well as the costs of operating it.

The old gas-fired steam plants and peakers drove up the marginal costs of production for three reasons: the NOx emission certificates for older power plants are more expensive, the price of natural gas increased over time, and the plants themselves are more expensive to run because they are less efficient.[70] To keep the costs of production low, new generation would have had to be built, but while restructuring led to a lot of applications, these were not processed fast enough for sufficient power plants to come online in 2000.[71]

According to the first narrative, this is the reason why there was a supply shortage in California: declining imports in the face of growing demand had to be made up with domestic production. With hydro reserves depleted, larger parts of the demand were served by old natural gas plants. This, in turn, drove up the marginal costs of production and created a situation where minor deviations from expected demand could create bottlenecks for the provision of energy.[72] With generation in other states increasingly tied up in long-term contracts, situations could emerge where supply was simply insufficient, but even increasing prices would not quickly draw new resources to the markets. With this relationship between supply and demand, massive price spikes could occur without any untoward behavior—it would simply be a consequence of market forces indicating scarcity. This followed from the basic logic of short-run competition in electricity markets. The argument works like this: Generators have physical limitations on their ability to produce

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[70] These are part of generators' "variable" costs.
[71] Annual applications for certification averaged about 250 MW per year between 1990 and 1996, while annual retirements averaged about 450 per year. Over the seven years, installed capacity declined by about 1,400 MW. But from 1997 through 2000, applications averaged 3,300 MW per year. However, in 2000 none of this new supply was yet operational. Sweeney, *The California Electricity Crisis*, 101.
[72] Ibid., 111.

energy. An operator can choose to produce below capacity, but it cannot choose to produce above capacity. As you get close to the capacity limits, the efficiency of the generator decreases and the danger of malfunctions increases. This means that the supply function of a generator has a "hockey-stick" character in the short run. See figure 3-5 for an illustration:[73]

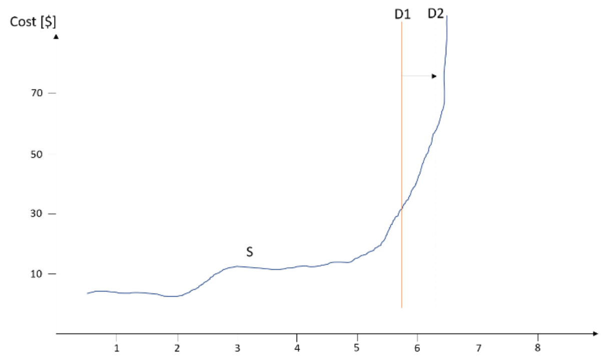

Figure 3-5 – Supply/Demand in Electricity System (Illustration)

If generators are below capacity limits, the cost of production only increases at a very low rate, but as soon as they approach the limit, the costs drastically increase and the curve becomes vertical, i.e., very soon, no amount of money can increase the output beyond the limit. Since this is a general characteristic of generators, it holds for the industry as a whole. The demand function has a similarly unusual shape. Electricity is foundational to modern life, which means that the demand is relatively inflexible. In addition, California's customers were insulated from the wholesale prices by the retail price freeze, which made demand nearly completely unresponsive to prices in the short run. Increases in price did not quickly lead to a reduction in electricity usage, and the demand curve is practically vertical. As figure 3-5 shows, even minor increases in demand (D1->D2) can therefore lead to drastic increases in the *cost* of energy production at the level of an individual generator and of the industry as a whole. In the mid- to long-run, the hockey stick

[73] Note that this is a stylized, inaccurate representation. The supply functions of generators often have special characteristics, such as non-convexity.

character of the supply curve is attenuated because companies and people will reduce their usage and thus free energy that can then be sold at a lower price. But in the short term, energy that was committed in long-term contracts was not available. Accordingly, given how supply and demand work in the short run, "wholesale price volatility should not be viewed as an anomaly of the California situation but rather as inherent in electricity markets, as long as both the supply functions and the demand functions are very steep at the point of their intersection."[74] In other words, by virtue of supply and demand structures, high prices in energy markets were perfectly normal when the system came to its capacity limits and various inefficiencies drove up the marginal cost of operation. To the extent that there was market manipulation, it was minor and did not cause most of the price spikes. The real culprits were regulators and politicians who did not adequately react to the price spikes in the summer of 2000. They should have let the utilities hedge their bets with forward contracts and fully deregulated the retail prices. The high prices would have led to demand responses and the long-term contracts would have reduced the exposure to the volatility during periods where the system operated at capacity limits. Apart from think tanks promoting the views of wholesale energy merchants, several academic economists told this story in journal publications and expert testimony.

In its initial attempts to come to terms with the crisis, FERC adopted a version of the narrative about fundamental economic forces. In response to a complaint by SDG&E in August of 2000, FERC began a staff investigation that culminated in a report dated November 1, 2000.[75] The investigation was based on informal interviews with market participants, regulators, and operators,

[74] Sweeney, *The California Electricity Crisis*, 119.
[75] *San Diego Gas & Electric Co. v. Sellers of Energy and Ancillary Services into Markets Operated by the California Independent System Operator and the California Power Exchange*, 92 FERC 61,172 (2000).

as well as limited data analyses. It effectively agreed with the narrative of the sellers but acknowledged that this situation created some opportunities for the exercise of "market power."

As the federal regulator of wholesale markets, FERC was responsible for making sure that the prices in these markets were "just and reasonable." This was a standard from the bygone time of regulated monopolies. Before the industry had been restructured, FERC used this standard when they analyzed the cost structure of utilities to determine whether a particular rate could be sanctioned. Just and reasonable basically meant that the rates covered justified investment costs plus a profit that allowed utilities to grow in step with demand. Moving to a system of competitive markets, FERC changed its interpretation. It now assumed that rates were "just and reasonable" if they were the product of competitive markets. If companies were exercising market power, the markets were not competitive and FERC could interfere to remedy these problems. Market power is the "ability of an individual supplier or group of suppliers to profitably maintain prices above competitive levels for a significant period of time."[76] In other words, a company has market power if it can individually or in collusion with other companies increase the market price above marginal cost in a way that is profitable for them. Given the shape of the supply curve, even minor attempts to withhold energy from the markets can have a drastic effect on the price as you get closer to the capacity limits. Similarly, with a relatively inelastic demand, there is a strong temptation to ask higher prices from customers. As supply gets tight, opportunities for market power become more frequent. Accordingly, even if de facto market power was not a big problem, the tight supply and demand conditions that sellers asserted created room for the exercise of market power.[77]

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[76] Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 13.
[77] Cicchetti, Dubin, and Long, *The California Electricity Crisis: What, Why, and What's Next*, 135.

This conclusion enabled the commission to interfere and led to the November and December orders. These orders focused on remedies that the first narrative suggested: they relieved utilities from the need to buy their energy in the PX, relaxed the restrictions on forward contracting, and established a "soft" price cap—companies had to submit justifications for charging prices above the limit. But the orders were met with little success: the prices stayed high and the crisis continued to escalate. FERC was bombarded with filings that explained an escalating number of cases where the soft cap had been violated, thoroughly overwhelming any attempt to actually check them. At this point, then, the second narrative began to crystallize and took shape.

3.4. The Second Narrative: Texans Conspire Against California

Having failed to bring the markets under control, FERC began to change its interpretation of the crisis, and the second narrative started to gain currency. Since August of 2000, the utilities and the California government had been arguing that the price spikes could not be explained with supply shortages, regardless whether viewed in terms of California or in terms of the Western Interconnection as a whole. They maintained that the only way to explain the high prices was manipulative behavior.[78] FERC was now ready to entertain that narrative. Since the just and reasonableness standard limited FERC's jurisdiction over the markets to issues of market power, the agency now moved to equate "manipulative behavior" with the exercise of market power. To prove their point and get FERC to act, the California parties now had to demonstrate that such market power was in fact driving the crisis.

The market monitoring units of the CAISO and PX as well as economists associated with these institutions had made this argument as early as 1998. Almost from the very beginning and

[78] McNamara, *The California Electricity Crisis*, 32-37.

long before the crisis, these economists warned that the markets might be liable to the exercise of market power. To sway FERC, the economists at the ISO now developed analyses to prove their point.[79] Initially, these analyses did not point fingers at anyone. They were merely designed to contest the dominant narrative of economic fundamentals and get FERC to act in the face of severe market imperfections. Their approach was seemingly straightforward. The analysts looked at episodes of high prices during the summer of 2000 and asked: Can these prices be explained with the kind of marginal cost pricing that perfectly competitive markets would create?[80] Markup studies, simulations of seller's behavior, and analyses of confidential data on sellers' bidding behavior provided the answer. To conduct a markup study, the authors calculated the different factors that influenced the cost of electricity production. More specifically, they calculated the cost for the plants that would serve peak demand at different time periods because those plants would set the market price in a competitive environment. Since all peak energy was provided by natural gas plants whose operating characteristics were well known, it was possible to determine their marginal cost.[81] Considering the impact of various external factors, the market clearing price could be

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[79] Anjali Sheffrin, "Empirical Evidence of Strategic Bidding in the California Iso Real-Time Market," in *Electricity Pricing in Transition*, ed. Ahmad B. Faruqui and Kelly Eakin (New York: Springer, 2002). "Comments of the ISO on November 1, 2000 Order, Attachment A, November 22, 2000," *FERC* EL00-95-000.

[80] Severin Borenstein et al., "Inefficiencies and Market Power in Financial Arbitrage: A Study of California's Electricity Markets," *The Journal of Industrial Economics* 56, no. 2 (2008); Severin Borenstein, "The Trouble with Electricity Markets: Understanding California's Restructuring Disaster," *The Journal of Economic Perspectives* 16, no. 1 (2002); Severin Borenstein, James Bushnell, and Frank A. Wolak, "Measuring Market Inefficiencies in California's Restructured Wholesale Electricity Market," *The American Economic Review* 92, no. 5 (2002); Severin Borenstein, James Bushnell, and Christopher R. Knittel, "Market Power in Electricity Markets: Beyond Concentration Measures," *The Energy Journal* 20, no. 4 (1999); James Bushnell, "California's Electricity Crisis: A Market Apart?" *Energy Policy* 32, no. 9 (2004); James Bushnell and Frank Wolak, "Regulation and the Leverage of Local Market Power in the California Electricity Market," in *Working Paper* ed. Competition Policy Center (Berkeley, California2000); Wolak, "Diagnosing the California Electricity Crisis."; "Lessons from International Experience with Electricity Market Monitoring," in *Policy Research Working Papers* (Washington, D.C.: World Bank, Development Research Group, 2005).

[81] Paul L. Joskow and Edward Kahn, "A Quantitative Analysis of Pricing Behavior in California's Wholesale Electricity Market During Summer 2000," *The Energy Journal* 23, no. 4 (2002): 4.

developed from these marginal costs.[82] By comparing the hypothetical, ideal prices with the actual prices during the summer, the authors developed a sense of the markup that had to be explained with "market imperfections."

The principal difficulties with these studies derive from the construction of the counterfactual: In a competitive market with given marginal costs, what kind of composition of resources would clear the market? An example makes clearer why this question can be tricky. Consider imports: How many imports would have been available at a different price level? In the real world, the extremely high prices during the summer presumably drew more imports than they would have if the prices had been lower. That means that the imports in the counterfactual need to be adjusted. This changes the level of demand that needs to be served by in-state generators. But such an adjustment can then have effects on other variables—for example, the level of forced outages on generators that must produce higher outputs or the impact of emission certificates on the availability of supply at different prices. Another problem is opportunity costs: Would a seller at a different price/output level sell into a different market and thus change the balance of supply and demand? Accordingly, as soon as you began to think carefully about the counterfactual that informed the computation of ideal prices, all manner of variables could suddenly start to change. To fend off objections, the economists chose very conservative assumptions and ran sets of sensitivity analyses to account for the different ways assumptions could affect the market clearing price. Even with extremely conservative models, the economists found that 21 percent of the increased prices were due to increased production costs, 20 percent due to increased competitive rent (scarcity prices), and the remaining 59 percent was attributable to market power.[83] These studies effectively

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[82] Ibid., 10.
[83] Borenstein, Bushnell, and Wolak, "Measuring Market Inefficiencies in California's Restructured Wholesale Electricity Market," 2.

argued that the claims of the first narrative left unexplained a gap between the real prices and the prices that would obtain under the logic detailed by the first narrative.

Despite massive pushback from sellers of energy, FERC eventually came around to these versions of the second narrative.[84] The countermeasures that the story of supply and demand imbalances suggested did not bear fruit. Accordingly, the commission began to switch sides and look more carefully at market manipulation. In November of 2000, they admitted for the first time that deeper structural causes might allow the exercise of market power. At the end of April 2001, the commission finally began to act on these insights and systematically cut off a variety of different avenues for the exercise of market power. In combination with California's efforts to sign long-term contracts for the delivery of energy, the crisis now began to abate. This seemed to support the second narrative, but the experts who argued on behalf of the sellers of energy and peddled the first narrative objected to this conclusion. They claimed that new generating capacity had come online and that demand had declined in the early months of 2001. This was enough to explain the lower prices from the perspective of the first narrative. Either way, FERC had decided that the California markets had suffered from the exercise of market power during the height of the crisis. Accordingly, it decreed that the prices had been unjust and unreasonable and much of the profits had to be refunded. In December of 2001, FERC determined how refunds would be established for the time period when the prices had been in excess of what a competitive market would have charged.

Despite the victory of the second narrative, the commission was hesitant to assess the behavior of individual sellers.[85] The economists' arguments pertained to market power in general

[84] See, for example, the objections voiced by Harvey and Hogan in "On the Exercise of Market Power through Strategic Withholding in California," ed. Harvard University John F. Kenedy School of Government (2001), 9.
[85] With very few exceptions, relating to some accusations of physical withholding.

and at the level of the market as a whole. They did not point fingers at individual players, and neither did FERC. Between 2000 and 2001, "market power" was a term without a clear referent—a demon that hovered above the markets pulling the strings rather than the actions of specific culprits. Indeed, it seemed that FERC was trying to move on as quickly as possible. Initial cases that dealt with accusations of "physical withholding" ended in settlements that did not even cover the profits the culprits had made. For a while, it seemed like things were going to just disappear in the murky depths of refund proceedings.

But then everything changed with the spectacular, unexpected, and complete collapse of Enron. More specifically, everything changed when the infamous Enron memos appeared in the press. In colorful detail and peppered with the trademark cynicism of Enron's corporate culture, these memos detailed several strategies that a group of traders had designed to manipulate the California energy markets.[86] The memos quickly made it onto national and international television, getting even Late Night Show hosts like Jon Stewart to talk about electricity markets—a topic that does normally not rank high on the list of hilarious subjects. Even the Simpsons had a joke about Enron. Part of the reason the scandal reverberated in media across the globe was Enron's symbolic importance. Before the bankruptcy in December of 2001, Enron was one of America's most prestigious companies. It had been voted America's most innovative company for years. It stood for the promise of unlimited growth and the superiority of markets over socialism. The largest natural gas merchant in North America and the United Kingdom, Enron had turned itself into a poster child of the new economy. Besides investing in large infrastructure projects, it was an active participant in financial markets for energy. It invented a variety of new products, pioneered online

[86] Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 83.

trading, pushed for deregulation in several different industries, and developed a vast trading operation whose employees made profits with speculative activities in a variety of industries.[87]

After its bankruptcy in 2001, it turned out that Enron's continued success had been a mirage that was the product of fraudulent accounting practices. Through a variety of tricks, Enron had generated fictional profits and used them to artificially inflate share prices. The world stood by in morbid curiosity as the details of a corrupt corporate culture of greed and cynicism whose core was unable to produce any real value emerged. It was during the investigations of these crimes that the aforementioned memos surfaced. They put the litigation of the California crisis on a new trajectory and provided new vigor to the elaboration of the second narrative.[88]

During the energy crisis, no one made more money than the large trading firms. In 2000, Enron's trading operations reported an operating profit of $1.6 billion. This represented an increase of 160 percent from 1999. Another large trading company, Williams, tripled their profits with reported earnings of $1.56 billion.[89] Sellers of energy like Mirant, Duke, Calpine, and others made similarly spectacular profits.[90] Enron, just like the other trading firms, had been one of the main beneficiaries of the crisis. When it fell, and when it became apparent with how much delight the traders had watched the system crumble, the perfect culprit had emerged. The second narrative

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[87] The best book on the company continues to by *The Smartest Guys in the Room*, by the journalist who broke the scandal. Bethany McLean and Peter Elkind, *The Smartest Guys in the Room* (New York: Potfolio Penguin, 2013 [2003]).

[88] See the overview over the history of litigation in Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 83-97.

[89] Michael Liedke, "Trading Floors Represent Ground Zero in Energy Crisis," *Las Vegas Sun*, March 26, 2001, https://lasvegassun.com/news/2001/mar/26/trading-floors-represent-ground-zero-in-energy-cri/, accessed on 05/27/2019. Of course, not all this profit goes back to the California operations—sorting out what was constituted a major problem during litigation.

[90] Carol J. Loomis, "...And the Revenue Games People (Like Enron) Play: Got Energy Trading Contracts?" *Fortune Magazine*, April 15, 2002, http://archive.fortune.com/magazines/fortune/fortune_archive/2002/04/15/321445/index.htm; McNamara, *The California Electricity Crisis*, 52-58.

now assumed its final form: big energy companies from Texas had manipulated the energy markets at the expense of ordinary rate payers.

Of course, this narrative ignored the fact that *all* net sellers of wholesale energy made the profits of a lifetime—independent energy producers, municipalities, and even government energy projects collected millions of dollars in revenues. Several of these episodes have the same shady character as the Enron revelations, but they were quickly swept aside by the larger story. For example, S. David Freeman, who headed part of the WEPEX process that implemented the California energy markets, later became the head of Los Angeles Department of Water and Power (LWP). During the crisis, this department used some of the same tactics as Enron, presumably fueled by insider knowledge.[91] Another such nugget is the fact that PG&E, which moved into bankruptcy in 2001, had an unregulated affiliate—as did all three utilities. The affiliate had the nondescript name "National Energy Group" and was financed with money that PG&E received during its stranded cost recovery. In 2000, it made $162 million in reported revenue. And where did all these remarkable profits come from? From various investments in unregulated power companies in the Northwest, but naturally, also the California energy markets. Of course, none of these profits ever made it to the ailing utility that would soon find itself in bankruptcy court, begging the state to lend a helping hand. No, the profits the National Energy Group quickly disappeared into PG&E's parent company, PG&E corporation.[92] The annals of the energy crisis are full of such stories. But the shady deals of governmental and beloved state actors were eclipsed by the constant and ever

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[91] Carl Ingram, "Freeman 'Surprised' at Alleged Gouging by DWP," *LAT*, August 2, 2002, https://www.latimes.com/archives/la-xpm-2002-aug-02-me-freeman2-story.html, last accessed 06/03/2020.
[92] Richard A. Oppel Jr. and Laura M. Holson, "While a Utility May Be Failing, Its Owner Is Not," *NYT*, April 30, 2001, https://www.nytimes.com/2001/04/30/business/while-a-utility-may-be-failing-its-owner-is-not.html, last accessed 06/03/2020.

escalating revelations about Enron and the other “Texan Energy Companies.” Either way, FERC had no choice now but to consider the behavior of individual sellers explicitly.

In response to cases brought by the California government and buyers of electricity, the commission determined that several of the strategies outlined in the Enron memos fulfilled the definition of behavior proscribed by the tariff that governed CAISO’s and PX’s market operations. This led to a new phase of litigation that lasted from 2002 until today. Initially, the commission limited the definition of manipulative behavior to Enron-style games, only considered spot-market transactions in the PX and CAISO, and restricted the time period for which claims could be made to the time from October 2, 2000 through June 21, 2001.[93] Due to remands from the Nineth Circuit Court of Appeals, these restrictions were gradually relaxed, and the search for manipulative behavior widened.[94]

In February of 2002, the commission started a fact-finding investigation to determine whether sellers had manipulated the markets. Between the moment the investigation started and the release of the final report in 2003, parties in dockets related to the crisis were allowed to conduct additional discovery. The submissions by the buyers in the PX and CAISO during these “100 days of evidence” were massive.[95] The California attorney general and buyers submitted evidence

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[93] The so-called “refund period.” The time period was limited because FERC was only able to issue refunds for prices in excess of competitive rates sixty days before the complaint was made.

[94] Part of the second narrative is to allege that FERC was complicit in hiding many of the crimes by sellers of electricity because the agency had been “captured” by powerful lobbyists from these companies The Foundation for Taxpayer and Consumer Rights, "Hoax: How Deregulation Let the Power Industry Steal $71 Billion from California," (Santa Monica, CA: The Foundation for Taxpayer and Consumer Rights, 2002).

[95] “Order on motion for discovery order re San Diego Gas & Electric Co v Sellers of Energy & Ancillary Services into Markets operated by the California Independent System Operator Corp et al under EL00-95 et al.,”101 FERC 61,186 (November 20th, 2002). For an example of the evidence see Fox-Penner, Peter: “Prepared Testimony of Dr. Peter Fox-Penner on behalf of the California Parties, Exh. No. CA-0001, February 25, 2003,” *FERC* EL00-950999.

from various investigations in California.[96] These detailed manipulative behavior with a variety of evidence such as trading data, supplier documents, emails, and phone conversations.[97]

After evaluating this material and concluding its investigation, FERC accused twenty-two firms of engaging in illegal strategies involving false exports (Ricochet). They accused sixty-five sellers of "gaming" the CAISO congestion management system ("Death Star") and twenty-six suppliers of misrepresenting their capabilities to sell ancillary services. Ten entities, finally, stood accused of having cooperated with Enron to implement its manipulation strategies. Another proceeding revoked Enron's market-based rates. Though virtually all sellers contested these allegations, most eventually settled. Since the accusations were based on the strategies in Enron's memos, they were relatively limited in scope—FERC did not have an independent standard to define manipulative behavior. But in 2009, a Ninth Circuit remand changed this and opened the door to additional litigation under a broader definition of manipulative behavior. On April 11, 2012, more than a decade after the crisis was over, nearly sixty days of testimony from thirty-one witnesses expanded the analysis of sellers' illegal behavior further. The judge decided, on a transaction by transaction basis, that sellers had violated the market tariff in over 30,000 transactions.[98]

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[96] Bill Lockyer, "Attorney General's Energy White Paper: a Law Enforcement Perspective on The California Energy Crisis" Office of the State Attorney General, California Department of Justice, California, April 2004, https://oag.ca.gov/sites/all/files/agweb/pdfs/publications/energywhitepaper.pdf last accessed 07/03/2020.

[97] *San Diego Gas & Electric Company et. al.,* "California Parties' Supplemental Evidence of Market Manipulation by Sellers, Proposed Findings of Fact, and Request for Refunds and Other Relief, March 3, 2003," *FERC* EL00-95-000.

[98] At that point, the remaining parties were APX, Inc. (APX) (f/k/a Automated Power Exchange), Avista Corporation (Avista Corp.) (d/b/a Avista Utilities, f/k/a Washington Water Power), Avista Energy, Inc. (Avista Energy), Bonneville Power Administration (BPA), California Polar Power Brokers, LLC (California Polar), Hafslund Energy Trading L.L.C. (Hafslund), Illinova Energy Partners, Inc. (Illinova), Koch Energy Trading, Inc. (Koch), Mieco, Inc. (Mieco), MPS Merchant Services, Inc. (MPS) (f/k/a Aquila Power Corporation), Powerex Corp. (Powerex), Shell Energy North America (US), L.P. (Shell Energy) (f/k/a Coral Power, L.L.C.), Shell Martinez Refining Company (Shell Martinez), Sunlaw Cogeneration (Sunlaw), TransAlta Energy Marking (U.S.) Inc. & TransAlta Energy Marking (California) Inc. (collectively, TransAlta), Western Area Power Administration (WAPA), c.f. "Initial Decision re San Diego Gas & Electric Company v. Sellers of Energy and Ancillary Services Into Markets Operated by the California Independent System Operator Corporation and the California Power Exchange under EL00-95," 142 FERC 63,011 (February 15, 2013), 19.

The decision was affirmed on November 14, 2014, and refunds were ordered.[99] Even though almost all the entities that had been accused of manipulative behavior had reached settlements before 2013, the decision established that the California markets had indeed been manipulated. Sellers in other proceedings settled in the subsequent years, with the last settlements with Shell and B.C. Power Exchange in 2018. But even though the definition of manipulation had been broadened, FERC's decisions only pertained to individual transactions that judges considered specifically.[100]

Though the complex tableau of litigation, expert analyses, and secondary literature finally established that the markets had been pervaded by the exercise of market power and different forms of market manipulation, FERC's transaction-by-transaction assessment left open the "root cause" of the crisis. Only a tiny subset of the transactions in the California markets had officially been marked as manipulative, and most companies had settled without ever admitting any guilt—often at sums that were a fraction of the profit they had made during the crisis. This meant that the legal system was not going to provide an ultimate judgment on which narrative was right.

Proponents of the first narrative assert that whatever manipulations occurred were ultimately a sideshow. These manipulative practices intensified the crisis, perhaps, but the real driver was economic fundamentals. The reason why California's politicians and regulators insist on the guilt of the Texas energy companies is simply that they needed a scapegoat to redirect attention from their own failures. They point out that the transaction-by-transaction judgments of the court left room for the conclusion that most of Enron's strategies were legitimate. They were nothing but different kinds of arbitrage trade—activities designed to make the market more, not less,

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[99] "Opinion No. 536 - Order Affirming Factual Findings, Directing Compliance Filing and Ordering Refunds re San Diego Gas & Electric Company v. Sellers of Energy and Ancillary Services et al under EL00-95," 149 FERC 61,116 (November 10, 2014).

[100] Given that there were hourly markets for every day of the year between 1998 and 2001 as well as additional forward markets, the 30,0000 transactions only capture a small part of the California markets.

efficient. Settlements without admission of guilt left room for the argument that companies simply preferred to settle in order to gain control over the costs of litigation and not because they were guilty. The FERC sentences were thus too murky and tentative to bury the first narrative.

In response to these objections, defenders of the second narrative expand their argument once again. To establish that the market manipulations were the root cause of California's problems, they draw from a variety of other sources. The first line of attack is directed against FERC itself. Several writers have suggested that the agency was subject to regulatory capture.[101] Again, the Enron scandal provided the most compelling evidence. It led journalists, congressmen, and lawyers to focus on the relationship between power merchants and the administrative structure of the federal government. The connections were truly astounding. Many power marketers, but particularly Enron, had actively lobbied for deregulation during the 1990s. On the federal level, they had spent vast sums of money on campaign contributions of politicians on both sides of the aisle. In a *New York Times* editorial, Senator Ernest Hollings put it bluntly: "In my 35 years in the Senate, I have never witnessed a corporation so extraordinarily committed to buying government. In the last decade, Enron gave campaign contributions to 186 House members and 71 senators, including $3,500 to me."[102] FERC was vulnerable to influence from the federal government. Not only were its decisions accountable to congress, the chairmen and commissioners heading the agency were political appointees. In a comprehensive article on the California energy crisis, a legal commentator writes: "In particular, the pervasiveness of Enron's relationships with policymakers illustrates how corporate interests are interwoven with legislative and administrative decision-makers to the

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[101] The economic theory of regulatory capture is, in its original formulation, nothing less but a theory of corruption. It views regulators as sellers who sell the desired policy to the highest bidder. George J. Stigler, "The Theory of Economic Regulation," *The Bell Journal of Economics and Management Science* 2, no. 1 (1971).
[102] Ernest Hollings, "Time for a Special Counsel," *NYT*, February 9, 2002.

point that they are often unable to consider the broader public interest when formulating and implementing policy."[103] Enron's influence with the Bush government was even more pronounced and problematic. Not only was Bush a personal friend of Enron's CEO Ken Lay, Dick Cheney's energy taskforce had adopted Enron's recommendations wholesale, sometimes without even changing the wording. The extent of these connections has been extensively discussed in the literature.[104]

Direct influence on FERC has been documented as well. For example, FERC's Chairman, Betsey Moler (1993–97), was the driving force behind the push for restructuring. Her connections to Enron were so close that she worked as a registered lobbyist for the company after leaving political office.[105] The three chairmen who headed FERC after Moler were James J. Hoecker, Curt Hebert, and Pat Wood. Despite different political backgrounds, each of these appointees had been vetted and explicitly recommended by Enron with the expectation that they would enact regulation in line with Enron's interests. During the energy crisis, Hebert went public with the statement that Enron's CEO Ken Lay had threatened that his career would be over if he blocked further progress towards deregulation. This was not an empty threat: Hebert was promptly replaced by Pat Wood after he refused to block California's attempts to impose lower price caps on the California markets.[106] The background of this refusal is no less problematic. When the energy crisis hit, the Bush administration put together a task force to deal with it. Enron provided Dick Cheney's group with a three-page memo outlining how the unfolding energy crisis might be combated. Prominently

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[103] Duane, "Regulation's Rationale: Learning from the California Energy Crisis," 474.
[104] McLean and Elkind, *The Smartest Guys in the Room*.
[105] Hearings Before the Subcommittee on Energy and Power on the Committee on Commerce: "Electricity Competition" (1999), Vol. 1 House of the Representatives, 106th Congress, 1st session, Serial No. 106-63. U.S. Government Printing Office, Washington, March 18, 1999, 53-55.
[106] Majority Staff Committee on Governmental Affairs (2002), "Committee Staff Investigation of the Federal Energy Regulatory Commission's Oversight of Enron Corp," Washington, D.C.: Committee on Governmental Affairs, U.S. Senate, 2002, 44.

featured in the memo is the following recommendation: “The administration should reject any attempt to reregulate wholesale power markets by adopting price caps.”[107] This point appeared almost verbatim in the administration’s energy policy plan.[108] As a historian of the crisis summarizes: “the unstated reason for opposing price caps was that they would stunt the huge profits being made by energy companies which had enormous political influence in Washington D.C.”[109]

Proponents of the second narrative thus claim that FERC was either completely in the pockets of the energy companies or tried to reduce attention to its involvement when it came to prosecuting wholesale traders. Even California government officials argued that FERC intentionally shut down most investigations with favorable settlements because it wanted to hide its own failing as a regulator. Perhaps most remarkable is the story of Snohomish County, a small public utility district north of Seattle. In 2001, Snohomish County had bought energy from Enron at $109 per MW/h—four times the price of previous years. When Enron went into bankruptcy and it became clear that they had manipulated the market, Snohomish voided the contracts. As part of its bankruptcy proceedings, Enron sued Snohomish for $122 million dollars of lost profit. To support their case and prove that Enron’s manipulative activities had violated the terms of the contract, Snohomish petitioned to access tapes that documented trader conversations at Enron. But FERC—far from aiding their investigation—tried to prevent Snohomish from gaining access. An official claimed that the tapes were part of criminal investigations by the FBI and the DOJ. They could therefore not release them because it would damage these other investigations. Snohomish

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[107] Quoted in David Lazarus, “The Enron Collapse – Memo Details Cheney - Enron Links,” *SF Gate*, January 30, 2002, https://www.sfgate.com/news/article/THE-ENRON-COLLAPSE-Memo-details-Cheney-Enron-3237974.php (last accessed 10/14/2019).
[108] Jake Bernstein and Lou Dubose, *Vice: Dick Cheney and the Hijacking of the American Presidency* (New York: Random House, 2008), 3-4.
[109] Beder, *Power Play: The Fight for Control of the World's Electricity*, 134.

persisted and obtained the tapes from the Justice Department. In a calculated bet, it spent $100,000 on transcribing the 2,800 hours of taped conversations, an astonishing move for a small Public Utility. The bet paid off when the transcripts turned out to be a treasure trove of evidence. "This is more than a smoking gun," said Russ Campbell, a lawyer for Nevada Power, another company fighting Enron in court. "It's an audiotape of the gun being fired, the bullet hitting the victim, and the murderer standing over the victim laughing." The transcripts had Enron traders boasting about lies during their negotiations with Snohomish and joking about the dismay that a variety of manipulative games had caused to California end users.[110] For example, on one tape two traders have the following conversation:

> "He just f---s California," says one of the traders, describing a third: “He steals money from California to the tune of about a million."
>
> "Will you rephrase that?" asks a second employee.
>
> "OK, he, um, he arbitrages the California market to the tune of a million bucks or two a day," replies the first.[111]

The tapes contain many other statements along these lines and have since become emblematic for the California crisis and the second narrative of the crisis.

When Snohomish submitted this evidence, it turned out that neither FERC nor the DOJ had been aware of their contents. The costs of transcriptions had prevented both FERC and the DOJ from examining the tapes themselves. Supposedly, no one at the FERC offices had even listened to some of them. But if that was the case, why did FERC try to prevent Snohomish from accessing those tapes? The proponents of the second narrative take FERC’s active attempts to repress the tapes as further evidence that the investigations represented an active attempt of obfuscation. The

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[110] “How a Small Utility Exposed Enron Traders,” *LA Times*, June 21, 2004: C2.
[111] Cited in Joel Roberts “Enron Traders Caught on Tape,” CBS, June 1, 2004, https://www.cbsnews.com/news/enron-traders-caught-on-tape/, last accessed 06/04/2020.

fact that so few transactions had been found to be manipulative was thus a function of FERC's desire to bury the issue as deeply as possible.

Another line of attack on the first narrative came from the California government. The state Senate's Select Committee to Investigate Price Manipulation of the Wholesale Energy Market conducted an independent investigation and held hearings that revealed additional wrongdoing. The hearing unearthed evidence that strongly suggested sellers' prior knowledge of the flaws in California's markets. Some even suggested that the conditions for the crisis might have been *manufactured* by sellers of energy who tried to influence the structure of the new markets during the process of restructuring.[112] Several pieces of evidence supported this claim.

First, during the political negotiations prior to restructuring, sellers had advocated for a market structure that would increase room for arbitrage trades.[113] Since they made money with trades that exploited price differences between locations, this was not surprising. But these rules also introduced inefficiencies that were the foundation of several of the manipulative strategies that occurred during the crisis. But did the companies know that this would be the case? There was some evidence that energy marketers anticipated what was yet to come. When the three big utilities began to divest their generation assets in anticipation of restructuring, they sold most of the plants far in excess of book value, to everyone's surprise. After all, some of these were considered "stranded investments." On net, the divestiture resulted in sales prices that exceeded the book values by more than 70 percent. And who bought the plants at such outrageous prices? Why, the big energy merchants, of course. Specifically, Duke, Southern Energy, Calpine, AES, Houston

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[112] Beder, *Power Play: The Fight for Control of the World's Electricity*, 94-100.
[113] Steven Stoft and others recognized this prior to market opening. Steven Stoft, "What Should a Power Marketer Want?" *The Electricity Journal* 10, no. 5 (1997). He also points out that obscure market rules would increase the value of services that market makers would be able to offer.

Industries (Reliant), and NRG bought these plants. *All* of them were later accused of market manipulation and either settled or paid fines.[114] Buying the plants far above book value from companies that had a strong incentive to overvalue them only made sense if they anticipated that the prices were going to go up *significantly* above marginal cost.[115] But the only conceivable reason for prices that high would be market manipulation. So, the pre-crisis actions of the power marketers only make sense if we assume they knew that they would be able to manipulate the markets.

Another piece to this puzzle emerged from the regulatory record at the CPUC. Looking at the original filings, it turned out that one of the parties that was most vehemently opposed to long-term forward contracting were…the independent generators. They argued that the long-term contracts would reduce the liquidity in the markets. This is, of course, true. But forward contracts would also have reduced the potential for the exercise of market power.[116] It is hard not to see this as the true reason for their arguments given that independent generators would have had to compete harder in liquid markets. However, market power made them rich.

Lastly, the California Senate's Select Committee investigated Perot Systems, a software vendor that helped design the operating system for CAISO. The company had helped to coordinate the integration of the different software platforms. In the course of this work, employees had found loopholes in the market rules. When the work at the ISO seemed to have come to an end, Perot Systems turned around and tried (unsuccessfully) to sell knowledge of these loopholes to vendors. It offered workshops that the California parties referred to as "crime schools."[117] Testimony and

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[114] "Opinion No. 536 - Order Affirming Factual Findings, Directing Compliance Filing and Ordering Refunds re San Diego Gas & Electric Company v. Sellers of Energy and Ancillary Services et al under EL00-95," 149 FERC 61,116, (October 10, 2014), 10-14.
[115] Utilities had a strong incentive to exaggerate the cost of investments because their rates were based on a fair return on investment during the period when the industry was a set of regulated monopolies.
[116] Paul Krugman, "Reckonings; The Unreal Thing" *NYT*, February 18, 2001.
[117] Joseph Dunn, "Perot Systems: Pied Piper of Gaming or Innocent Entrepreneur," letter to the congressman Doug Ose, dated July 22, 2002, included in "California's Electricity Market: the Case of Perot Systems," Subcommittee

reports by employees of CAISO and PX suggested that sellers had tested the boundaries of the system in the runup to the crisis, relying on precisely the kind of knowledge the Perot employees were trying to sell.

There was other such evidence. It turned out that the Texas-based company Industrial Information Resources, Inc. (IIR) sold a daily generation outage notification service to power industry subscribers. The information was plant and unit specific, disclosing the expected start date for an outage and the expected return to service date. Duke, Dynergy, and Williams (among others) used this information to coordinate the shutdown of generators. If these shutdowns made particular plants necessary to meet demand, the companies could then ask arbitrary prices for energy from these units. Though the companies did not have to provide regulators with reasons for their shutdowns, they usually claimed that it was necessary for maintenance purposes. Researchers found that such shutdowns for maintenance suddenly became much more frequent and lasted longer than they had in previous years. Between 1995 and 2000, plants shut down between 5 to 10 percent per year on average. In 2000, the average went up to *50* percent of the year.[118] Similar increases pertain to the duration of these shutdowns. Before deregulation, the utilities would do their best to get plants back online as soon as possible and could usually do so within two weeks. Now, the generators took an average of four weeks to bring the plants back online. However, they came online much faster when lucrative prices became available. In June of 2000, power plant engineers working for Duke accused their company of virtually sabotaging one of their own plants by “running it up and down like a yo-yo,” shutting the plant on and off.[119] Observers noted that the patterns of

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on Energy Policy, Natural Resources, and Regulatory Affairs, House of Representatives, 107th Congress, 2nd Session, July 22, 2002, 11-13.

[118] Beder, *Power Play: The Fight for Control of the World's Electricity*, 109.

[119] Greg Palast, "Why the Lights Went out All over California," *The Observer*, July 1st, 2001.

shutdowns and bids represented an image of the existing generation capacity that was highly unlikely to correspond to the facts.[120]

The problematic activities of the sellers were not confined to the electricity markets. Over 80 percent of the natural gas consumed in California was imported from out of state. During the crisis, energy was increasingly provided by natural gas plants. The prices for natural gas first doubled, then tripled between 1999 and 2001. In 2003, the California attorney general filed a suit against El Paso, a Natural Gas merchant, that showed that El Paso had engaged in a variety of manipulative strategies to withhold natural gas from California's markets and drive up the prices.[121] In June, El Paso settled this suit for $1.7 billion. Despite the doubts about its integrity, FERC revealed even more egregious attempts to manipulate the markets. In the course of FERC's fact-finding investigation of 2002–2003, the agency found evidence of several different manipulative strategies.[122] Practically every trader of natural gas used Enron Online (EOL), a virtual trading platform. FERC found that EOL enabled big trading companies to engage in churn trading—rapid purchases and sales of gas between affiliates or colluding companies that drove up prices and increased volatility. In addition, with proprietary knowledge of these movements through Enron Online, Enron had during 2000 and 2001 realized almost $600 million in speculative, derivative-based profits from these manipulative strategies. In other words, the companies drove the price for natural gas up and down through rapid-fire trades between affiliates or partners and then used the knowledge about these price movements to make profitable bets in the derivative markets. Lastly, the companies also manipulated the published natural gas price indexes, which serve as a

[120] Steven Stoft, *Power System Economics* (New York: IEEE Press, 2002).
[121] Jeremiah D. Lambert, *Energy Companies and Market Reform: How Deregulation Went Wrong* (Tulsa, Oklahoma: PennWell, 2006), 127.
[122] Ibid., 121-41.

tool for price discovery. These indexes are compiled and published by the trade press. They rely on price information that energy companies provide to them voluntarily. It turned out that virtually all big sellers of electricity in California who were also trading in Natural Gas were guilty of price index manipulations. Among them were El Paso, Dynergy, AEP, Williams, and Enron. By skewing the price indices, the companies could engage in profitable arbitrage businesses and bets in derivative markets. Of course, the increased natural gas prices allowed them to make higher profits in California's electricity markets, where natural gas was desperately needed during the crisis.[123]

In sum, the second narrative slowly expanded. It began with a general contestation of the story that asserted supply/demand imbalances. It then revealed the exercise of market power and later began to look at specific behavior of sellers. Once the proponents of the first narrative contested these findings based on the limited results of the FERC litigation, the economists, journalists, and lawyers reacted by tying together a variety of additional findings from different investigations. Though complex in its details, the basic claim is that the crisis was caused by sellers of energy who planned to raid the markets and then executed these plans, which led to the crisis. They manipulated the natural gas, electricity, and financial derivative markets and exercised unprecedented levels of market power to drive up the prices to the point where the system began to crumble.

3.5. The Strange Persistence of Both Narratives

Even though the evidence of outrageous trader behavior is crushing, the revolving door between Washington and the lobby of energy marketers widely visible, and the failures of regulators well documented, the second narrative has not triumphed. It does not matter how sophisticated

[123] Ibid., 176-81.

it has grown over time. Regardless how many different versions of the story exist in legal, academic, and journalistic treatments, an equal number of treatments will appear to tell the other story. The battle of the narratives continues to be the decisive concern of most stakeholders. To give just one example from my own fieldwork: I met George Sladoje, the former CEO of California's PX, for the first time at the Union League Club in downtown Chicago. We sat across from each other at a table in the vast, empty dining hall of the club, and I had just started to record the conversation. Before I could ask a question, he started by saying:

> I have a first comment, even before we start talking about the exact situation that we're researching here. The purpose of the study is to determine why the California markets were designed in a way that made them unable to counteract destructive behavior by market participants. So, your professor has already come to the conclusion that the problems were due to destructive behavior by market participants? I wonder what his conclusion is based on.

I responded that we meant "behavior that contradicts the reliability requirements of the grid," and I did not *assume* that the behavior was causal for the crisis or the intended consequence of particular design decisions. But he pressed on:

> My point is that the political situation and primarily the California government had a lot to do with creating the conditions, which enabled things to go on, which were not all unethical or, which were not all unreasonable. For instance, when they impose price caps in California and there are no price caps in Nevada, or Oregon, or any of the surrounding states; what is a publicly owned company, who most of these generators were, supposed to do? Sell in state at a considerably lower price because it was mandated by the government, or send it out to somewhere else in the western part of the grid.[124]

The passage illustrates that he felt the need to defend the behavior of market actors as rational and reasonable, even after I tried to explain that I did not intend to presume which of the two narratives was right. His most urgent interest at the beginning of the interview was to straighten out my misconception that the crisis had been caused by sellers of energy. Practically

[124] Interview with George Sladoje, 03/30/2018.

all my interviewees fell on one side or the other of the debate and tried to convince me in similar ways. Their urgency illustrates well how unsettled the divide continues to be.

For each revelation that the proponents of the conspiracy story raise on their flagpole, the defenders of the first narrative have a riposte. Three general kinds of strategies are available and keep showing up.

First, they argue that sellers' behavior was not, in fact, illegal, but constituted legitimate attempts to protect the integrity of the generation assets or engage in arbitrage business. They point to FERC's spotty and inconsistent judgments about individual transactions to support their case. In cases where FERC did find manipulative behavior, they accuse FERC of applying post-hoc standards to the time of the crisis and point to a dysfunctional political system in California, which really drove the crisis. This was the line of argument Sladoje pursued, for example.

Second, they claim that even if the sellers did engage in manipulative behavior, this behavior did not have the alleged effect on the markets. Other factors explained most of the price increases. For example, the explosion of one of El Paso's natural gas pipelines in New Mexico in 2000 was often cited to explain the increases in natural gas costs. The material conditions of generators under adverse conditions were often used to explain increased maintenance during the summer of 2000.

Third, they argue that even if the behavior existed and had an effect, it could only be demonstrated for individual instances and did not constitute a systematic strategy. Each line of defense is backed up by complex econometric analyses, anecdotal evidence, witnesses, and transaction records. While the complex history of litigation has established that many sellers of generation did in fact manipulate the markets during the California Energy Crisis, it is still contested whether they were really the cause of the crisis or merely benefited from it.[125]

It is easy to disregard the arguments of the first narrative and suggest that they are attempts to blatantly deny what is obvious. But that would be too easy. It is certainly true that the California markets saw manipulative behavior that drove up the prices, and even behavior that sustained the prices at a high level. But it is far from clear whether this behavior caused the crisis in the first place or if it merely was a surface phenomenon that distracted from more fundamental factors driving the crisis and enabling the behavior.

As one traverses the vast record of studies, analyses, legal, and journalistic accounts, one thus gets the impression of a fundamental ambiguity at the heart of the crisis. When I first began writing this dissertation, I wanted to know which side was right. But the more I read, the more I realized that the true causes of the crisis remain forever shrouded in ambiguity because both the means for and the standards of a decisive evaluation remain elusive.

To give an impression of what I mean, consider the following episode from January 16, 2001, the day before the fateful blackouts in California. It involves Bill Williams, one of the traders who worked at Enron's West Desk in Portland, Oregon. The West Desk was a tight-knit operation that traded electricity in the Western states: all traders worked in a single, large room equipped with telephones and computers. Throughout the day, the different "desks" cooperated in identifying and executing speculative trades in energy markets. Bill Williams was one of twelve employees

[125] It may not surprise the reader that the defenders of the first narrative invoke causality in sense of legal liability. This notion of causality is based on our everyday experience, where we claim that someone caused an event if we perceive them to be responsible for it. This happens when the cause is (a) necessary for the event to occur, (b) the consequence of free human action, and (c) not interrupted by an intervening action. C.f. Hart and Honoré, *Causation in the Law*. The arguments to defend the first narrative all turn on the question of whether causality in this legal sense can be established.

who specialized on short-term trades. This involved buying and selling electricity at different locations to realize arbitrage profits. Most trades were executed via phone.[126] In the following conversation, Williams talks to an operator at a small plant in Las Vegas that usually exported energy to California.

After the operator picks up, Williams says, “This is going to be a word-of-mouth kind of thing. We want you guys to get a little creative and come up with a reason to go down.” The operator responds that he could certainly switch off the plant. Somewhat uncertain, he then asks, “O.K., so we're just coming down for some maintenance, like a forced outage type of thing? And that's cool?” Bill responds: "Hopefully." At this, both men begin to laugh.[127] On January 17, the plant declared technical outages and did not come online. It was one resource less that McIntosh, Riley, and the other operators at the CAISO could draw on.

An administrative law judge at FERC released the tapes of this and similar conversations in 2005 during the Snohomish investigation mentioned earlier. Some members of the press heralded them as the smoking gun that finally proved power marketers had created artificial shortages of energy to drive up the prices in California, deliberately risking the system’s breakdown.[128] Yet, while there can be no doubt that the conversation documents how Enron’s traders orchestrated physical withholding of electricity at a crucial moment of the crisis, it is not at all clear whether this attempt was successful: the power plant could not possibly have provided the energy necessary

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[126] The operations of the West Desk are outlined in, for example, Robert McCullough, “Enron Discovery, June 9, 2004,” *FERC* EL03-137/180. By strategically disaggregating deals into “strips” that traders entered into the general accounting software (Enpower), it became very difficult even for insiders to see how the profits were generated. But the West Desk also used private accounting ledgers (Inc Sheet and others), in which the trades were clearly listed. These ledgers were eventually found in a warehouse and analyzed by a team of investigators. They reveal the extent to which the West Desk used the schemes outlined in the famous Enron memos.
[127] In 2005, an administrative law judge of the Federal Energy Regulatory Commission (FERC) released this tape and others to the public. They can be found in docket: EL03-180-000.
[128] Julian Borger, “Tapes Reveal Enron's Secret Role in California's Power Blackouts,” *The Guardian*, February 4, 2005, https://www.theguardian.com/business/2005/feb/05/enron.usnews (last visited: 04/09/2019).

to prevent the blackouts on January 17. So, even if it had sent all its energy to California, the prices would not have changed, and the blackouts could not have been avoided.

But if the energy from the power plant could not have made a difference, how can we say that this action really did have anything to do with the crisis? Conversely, while it was obvious that *other* outages did in fact impact prices and system reliability, it could rarely be established with certainty that the generators were shut down to impact prices. If the regulators showed up at the power plants that were under maintenance, the operators always provided some plausible explanation: algae were stuck in the turbines, a rotor malfunction occurred, a generator had overheated due to overuse during the summer, etc.

In official proceedings, the generators kept insisting that they had been doing the best to meet the emergency needs of the system operator—even in the face of damning evidence, the generators retained plausible deniability. To get a sense of how damning the evidence was, just consider an email that circulated widely among generators that documents the culture that prevailed among California's wholesale merchants. The email chain started on April 20, 2001 when the government had already begun to engage in emergency energy purchases to avoid a system collapse. In the email, Enron employee Jeffrey Fawcett offers the generators a sing-along song to the theme music from the TV western "Rawhide." He suggests that this could be the theme song of the industry:

The Rolling Blackout Theme Song[129]

[129] Cited in Bill Lockyer, "Attorney General's Energy White Paper - A Law Enforcement Perspective on The California Energy Crisis," (Sacramento, CA: Attorney General's Office), 22.

Rollin', rollin', rollin',
Though the state is golden,
Keep them blackouts rollin',
statewide.

A little colder weather,
And we all freeze together,
Wishin' more plants were on the line.
All the things I'm missin',
Like lights and television,
Are waitin' 'til we can pay the price.

(Chorus)

Turn 'em on, turn 'em off,
Shut 'em down, block 'em out,
Turn 'em on, turn 'em off, statewide!
Brown 'em out, black 'em out,
Charge 'em more, give 'em less,
Let the pols fix the mess, statewide!

Keep movin', movin', movin'
Though they're disapprovin',
Keep them rates a-movin', statewide.

Don't try to understand 'em,
Just raise, charge, and collect 'em.
Soon we'll be livin' high and wide.
My heart's calculatin',
Nuclear plants will be waitin',
Be waitin' at the end of my ride.

(Chorus)

Turn 'em on, turn 'em off,
Shut 'em down, block 'em out,
Turn 'em on, turn 'em off, statewide!
Brown 'em out, black 'em out,
Charge 'em more, give 'em less,
Let the pols fix the mess, statewide!

STATEWIDE! Hyaah!

If you had to imagine a perfect piece of evidence for a widespread culture of market manipulation, you would probably come up with something like this. Yet even such revelations were unable to tilt the scales of expert discourse and litigation in a definitive way.

The opposite side argued that the kinds of activities described in such emails were either perfectly legitimate (who could deny a seller the right to *not* sell power?) or that "games" were part of the evolutionary development of market environments.

The familiar argument went like this: Market participants always take advantage of loopholes in market rules—that is simply what it means to act as a profit-maximizing enterprise. But by virtue of doing so, regulators get a chance to learn where the problems are and improve the market rules, which in turn helps markets to become more robust and efficient. This defense rested on the point that "gaming" usually involved loopholes in the laws governing markets rather than direct violations of law.[130]

In yet other cases, there was a set of behaviors that clearly drove up prices. But it was not clear whether this behavior was widespread and, even if it was, how exactly it related to the overall crisis. Economists working for power marketers repeatedly showed that the various analyses that created systematic connections between the company behavior and higher prices had margins of errors that were larger than the estimated effect. A myriad of technical factors could influence the cost of electricity on the ground, and so where exactly was one to draw the line? What was the real difference between normal behavior in a competitive industry and illegal manipulation if the standards had not been drawn up clearly by law and if the causal mechanisms were unclear?[131]

If we withhold for a second the instinctive outrage we might feel about such contentions, there can be no doubt that they are, in some sense, correct: markets are supposed to drive innovation and companies ARE supposed to develop new and better ways to make money. As long as it is not illegal, who is to ask a regulator to enforce purely ethical rules of business? Even if we would like that, who would decide which ethical rules should apply?

If such objections remain mute even in egregious instances of manipulative behavior, they are even more damning for the more subtle points of the second narrative. Consider, for example, the investigation of Perot Systems. During a congressional investigation, it turned out that the employees at Perot Systems had warned regulators and personnel at CAISO of the very same problems they tried to sell to the power marketers as information.

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[130] The defense of Perot's employees was particularly impressively done, in "California's Electricity Markets: The Case of Perot Systems," 82-117.

[131] Again, these questions point to the legal notion of causality, discussed in fn. 125. Since the research developed in close relation to litigation, both narratives have appealed to the standard of "personal" causality that is more about responsibility than the ontology of the social world.

Virtually identical presentations had been given to a variety of state and federal actors responsible for parts of the technological infrastructure for California's markets.[132] Other examples include the seemingly obvious conclusion that power marketers must have known about the manipulative possibilities in California when they bought the plants at inflated book value. Perhaps they anticipated that supply shortages would occur and that there would be price increases. But is that to be equated with an attempt to manipulate the markets?

To give another example: the California government has repeatedly argued that FERC's prosecution of sellers was a lackluster affair either because they tried to hide their own involvement and/or incompetence, or they tried to get rid of the bureaucratic nightmare of litigating a crisis now more than twenty years in the past, or they were trying to protect energy merchants.

In response, energy merchants have pointed out that California's politicians and litigators focused their accusations on energy merchants and federal regulators because they were trying to hide that a variety of state entities—such as the Los Angeles Department for Water Resources—profited during the crisis, just like anyone else. They argue that the conspiracy theory is meant to hide a history of political and regulatory incompetence and corruption and to provide simple scapegoats outside the state when they should look in their own backyard.

For every piece of evidence that seems to provide incontrovertible proof that manipulation explains the price spikes during the Western energy crisis, other information or arguments that undermine these certainties creep up, demonstrating the workings of economic forces while revealing political interference that distorted them.[133]

[132] Ibid.
[133] The various reasons that could explain a legitimate reduction of generator output are discussed in Scott M. Harvey and William W. Hogan, "Identifying the Exercise of Market Power in California," *LECG Research Paper* (2001); "On the Exercise of Market Power through Strategic Withholding in California."

Underneath the ambiguities created by inconclusive evidence and political maneuvers, there is thus a deeper reason that both narratives persist: the criteria guiding the evaluation of evidence are not clear or set in stone. This begins with the law: at the time of the crisis, FERC did not have a clear standard of market manipulation. To detect the market power in California, it first had to change its metrics. This change redefined the understanding about the nature of market power and arguably changed the substance of their regulatory approach.[134] Only after the Enron memos appeared did FERC declare their provisions to be in violation of the CAISO/PX tariffs. For almost a decade, illegal behavior was almost exclusively defined in terms of these memos. This arguably imposed a new legal standard into the past.

Where the legal foundation was shaky, the political and econometric standards were even more so: What looked like a clear form of manipulation to some politicians appeared as contributions to an evolutionary market logic that was the cornerstone of American success. What was to one set of economists a good econometric model to understand market power, to another group it was a terribly flawed abstraction from the reality of business decisions.

When studying the two narratives and the back and forth of argument and analysis across a variety of different venues, we therefore do not simply see attempts to determine "what really happened." We see a negotiation over the criteria of evaluation and the weight that should be given to any particular factor. On top of this negotiation, we face the problem of missing or ambivalent evidence.

Both narratives fundamentally agree that the California markets *enabled* manipulative behavior, at least to some degree. Both also agree that political, regulatory, and criminal activities

[134] Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 178-82.

played together under conditions of scarcity to drive up the prices. But they disagree about the weight that should be placed on the different factors, what has been proven, and what has not. And because the legal system could never find its way to a *general* conclusion, which would have settled the score by virtue of its position in the hierarchy of truth production, the debate continues. While one side continues to argue that the crisis would never have occurred if the politicians had not tried to frustrate the logic of the market, the other side continues to argue that the politicians only protected the population from a corporate conspiracy.

In the final analysis, it is impossible to draw a causal arrow that settles which factor was most influential. This, then, leaves the question of how this dissertation should approach the case. A first step to find a way out of these interpretative quandaries is to consider the *structure* of the explanation that the existing literature seeks to develop.

Both the search for culprits in the legal proceedings as well as the various econometric analyses involved the search for an underlying root cause. Econometric analyses try to build counterfactuals that make it possible to isolate a single factor that precipitated the events. Particularly, the legal proceedings that started with the 100 days of evidence tried to do the same: they tried to establish links between particular transactions and high prices by establishing accurate counterfactuals based on economic methodology. While legal and journalistic treatments have a narrative structure that trace the rationale for action from one context to the next and isolate constraints on action, economic analyses typically provide causal mechanisms that describe how different features of supply and demand play together in a world of strategic interactions to produce prices. They then use the evidence from these counterfactual scenarios to link events to actions. Accordingly, the explanations always take the shape of "if politician A had not done X, B would not have happened." For example: if the CPUC had not blocked utilities from hedging their positions, they would not have suffered from the price hikes in the spot markets; if imports from the West had not declined, the energy production in California would have been cheaper, etc.

These explanations do recognize that the California crisis was precipitated by a variety of overlapping factors—weather, politics, supply imbalances, etc.—but they react to this problem by trying to find the most important antecedent or weightiest factor. There are two reasons for this.

First, the two narratives of the crisis are largely produced with legal and econometric methodology. Despite their differences, these explanations are beholden to a form of causal thinking that focuses on causes in a chain of events (narrative) or on a composition of factors that jointly cause an observed pattern (economic mechanisms).

Second, both explanations ultimately treat the California energy crisis as a consequence of atomistic behavior. A variety of actors do things in a variety of contexts, and the interactions between these contexts then produce the crisis.

Together, these two features make it possible to order the world in a variety of ways—to subtly shift the importance of this or that factor and rearrange where the causal arrow points. Within narratives, it is easy to shift levels or actors and manipulate what is in the fore- or background. Within mechanistic explanations, it is easy to rearrange the relations between the different analytical parts, add new ones, and contract or expand the data one is looking at in order to support statements about these relations.[135] The instabilities are thus built into the nature of the explanations that the literature is after. This, then, suggests that we might take a different approach.

I suggest that we should not look at the precipitating causes of the crisis, i.e., the specific events, actions, or factors that triggered the chain of events leading to the price spikes. We should

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[135] These are just features of these kinds of explanation—it does not entail a negative judgment about them. Andrew Abbott, *Methods of Discovery* (Chicago, IL: University of Chicago Press, 2004), 69-75.

not ask questions about the *magnitude* of influence of specific factors, as in: How much manipulative behavior occurred and how was it related to the ongoing price spikes? Or how much would have occurred if the retail markets had been deregulated?

Instead, I suggest that we should ask about the *structural* preconditions of the crisis, i.e., what kind of behavior was *possible* given the kind of market environment it was, and why was this behavior possible in the first place? Rather than suggesting that a particular quantity of manipulation caused the crisis, it is more promising to ask: What created opportunities for behavior that was not compatible with the stability of the electricity system? For there can be no doubt that the behavior in the markets was dysfunctional, regardless of whether we view it as legal or illegal, manipulative or straightforward. Whatever the reason, people acted as they did, and what they did led to reliability problems in the grid and a market that needed to be restructured after the government interfered. This dissertation asks: What structural features of these markets created these opportunities and where did they come from?

This empirical question puts the investigation of the California energy crisis on a different trajectory because we now have to ask: What exactly were the markets supposed to look like? How was the system supposed to work and why did it not do what it was supposed to? These questions point to the fact that the markets were *designed*. To turn electricity into a tradable commodity, a vast amount of social engineering had to take place: new organizations had to be created, ownership structures had to be changed, new institutions needed to be invented, new ways of doing business had to take hold. Practically everything the utilities had done in the past had to change. And this project was guided by a plan, albeit roughly and not always as the architects had intended. The markets were the creation of experts, stakeholders, and politicians who tried to engineer markets according to a new vision of how the system should work. The question about the structural preconditions for the crisis require us to investigate what these people were doing, what they created, and why it did not work the way they wanted it to work. It requires us to look at the crisis as a failure of market design. This ultimately leads to a focus on a different and often neglected part of the history: the different contexts in which an intellectual project was translated into institutional and material reality.

Most existing studies view the design period as a yet another instance of the 1990s' obsession with deregulation and focus on the political process that led to the creation of AB1890, the law that provided the foundation for restructuring.[136] The political history is full of interesting characters, such as Steve Peace, a charismatic senator who forced compromise by debating people to exhaustion, berating them, or ridiculing them during the nightlong sessions of the "Steve Peace Death March" in the California Assembly in August of 1996.

The stories prominently feature Enron executives like Jeff Skilling, influential lobbyists, and Washington supporters. They tend to explain the architecture of the California system in terms of political compromise, naïve utility officials, or cunning power marketers who tried to create a system they could game.[137] But while politics, special interests, and utilities' inertia did play their

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[136] Beder, *Power Play: The Fight for Control of the World's Electricity*; Bushnell, "California's Electricity Crisis: A Market Apart?"; Cicchetti, Dubin, and Long, *The California Electricity Crisis: What, Why, and What's Next*; Marcus and Hamrin, "How We Got into the California Energy Crisis."; Robert McCullough, "Price Spike Tsunami: How Market Power Soaked California a Look at the Data Reveals How Ordinary Were the Summer's Fundamentals. Did the I.S.O.'S Secretive Operations Encourage Collusive Behavior?" *Public Utilities Fortnightly* 139, no. 1 (2001); McNamara, *The California Electricity Crisis*; Navarro and Shames, "Electricity Deregulation: Lessons Learned from California."; Rights, "Hoax: How Deregulation Let the Power Industry Steal $71 Billion from California."; James Walsh, *The $10 Billion Jolt: California's Energy Crisis: Cowardice, Greed, Stupidity and the Death of Deregulation* (Los Angeles, CA: Silver Lake, 2004); Chi-Keung Woo, Debra Lloyd, and Asher Tishler, "Electricity Market Reform Failures: U.K., Norway, Alberta and California," *Energy Policy* 31, no. 11 (2003); Chi-Keung Woo, "What Went Wrong in California's Electricity Market?" *Energy* 26, no. 8 (2001); Woo, Lloyd, and Tishler, "Electricity Market Reform Failures: U.K., Norway, Alberta and California." But see Vernon L. Smith, Stephen J. Rassenti, and Bart Wilson, "California: Energy Crisis or Market Design Crisis?" (paper presented at the Hoover Institute Conference on the California Electricity Problem 2002).

[137] In particular, Beder, *Power Play: The Fight for Control of the World's Electricity*; Blumstein, Friedman, and Green, "The History of Electricity Restructuring in California."; Toshiyuki Sueyoshi, "Beyond Economics for Guiding Large Public Policy Issues: Lessons from the Bell System Divestiture and the California Electricity Crisis,"

roles, most of the technical design decisions go back to engineers and economists involved in a variety of working groups and public forums. Without considering the enormous technical challenge of electricity market design, it is easily forgotten how much intellectual firepower the task brought to the table. The stories of political naiveté and seduction by the empty promises of Texan companies capture some of the situation in California during the 1990s. But they ignore that it was also a moment of tremendous hope and ambition.

Joan Didion once observed, "California is a place in which a boom mentality and a sense of Chekhovian loss meet in uneasy suspension; in which the mind is troubled by some buried but ineradicable suspicion that things had better work here, because here, beneath that immense bleached sky, is where we run out of continent."[138] This sentiment captures the spirit of the moment well. At the time, California was facing the early trembling of the internet industry's spectacular growth, but it had the highest rates of electricity in the nation. There was a sense that the utilities were wasting rate payer money, that the regulatory structure was deficient, and that the industry might choke the economy. This led California's politicians to pursue restructuring more aggressively than anywhere else. They wanted California not only to be the first state to move to a market regime, but they also wanted to execute the transformation in the shortest period of time and in the most complete way. While other states explored opportunities for a gradual transformation, California quickly decided on a comprehensive design project.

The urgency and ambition of the project made being in the industry *cool*, as one of my interviewees put it.[139] What had, for decades, been a backwater for heavyset engineers with

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Decision Support Systems 48, no. 3 (2010); de Vries, "The California Electiricty Crisis: A Unique Combination of Circumstances or a Symptom of a Structural Flaw."

[138] Joan Didion, "Notes from a Native Daughter," in *We Tell Ourselves Stories in Order to Live: Collected Nonfiction*, ed. Joan Didion (New York: Everyman's library, 2006), 131.

[139] Interview with Jan-Smutny Jones, 02/21/2017.

mustaches and low grades from public schools suddenly turned into a promised land for young go-getters who had picked up their self-assured mannerisms in the classrooms of the Ivies.[140] Some of the young talent came West to make money. Words like “deep liquid pool,” “forward markets,” “asset divestiture,” and “market efficiency” occupied the imagination of stakeholders and regulators alike—words that sounded sharp and exciting and glimmered with the promise of untold profits.[141]

The market designers came for the intellectual challenge. To them, the California industry was a thankful laboratory to try out the limits of market design. As Paul Joskow and Richard Schmalensee wrote in their landmark study of potential avenues toward deregulation,

> Currently electric power is supplied by complex and highly developed systems with unusual technical characteristics. These make it likely that reliance on an economist’s instinct, developed through countless examples drawn from agriculture and manufacturing, will produce incorrect conclusions.[142]

Due to its unusual characteristics, the industry served as an exciting *terra incognita* for market designers. From all over the country, intellectual talent began to track to California. Market designers came from Harvard, MIT, CalTec, Berkeley, and Stanford to collaborate with utility officials, engineers, and lawyers.[143] United under the banners of game theory, mechanism design, information economics, and industrial organizations, the designers followed an intellectual vision that had first been spelled out at MIT and Harvard during the late 1970s. It was their project, a chance to prove the power of market design and build the world that economic theory had promised

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[140] Richard F. Hirsh, *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System* (Cambridge, MA: MIT Press, 1999), vii; O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 50-51.
[141] See, for example, the presentation of Enron’s Jeff Skilling before the CPUC. “Hearing Before the California Public Utility Commission, Reporter’s Transcript, Los Angeles, June 14, 1994, vol. 1, Pages 1-298,” Box 69, *CPUC*, 272.
[142] Paul L. Joskow and Richard Schmalensee, *Markets for Power: An Analysis of Electrical Utility Deregulation* (Cambridge MA: MIT Press 1988), 9.
[143] Interview with Jan Smutny-Jones, 02/21/17.

from old. Several of my interviewees thus told me that the creation of California's markets was the most generative period of their life. For example, a prominent market designer who worked for PG&E, one of California's big utilities, described the period of intense collaboration like this this:

> I have to tell you: this was the most productive period of my life. I was a young PhD, learning how to fix [problems], taking stock in different people. You learn new things, you meet new people, you hear different things from various people in different disciplines that you didn't get a chance to hear when you were just talking to PG&E. You know, we're speaking various skills, people. Really, it was a very productive process and intellectually a very intensive debate.[144]

For years, experts with broad authority to make decisions about the technical details of the design and significant intellectual acumen worked on California's market design. And yet, despite intensive efforts of some of the smartest people in the industry, the project failed. Within two years of opening, the system was at the verge of collapse. The question is why.

Once we conceive of the California energy crisis as an instance of market design failure, the divided state of the literature itself becomes a puzzle. The designers were trying to create a market environment that would function according to a specific, idealized plan. Surely, they should have also developed an oversight regime that would allow them to ensure that the markets worked as planned? After all, how could they have known if they succeeded in their design efforts if they could not see what the market was doing? What, then, are the structural features of the market that made it difficult to know what was going on and why did the designers make the decisions that created these structural features?

The following chapters will try to answer these questions. But before we can begin to re-cover the structural preconditions for the crisis and then trace their origin, two prior steps are

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[144] Interview with Armin P., 01/25/18.

necessary: First, we must recover the plan. What exactly was the vision market designers were pursuing? What is this project whose realization we are going to trace? Then, we need to show that the markets can indeed be understood as an attempt to realize this project. These two steps are necessary to establish the parameters for an investigation of what went wrong and why. I will now turn to this task and ask: What were market designers trying to do?

4. The Intellectual Project of Market Design

4.1. Introduction

The ambiguities surrounding the narratives of the California energy crisis have led us toward a different path of inquiry. Instead of continuing the endless search for the ultimate culprit that triggered the crisis, I will examine the crisis as a case of market design failure. This means that we will no longer ask which kind of behavior was causally the most relevant for the high prices and whether this behavior was legal, illegal, manipulative, or simply prudent. Instead, we are going to start with the generally accepted insight that the markets produced incentives and opportunities to charge very high prices for energy. These prices eventually undermined the financial stability of the three utilities and led to a reliability crisis. Once we no longer focus on the quantity and relative weight of different kinds of behavior, the question becomes: What were the structural features that created these incentives and opportunities? And, given that we are dealing with the intentional creation of the market structures, we ask: What drove the decisions to put these structural conditions into place?

As I have already observed in the introduction, not much research in economic sociology has asked about the conditions for the success and failure of market design. Most of economic sociology views economics as an explanatory enterprise and asks: Where are economic explanations incomplete or mistaken?[1] Studies in the broad literature on performativity also view economics as an explanatory enterprise, and ask: How is the truth of economic theories a function of social

[1] The "new" economic sociology of the 1980s was effectively an attempt to leverage a counterattack on economics after Gary Becker and his followers started to infringe on the turf of sociology. The main thrust of this research was to establish the many ways in which economics is operating with an inaccurate understanding of how markets *really* work. In other words, it treated economics as an explanatory enterprise with bad assumptions. Granovetter, "The Old and the New Economic Sociology: A History and an Agenda."

processes that render them *performatively* true, i.e., by virtue of believing in them, enacting them, etc.? This leaves a third avenue of research motivated by the insight that market design involves a genuine shift in the epistemic orientation of economics. They no longer try to explain the world; they are trying to change it on the basis of a plan. This means that we should no longer evaluate economic theory in terms of some analytical standard of what a good explanation is. Instead, we should evaluate it in terms of its *feasibility*, i.e., the possibility of actually realizing the internal aspiration of economics. From this perspective, performativity *itself* is not surprising anymore: economists are aware that their theories only become true if people act in accordance with them, which is the very point of these theories. The question is, rather, what are the conditions under which market design succeeds or fails on its own terms? What is the difference between a feasible and an infeasible market design? This requires us to compare the intellectual project market designers pursue and the blueprints they develop with the actual markets and their creation.

Now, since there is not much research in economic sociology that is directly relevant to the questions I want to pursue, I will go a more circumspect way to develop an analytical framework and guiding hypothesis. This chapter will dive into the history of market design to recover the intellectual project of market design as well as its aspirations. The very first question is how market design fits into economics as a whole. The advent of the economist as engineer represents a noticeable shift in the self-presentation of the discipline. For much of the twentieth century, economics has branded itself as a science of neutral observation.[2] As a “hard science,” it studies a theoretical entity called “the market” and empirically examines the ways in which the real world violates the assumptions of theoretical models that describe this entity. The corresponding self-presentation

[2] C.f. the definition in the most widely cited undergraduate textbook for economics, “Economics is the study of how societies use scarce resources to produce valuable goods and services and distribute them among different individuals,” Paul Samuelson and William D. Nordhaus, *Economics,* 19th ed. (New York: McGraw-Hill, 2010), 4.

is one of objective detachment. From this vantage point, the rise of market design during the last two decades must appear rather strange.[3] The sudden commitment to social engineering seems to directly contradict the pose of objective detachment. In order to understand what market design is about and how it relates to the things that economists *do*, I will begin by giving a brief sketch of economics as a *profession*. This reveals how closely economics has always tried to gain jurisdiction over political questions concerning the management of the economy. The first section thus reveals that aspirations for social control have always been close to the heart of economics and that market design represents merely the latest stage in a long quest for tools to perfect projects of social engineering.

In the next section, I then reconstruct the intellectual project of market design. I argue that it can be understood as a form of *centralized planning* that resonates with socialist tendencies long slumbering below the surface of mainstream economics. Going back to the Socialist Calculation debate of the 1920s and 1930s, I argue that we can understand the two dominant schools of market design (experimentalism and mechanism design) as responding to challenges against the possibility of using economic models as a tool of centralized planning. This suggests comparisons with other forms of centralized planning, which provide us with a guiding analytical framework. Specifically, I am going to argue that market design views markets as algorithms that solve optimization problems under constraints. These algorithms are composed of software and people. The people interact strategically and the software processes and aggregates the decisions of these actors. The goal of market design is to create institutions that structure the strategic interactions in such a way that they enact subroutines of the larger algorithm. Together, software and people produce a

[3] Market designers have received several of the most recent Bank of Sweden Nobel prices, and they have begun to appear in a variety of policy contexts. Mechanism design is now part of the standard curriculum of PhD students at R1 programs.

solution to the optimization problem, which has predefined, desirable welfare consequences, e.g., Pareto optimality or allocative efficiency. Effectively, market design is an attempt to shape the nature of strategic interactions in a marketplace according to a particular plan for calculative behavior. From other forms of centralized planning, we then observe the promise as well as the potential pitfall of market design. The promise is that market designers do not constrain the substance but only the *form* of decentralized decision-making—individual actors still get to decide how and how much to produce, as well as how much to offer at what prices. Individual actors also still bear the risks and benefits of their action. The centralized bureaucracy—in this case, the software engineer—merely ensures that the way these decentralized activities aggregate into a global allocation follows a predetermined logic of exchange. Market designers are like planners of city grids who impose structure on decision-making but leave the substantial decisions to the people who wander the streets. The crucial question is *how much control* is necessary to enforce the correct *form* of behavior required for the algorithm to work. Depending on how much control is necessary and how difficult it is to impose, the bureaucratic requirements for oversight may overwhelm the market design project just like other enterprises in centralized planning. This discussion provides the grounds for the rest of the dissertation where I will investigate what exactly is involved in controlling the correct "form" of economic behavior, to what extent this contradicts the imperatives of local decision-making, and to what extent it contradicts the limits of bureaucratic control. I will now begin by providing an overview of economics as a profession to explain the sudden rise of market design during the last two decades.

4.2. Economics as a Profession: The Seedbed of Market Design

If we look at economics as a science of objective detachment and rigorous empirical analysis, the appearance of market design in the mainstream of economics is surprising. However, this changes if we view economics as a profession rather than in terms of its self-presentation.[4] In the U.S., the development of economics has been closely entangled with politics from the very beginning. During the last decades of the nineteenth and the first of the twentieth century, the progressive movement challenged political patronage on all levels of government and created a new demand for unpoliticized, technical expertise. Without an elite of public technocrats and the need to keep technical expertise outside government where it might be perceived as biased, the university became the natural source of this expertise. Confronted with the demand for professional advice, economics was developed as an *applied science*.[5] This established a *codependent* relationship with governmental administrations: academic institutions were encouraged to professionalize along technocratic lines to meet the requirements for “scientific” advice, while public service relied on the academic disciplines to provide job classifications and recruitment criteria. Over the course of the twentieth century, economics became the discipline that could help government *manage* an economy.

Perhaps an even more important factor for the unique level of influence that U.S. economics gained for government was its close relationship with the military. Operations research during World War II and the demands for macro-economic planning put economists at the heart of the war economy, which secured their influence and served as an important driver for its push toward

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[4] Marion Fourcade, *Economists and Societies: Discipline and Profession in the United States, Britain, and France, 1890s to 1990s* (Princeton, NJ: Princeton University Press, 2009).
[5] Robert H. Nelson, "The Economics Profession and the Making of Public Policy," *Journal of Economic Literature* 25, no. 1 (1987): 53-54.

quantification. This, in turn, cemented their influence further.[6] Military projects often involved cooperation between scientists from different disciplines. They introduced economists to mathematical techniques developed in operation research and cybernetics, which were themselves borrowed from planetary mathematics, electrical engineering, and physics. In particular, economists learned about new computational tools such as linear and dynamic programming.[7] The influx of these mathematical techniques from the "cyborg sciences" and their successful application for various purposes of the war economy was so formative that Paul Samuelson, who is often regarded as the father of neoclassic economics, termed the Second World War "the economists' war." Though Samuelson probably meant to refer to the influence of economics on politics, the quote more appropriately describes the influence of the hard sciences on economics.

As influential as the lessons of the Second World War may have been, it was the subsequent Cold War that proved most fateful for the development of economics and its ascent to political influence. In modelling scenarios for the nuclear standoff with communist powers, economists began to develop and integrate game theory, whose foundation had been laid in 1944 when John von Neumann and Oskar Morgenstern published *The Theory of Games and Economic Behavior*.[8] The exposure to game theory and tools of Dynamic System Analysis by the military turned economics into a discipline that could lay claim to the status of a general science of rational decision-making uniquely qualified to address questions of macroeconomic planning.[9] The more deeply economics got implicated in governmental processes, the more it resembled a science that could

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[6] Fourcade, *Economists and Societies: Discipline and Profession in the United States, Britain, and France, 1890s to 1990s*, 99.
[7] Philip Mirowski, "Cyborg Agonistes Economics Meets Operations Research in Mid-Century," *Social Studies of Science* 29, no. 5 (1999).
[8] Sonja M. Amadae, *Rationalizing Capitalist Democracy: The Cold War Origins of Rational Choice Liberalism* (Chicago: University of Chicago Press, 2003), 6-7.
[9] Michael A. Bernstein, *A Perilous Progress: Economists and Public Purpose in Twentieth-Century America* (Princeton, NJ: Princeton University Press, 2001), 73-90.

provide the neutral expertise they required. Institutionally, the close integration of economics, the military, and the government was facilitated by capitalist foundations and think tanks like the right-leaning RAND Corporation, the Carnegie Corporation, the Rockefeller Foundation, and the left-leaning Cowles Commission. These institutions operated as the central nodes in the network that linked universities, military, business, and government. Endowed with massive funding streams, the think tanks and foundations pushed for the development of mathematized tools that could be applied in the interest of national defense and macroeconomic management. The Cowles Commission developed large models of the national economy. Subsequently, they played a key role in making model construction and their statistical estimation a central part of the discipline's approach. It was from experiences with these early models that the commission developed the claim that they would be able to "manage" the economy. There was thus a symbiotic relationship between the discipline of economics and various parts of the administrative state facilitated by a nexus of intermediate institutions.

The way economic knowledge adjusts to and diffuses through this nexus also explains the prevalence of economic language outside governmental administrations. Much of the policy-relevant research in the United States is not conducted directly by government agencies, but by an independent economics industry. This has partly to do with the fragmented character of American politics, where each level develops its own tools, often in conjunction with private partners. The main reason, however, lies in the antagonistic structure of governmental decision-making processes in which different bodies, as well as external stakeholders, compete with each other.[10] Together with the constant expansion of industries that are entrusted to the market mechanism, the

[10] Fourcade, *Economists and Societies: Discipline and Profession in the United States, Britain, and France, 1890s to 1990s*, 115-16.

reluctance of government to internalize research and the decentralization of administrative and corporate decision-making provide the opportunity for the widespread commercialization of academic skills. Economic forecasting, for example, became an increasingly profitable enterprise with the rise of the financial industry in the 1970s.[11]

Similarly, legal rules are subject to constant formal and informal negotiations on various levels of government in the American system. American corporations are therefore constantly trying to figure out an evolving and ambiguous regulatory environment. By providing quantifiable standards, economists help to reduce this massive uncertainty for all players involved—businesses, governmental agencies, and courts. This establishes yet another symbiotic relationship between a heavily mathematized economics and an important infrastructural system: the law increasingly adopts the language of economics while economists develop more and more exact ways of resolving the interpretative difficulties of legal disputes by means of quantification ("law and economics" movement).[12] Lastly, private think tanks rely on economic expertise precisely because the policy-making process has become so dominated by economic rationales—lobbyists and firms that want to play the game have to rely on economists to provide acceptable rationales to the policy discourse that translate their ideological differences into objective numbers. The close connection between economics departments and business schools also explains why almost anyone who works in business has some sort of "economics background;" since the 1960s, business education has been increasingly shaped by formal economic knowledge.

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[11] Roger E. Backhouse, "The Rise of Free Market Economics: Economists and the Role of the State since 1970," *History of Political Economy* 37 (2005): 385-86.

[12] This movement is also one of the main drivers for the ideological shift that promoted deregulation—the analysis of governmental action along the lines of the principal-agent dilemma establishes that governments are motivated by other, often conflicting goals and can therefore not be expected to intervene effectively in the economy. Fourcade, *Economists and Societies: Discipline and Profession in the United States, Britain, and France, 1890s to 1990s*, 118-22.

In the U.S., economics has thus developed a tight relationship to politics, mediated by a complex nexus of military institutions, think tanks, legal research, and foundations. It is almost paradoxical that the discipline was able to maintain its self-presentation as a neutral science in light of this proximity to political decision-making. This has much to do with the internal structure of the discipline. Despite its various ties to government and think tanks, modern economics is primarily based in the university, and its academic discourses are closed off from the outside world.[13] The PhD plays a crucial role in this almost paradoxical structure: On the one hand, it allows for strict intellectual standardization inside. Very few top departments have a monopoly on certifying economists and have established homogenous and exacting standards that generate an impression of neutrality and rigor. The curriculum of these degrees is characterized by a certain "moral purity," which manifests as the exclusion of laymen, powerful high-theory discourse that is far removed from any application, a strict boundary against practical education (evidenced in the strict distinction between business schools and economics departments), a defensive attitude towards politics, and a focus on technical sophistication as *the* marker of economic expertise.[14] Yet, at the same time, the PhD also serves as a key instrument of professional standardization vis-à-vis the external markets. By virtue of their ivory-tower education, economists appear as neutral scientists whose advice can be unproblematically adapted within politics.[15] In other words,

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[13] This striving for a certain "cognitive and moral" purity beautifully captured in her examination of the struggle between economics departments and business schools that led to a much more "scientific: curriculum for the latter. Marion Fourcade and Rakesh Khurana, "From Social Control to Financial Economics: The Linked Ecologies of Economics and Business in Twentieth Century America," *Theory and Society* 42, no. 2 (2013).

[14] Fourcade, *Economists and Societies: Discipline and Profession in the United States, Britain, and France, 1890s to 1990s*, 64.

[15] The rhetorical power of economics has been analyzed by McCloskey, who makes a postmodernist argument to embrace this performative dimension as the *true* mark of scientific expertise. His work has, understandably, been heavily contested and debated. Deirdre N. McCloskey, *Knowledge and Persuasion in Economics* (Cambridge, UK: Cambridge University Press, 1994); *The Rhetoric of Economics*, 2nd ed. (Madison, WI: University of Wisconsin Press, 1998).

precisely by separating itself from the concerns of political life and retaining an appearance of neutrality, the discipline can secure its influence.

The position of economics in the system of professions prepares the ground for the appearance of the economist as engineer. In practice, economists (although not economists in university departments) hold jurisdiction over all questions regarding the nature and proper management of markets.[16] Political and regulatory agencies draw on economists to establish claims about what the market is, how it should be evaluated, and what needs to be done to keep it under control. The claim that markets cannot just be managed on the basis of economic knowledge, but must be designed to achieve desired goals merely represents an additional step in the general trajectory of jurisdictional claims the discipline has advanced in the twentieth century. The close connection to engineering and operations research provides not just the tools, but also the attitude of control that is characteristic of these applied sciences. Thus, from the perspective of the discipline's self-presentation, the emergence of the economist engineer may appear surprising: with the market no longer appearing as a natural phenomenon, both the role of the economist and the nature of the market suddenly change. But from the perspective of the discipline's professional role in American society, the emergence of the engineer represents just an incremental change. In its move from natural science to a discipline of engineering, economics resembles a caterpillar who prepares for transformation into a butterfly in a pupate state. By posing as a neutral science, economists gained the influence that eventually allowed the discipline to reemerge on the stage as a full-fledged social engineer. Their institutional power is transmitted through an organizational nexus that links elite universities to think tanks, private companies, and governmental organizations.

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[16] Martha Derthick and Paul J. Quirk, *The Politics of Deregulation*, ed. Institution Brookings (Washington, D.C.: Brookings Institution, 1985); Paul S. Dempsey, *Airline Deregulation and Laissez-Faire Mythology*, ed. Andrew R. Goetz (New York: Quorum Books, 1992).

This brief overview suggests two conclusions. First, market design developed in a discipline with a professional infrastructure that is equipped to turn aspirations into reality. Second, we should distinguish two types of economists in the subsequent analysis. The intellectual project of market design is largely being articulated within the confines of academia and research institutes. Here, market design appears as a progression of ideas and techniques developed in relative distance from issues of implementation. However, market designers "in the wild" who work on issues of market construction are a broader group. They are experts who travel between university and practical contexts of application and market construction. While many of the main protagonists are university professors, the group also includes experts working for utilities, think tanks, or governmental agencies. They may or may not have PhDs, and their pursuit of the intellectual vision is mediated by the practical goals and constraints of the work they do.[17] In this chapter, I focus on the intellectual project of market design because it provides the orienting vision for market design as a professional enterprise. As such, it will provide criteria for the success and failure of market design and allow us to develop some theoretical hypotheses that will guide the subsequent analysis of the California markets and the expert practices that created them. I will now reconstruct the evolution of market design and argue that it is a form of centralized planning.

[17] Sometimes, the efforts to implement markets by "economists in the wild" may look more like acts of ongoing experimentation rather than the creation of clearly theorized objects. Michel Callon, "Civilizing Markets: Carbon Trading between in Vitro and in Vivo Experiments," *Accounting, Organizations and Society* 34, no. 3-4 (2009). But such a purely practice-based understanding of market design underestimates the porous connections between university and practical work as well as the importance of guiding ideals. It certainly does in the case of electricity markets. For a critical view of Callon's description of carbon offset market design, see Declan Kuch, *The Rise and Fall of Carbon Emissions Trading* (New York: Palgrave Macmillan, 2015), 120-1.

4.3. Market Design as a Form of Centralized Planning

Just like all other social sciences, economics is not a particularly unified discipline. It consists of many different traditions, tools, and research programs.[18] Since market design developed below the surface of the mainstream, it is particularly fragmented. It composes several strands of research that developed partly together and partly in isolation from each other. The dominant strands are information economics, experimental or behavioral economics, game theory, and mechanism design. Different people in different departments developed these subdisciplines into different directions. Accordingly, a reconstruction of the intellectual project of market design that focuses exclusively on people will appear confusing. Instead, I contend that the different endeavors are linked via a conceptual core that organizes the intellectual project and allows market design to enter the world as a seemingly unified discipline. The easiest way to recover this conceptual core is to follow the traces of a socialist program that has long been implicit in economic thinking. Specifically, we can understand the evolution of market design as a relatively coherent body of work by viewing it as successive attempts to respond to challenges that were first raised during the Socialist Calculation debate of the 1920s and 1930s.[19]

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[18] It is an interesting question of how economics maintains that appearance of unity to the outside. Michael J. Reay, "The Flexible Unity of Economics," *American Journal of Sociology* 118, no. 1 (2012).

[19] There are at least three distinct readings of the Socialist Calculation Debate. The "standard version" of the debate prevailed in Neoclassic economics until about the 1980s. Its dominant proponents are Joseph A. Schumpeter, *History of Economic Analysis* (New York: Oxford University Press, 1954), 985-1002; *Capitalism, Socialism and Democracy* (New York: Harper, 1975 [1942]), 172-200. Bergson Abram Bergson, "Socialist Economics," in *A Survey of Contemporary Economics*, ed. H. S. Ellis (Homewood, Illinois: Richard Irwin, 1948). and Samuelson Paul Samuelson, *Economics* (New York: McGraw-Hill, 1948). To the extent that the debate reverberates in market design, this is the decisive reading. Accordingly, my reconstruction will focus on this reading and the responses it provoked by market designers. Nonetheless, in the 1980s, a series of papers found that the neoclassic reading had misunderstood the Austrian position on a variety of foundational, conceptual issues. C.f. Peter Murrell, "Did the Theory of Market Socialism Answer the Challenge of Ludwig Von Mises? A Reinterpretation of the Socialist Controversy," *Socialism and the Market: The Socialist Calculation Debate Revisited* 7 (1999); Gabriel Temkin, "On Economic Reforms in Socialist Countries: The Debate on Economic Calculation under Socialism Revisited," *Communist Economies* 1, no. 1 (1989); Don Lavoie, "A Critique of the Standard Account of the Socialist Calculation Debate," *Journal of Libertarian Studies* 5, no. 1 (1981). More recently, a new reading has appeared in the context of Cotrell's and Cockshott's defense for a new socialism." Paul W. Cockshott and Allin Cottrell, *Towards a New Socialism*

During the debate, some of the world's foremost economists fought fervently over the theoretical properties of socialism.[20] Specifically, they argued about the question of whether or not socialism is logically impossible. The debate featured, on the one side, the Austrian School of Economics, represented most notably by Ludwig von Mises and Friedrich Hayek, and on the other side, Marxist and neoclassic economists, most notably Oscar R. Lange, Abba P. Lerner, Fred M. Taylor, Frank Knight, and later, Joseph Schumpeter. To understand why famous economists from all over the world were obsessed with this seemingly obscure question, it is important to remember the historical context of the 1920s and 1930s. At the time (and perhaps in some way similar to the way things are now), dismay and uncertainty about the prospects of capitalist democracies pervaded intellectual and public discourses. The Great Depression suggested that the superiority of capitalist systems might be illusionary. There was a sense that the system might lead to vast inefficiencies on the basis of internal tensions that might lead to its collapse. At the same time, the U.S. witnessed the meteoric rise of fascism and socialism in Europe. Early experiments with collectivized farming seemed promising and enabled Russia's rapid development into an industrialized society. Many intellectuals in the U.S. therefore felt like capitalism was in need of a thorough defense, while intellectuals who had been socialized in the East believed in the technocratic vision

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(Nottingham, UK: Spokesman Books, 1993); Allin Cottrell and W Paul Cockshott, "Calculation, Complexity and Planning: The Socialist Calculation Debate Once Again," *Review of Political Economy* 5, no. 1 (1993). Their proposal retains the thrust of the revised version," but tries to recover central points of the neoclassic reading. It then levels an effective defense against these recovered objections. I will make some use of the Lavoi interpretation to highlight conceptual incongruities in the market design project later on.

[20] The socialist roots of economics are sometimes invoked to explain the discipline's development into a hard science after the 1940s. When the political situation changed after WWII and the U.S. entered the era of McCarthyism, the ideas for centralized planning and management of capitalist processes that many economists had advocated became a dangerous liability. The mathematization of the Keynesian framework allowed economists to move to safer territory; as a neutral science, whose applicability had been proven during the wars, economists operated seemingly above the ideological divides that haunted the political scene.

behind socialism. In light of the fundamental challenge to the very concept of liberal democracies, the question of which system might be superior animated intellectual debates at the highest levels.

The debate began when Ludwig von Mises developed a novel argument as to why socialism was logically impossible.[21] Since this argument was simple and elegant and seemingly offered a silver bullet against centralized planning, it provoked a heated response from all quarters.[22] Until Mises published his article, the main objection against socialism had been the well-known incentive problem. If everyone gets the same income or receives goods according to their needs, it is not clear why anyone would still be willing to do dirty jobs or perform a given job well. The main responses to this challenge turned on human nature. Appealing to Rousseau and a long line of thinkers from Marx to Kropotkin, socialists usually claimed (and often still claim) that humans would develop new dispositions under a socialist order. The "New Socialist Man" would not respond to material incentives but moral ones, and the dirty jobs would be done by freely and joyously consenting workers.[23] But since such arguments build on ontological propositions about the malleability of human nature, there was no way to assess their validity. The only way to decide the issue was to create a socialist system and see what would happen. This, of course, was not suited to allay any insecurities about the current state of liberal democracies.

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[21] I am here largely sticking to the script of the "standard version" of the socialist calculation debate. This reading would pervade the mainstream of economics for decades and therefore provides the foil against which market design unfolded. However, I am using insights from the "revised reading" to reveal blindspots in the project of market design later on.

[22] The article first appeared in German under the title "Die Wirtschaftsrechnung im sozialistischen Gemeinwesen" in 1920. In 1935, it became available in English in an edited volume as Ludwig Von Mises, "Economic Calculation in the Socialist Commonwealth," in *Collectivist Economic Planning*, ed. Friedrich August von Hayek, et al. (London: Routledge 1935). Here, I am citing from the version that was republished as a monograph in 1990. *Economic Calculation in the Socialist Commonwealth* (Auburn, Ala: Ludwig von Mises Institute, 1990).

[23] Murray N. Rothbard, "The End of Socialism and the Calculation Debate Revisited," *The Review of Austrian Economics* 5, no. 2 (1991): 51-52.

Mises now offered an argument on why socialism was infeasible *on principle*. The key move was to shift the argument to the terrain of epistemology. Mises argued that markets solve an epistemic problem that a board of centralized planners would not be able to solve.[24] The argument begins with basic issues of decision-making under scarcity.[25] As soon as we enter the world of production and consumption, certain basic calculation problems emerge. Given that there are scarce resources, any society needs to make decisions about *how* to produce goods to meet wants. The producers need to choose between a variety of different possible production processes, which use different resources as inputs. It does not matter whether we are in a capitalist or a socialist society—these decisions need to be made, and they need to be made in a way that uses the available resources wisely, i.e., in a way that optimizes the outputs to meet demand.

In a capitalist market society, the entrepreneur can make his or her choice by simply looking for the cheapest production process. He or she only needs to compare the prices for all "factors of production" and choose the most affordable process relative to anticipated prices for demand at different levels of output.[26] This simple calculation aligns the entrepreneurial activities with the

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[24] David R. Steele, *From Marx to Mises: Post Capitalist Society and the Challenge of Ecomic Calculation* (La Salle, IL: Open Court, 2013 [1992]), Chapter 1.

[25] As John O'Neill has repeatedly argued, the mainstream reading of the socialist calculation debate has projected the concerns of the later debate between Hayek and Lange back onto the original article by Mises. Originally, Mises's article was meant as a response to Otto Neurath and dealt with questions that later moved out of the debate's focus. In particular, the early debate concerned the issue of what economic rationality is and how far it extends into practical reason more generally. Mises defends the view that *any* economic decision can be turned into an issue of algorithmic calculation and that any decision can be turned into an economic decision as long as a price is available. In contrast, Neurath and others argue that even economic decisions have political and ethical dimensions that cannot easily be reduced to price calculations. John O'Neill, "Who Won the Socialist Calculation Debate?" *History of Political Thought* 17, no. 3 (1996); "Knowledge, Planning, and Markets: A Missing Chapter in the Socialist Calculation Debates," *Economics and Philosophy* 22, no. 1 (2006). Though tangential to my discussion here, this early debate is interesting because it reveals the imperialist character of modern economics—it seeks to absorb every issue into the accounting system of price competition. Once a market exists, economics can always generate instructions for decision makers. But it has nothing to say about when the instrumental means-ends rationality is appropriate or what is lost if we use it at the expense of alternative ways to reason. These issues are, of course, of central relevance to the development of critical theory in the twentieth century. See, for example, the famous critique of the colonization of the lifeworld in Jürgen Habermas, *The Theory of Communicative Action: Lifeworld and Systems, a Critique of Functionalist Reason*, trans. Thomas McCarthy, vol. 2 (Cambridge, UK: Polity Press, 2006 [1987]), Section VII.2.

[26] Von Mises, "Economic Calculation in the Socialist Commonwealth," 8-9.

economy as a whole because it responds to the relative scarcity of the commodities for all other production processes in the economy.

Mises's argument is now that the simple calculation is only available within the context of *markets*. The market establishes the prices for factors of production. Since everyone wants to buy the resources they need for their production processes (or consumption), the price that emerges in the free exchange of goods depends on the factors' relative usefulness for all different processes of production. This means that the price effectively expresses the opportunity costs of that factor, i.e., how much all other production processes would have to be cut back if the resource was used in one process rather than another.[27] Folded into this relation of "usefulness" is the degree to which products are desired by individuals who will purchase them. Markets thus compile information about the relative usefulness of factors of production in a dynamic environment of alternative uses. When the entrepreneur makes the simple calculation about which production methods will be best suited for the desired outputs, he or she therefore aligns the productive activity with everyone else's.

The next step in the argument explains why socialism is impossible. Without the market, Mises argues, a socialist planning board would not be able to rely on the price to make decisions about the ideal combination of production methods and factors of production relative to some aggregate demand.[28] Scientists, technicians, and administrators could only distinguish the usefulness of productive processes in terms of absolute costs. They would know that process A uses less resources than the alternative process B. But they cannot distinguish between two processes that use equal amounts of *different* resources. To choose, they would have to know about the alternative

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[27] Steele, *From Marx to Mises: Post Capitalist Society and the Challenge of Ecomic Calculation*.
[28] Ludwig Von Mises, 2008, 18-32.

value of these resources for all other production processes at that moment. Without a common unit of measurement that is indexed to these different processes, this cannot be done.

This argument has two dimensions. One is about the *comparability* of alternative uses for a given resource. For example, how do you determine whether bread is more important than honey if there are no prices? If production processes that deliver bread encounter higher demand in a capitalist society, the price will go up and indicate that those production processes will need the resources for bread more urgently than the production processes that require honey. Without a price, it will be necessary to resort to measures like "socially necessary labor time" for a given resource, which do not reflect the relation to the existing demand. Lacking market prices as a guide, the planners would be unable to determine the relative scarcity of different components of the production process and so would invariably fail to combine and use them efficiently.[29] This argument hinges on the role that money plays as a *tertium comparationis*.[30] The second dimension of the argument concerns the complexity of the calculation that socialists would have to execute. Even if you could measure the relative usefulness of all resources for all production processes in society, you would be unable to compute the optimal combination. You have to consider different combinations of resources for different production processes and find the combination that optimizes the use across all processes. Mises's argument is, in essence, that the *combinatorial* possibilities get too complex to compute. While the first part of the argument suggests that the calculation cannot be set up without money as a means of comparison, the second dimension suggests

[29] Lavoie, "A Critique of the Standard Account of the Socialist Calculation Debate," 41.
[30] Since market design does not usually abandon money, the argument is of secondary importance here—though particularly successful market designs substitute scrip currencies for money.

that the socialist planning board cannot execute the calculation.[31] One of Mises's examples summarizes this twofold argument colorfully:

> Even Robinson Crusoe, when he has to make a decision where no ready judgment of value appears and where he has to construct one upon the basis of a more or less exact estimate, cannot operate solely with subjective use value, but must take into consideration the intersubstitutability of goods on the basis of which he can then form his estimates. In such circumstances it will be impossible for him to refer all things back to one unit. Rather will he, so far as he can, refer all the elements which have to be taken into account in forming his estimate to those economic goods which can be apprehended by an obvious judgment of value—that is to say, to goods of a lower order and to pain-cost. That this is only possible in very simple conditions is obvious. In the case of more complicated and more lengthy processes of production it will, plainly, not answer.[32]

In other words, as soon as you consider more than just a few possible production processes, it becomes difficult to express the various alternative uses relative to our wants in a single metric of value that is subjective, e.g. "pain cost." That is partly so because the combinations of possible ways to use resources relative to one's wants becomes intractable. There are billions of possible combinations if resources can be inputs and outputs for a variety of different production processes. The socialist planning board will therefore simply be unable to compute the optimal assignment of resources to production methods.

What makes this rather esoteric argument so consequential is that it turned on the novel idea that markets have an *informational* function. The market collects and condenses information on the relative uses of all factors of production into a simple price. This is precisely why it is possible that the activities of the entrepreneur move into alignment with all other productive processes without explicit planning. The market thus appears as a mythical information processor that computes information more readily than any human being ever could. Mises made this argument

[31] The response by the socialists usually focused on the second issue, c.f. in his review of the latest iteration of the debate, Brewster points this out. Len Brewster, "Review: Towards a New Socialism? By Paul Cockshott and Allin F. Cottrell. Nottingham, Uk: Spokesman," *Quarterly Journal of Austrian Economics* 7, no. 1 (2004): 66.
[32] Von Mises, *Economic Calculation in the Socialist Commonwealth*, 9.

before Turing and von Neumann had created the foundation for the first real computers. Once they emerged, the conceptual innovation took on a life of its own, changing the course of modern economics.

The response to Mises's challenge came from neoclassic "market socialists" associated with the Cowles Commission at the University of Chicago. Despite the popular narrative of the Chicago school of economics as the seedbed of neoliberalism, things were quite different in the 1920s and 1930s. At the time of the socialist calculation debate, neoclassic economics was not yet "neoliberal" but animated by socialist and Keynesian ideas. The Cowles Commission, only indirectly tied to the economics department, brought together a variety of academics who had socialist leanings. Their answer to Mises was inspired by the disciplinary background of economics at the time. Around the onset of the twentieth century and under the influence of the Progressive Movement, the U.S. government had begun to increase its efforts to collect economic information about the country. The practical problems of this enterprise led to the invention of measurement theory, which dealt with the question of how aggregate phenomena could be captured by collecting, weighing, and combining various indicators.[33] Suddenly, economists could draw on a wealth of "official" data whose production only increased with the new requirements of the war economy and the social projects of the Depression era. To manage this data, they developed statistical methods that first allowed for causal analyses. Since these methods allowed the manipulation of data that was central to nearly all economic questions, they were quickly embraced by *both* the mathematized neoclassic tradition and the more dominant institutionalist schools. This paved the way for the development of "econometrics" and the unique style of scientific reasoning that is

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[33] Daniel Breslau, "Economics Invents the Economy: Mathematics, Statistics, and Models in the Work of Irving Fisher and Wesley Mitchell," *Theory and Society* 32, no. 3 (2003).

mathematical modeling. Econometrics was formed as a subfield to bridge the gap between theoretical (i.e., mathematical) reasoning and statistical data analysis. It combined the potential of the methods that had been developed since the marginalist revolution with the wealth of empirical data and statistical methods that had become available since the 1920s and 1930s.[34] The central econometric technique—modeling—combined mathematical and statistical elements. It could be used to build simple mathematical representations of complex economic processes, and at the same time, served as a means to generate statistical descriptions of the actual historical and structural relations represented in the government's aggregate data. The complexity of models could be easily scaled up and down. The available models ranged from descriptions of time patterns to representations of underlying behavioral mechanisms, from single equation to large models of several hundred equations that were constructed to mirror the economy as a whole. Since they could be used to build, explore, and test theory at almost any level of abstraction with data, they began to permeate all areas of economic research with each subdiscipline developing its own models.[35] At the time of the socialist calculation debate, the advance of models was in its infancy. Computers did not exist yet, and economics had not yet attained an image as a "hard science," unified by a technical toolkit of models—but it was at the cusp of a transformation.

But the idea that the economy could be represented in a mathematical model already existed. In 1908, Alfredo Pareto's disciple Enrico Barone had formalized Walras's General Equilibrium Theory into a mathematical model of the economy.[36] The model demonstrated that a

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[34] Beaud and Dostaler, *Economic Thought since Keynes: A History and Dictionary of Major Economists*, 64-67. In the 1940s, prior to entering the Second World War, the Cowles Commission gave up on econometrics for a while and embraced the path of formal mathematical theorizing, which would give rise to the formalization of the general equilibrium model.

[35] Mary S. Morgan, "Economics," in *The Cambridge History of Science: Volume 7: The Modern Social Sciences*, ed. Dorothy Ross and Theodore M. Porter, The Cambridge History of Science (Cambridge, UK: Cambridge University Press, 2003), 288.

[36] Lavoie, "A Critique of the Standard Account of the Socialist Calculation Debate," 42.

Walrasian economy—a highly stylized auction with only one time point and perfect knowledge of technologies, preferences, and endowments as well as perfect competition and infinite suppliers—had an equilibrium with desirable welfare attributes.[37] The early model was simply a giant set of supply and demand functions for all commodities in the system. The demand for each commodity depended on the demand of each other commodity expressed as a price. Similarly, the supply depends on the supply for each other commodity, expressed as a price.[38] The economy is in equilibrium if supply and demand for each commodity match, which leads to a system of simultaneous equations with as many equations as there are unknown (equilibrium) prices. Accordingly, the system can in principle be solved.[39] This means that the model can tell the user exactly what the best uses of all available resources are. It captures the relative importance of these resources for the different processes of production and solves for an ideal distribution. The existence of a formal mathematical model for a perfect economy created a straightforward response to Mises's challenge: if it is possible to model the economy as a whole and show how the interactions of the different productive processes can lead to an efficient equilibrium, the socialist planning can simply solve those models to determine the efficient distribution of resources. Since the economic model shows exactly how the invisible hand works, it can replace the invisible hand.

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[37] The general Walrasian equilibrium model was still based on the calculus of energy physics that the "marginalist revolution" had introduced into economics. Philip Mirowski, *More Heat Than Light: Economics as Social Physics, Physics as Nature's Economics* (New York: Cambridge University Press, 1991); "Physics and the 'Marginalist Revolution'," *Cambridge Journal of Economics* 8, no. 4 (1984). It was during the 1930s and 1940s that economics slowly moved on to different mathematical tools, more in line with the idea of the economy as a dynamic system, animated by agents who face problems with a certain degree of uncertainty and information from past decisions. *Machine Dreams: Economics Becomes a Cyborg Science* (New York: Cambridge University Press, 2002), 21-23.

[38] Additional variables are the stock of available money and the wealth of the economy expressed as an index of its holdings. These variables, M and A, are externally given.

[39] William J. Baumol, *Economic Theory and Operations Analysis* (Englewood Cliffs, NJ: Prentice-Hall, Inc., 1977), 480-1.

It is hard to overstate the significance of this move. The conceptual entity "market" has changed from a description of decentralized exchange relations into the image of a machine that works like an information processor. By deciphering this information process as a mathematical model, the invisible hand ceased to be invisible. It became a mechanism to be modeled, controlled, and, ultimately, *created*.[40] This move prepared the ground for a world where the economist first understands and then engineers the process that leads to welfare maximizing equilibria. The market as model becomes a cipher for a new form of centralized planning. The experts at the Cowles Commission concluded that socialism was at least logically feasible since Barone's system of simultaneous equations had an equilibrium. Economic theory could be used to replace the market with a board of centralized planners.

This board simply had to collect all the necessary information about demand and available resources, plug it into the model, and then send the equilibrium solution for ideal quantities of commodities (based on nominal accounting prices for commodities) to the various managers of industrial processes to choose the appropriate production processes.[41] The response by the socialists focused entirely on the question of whether the computation of the relationship between all resources was possible and ignored the parts of the argument that were not amenable to the mathematical framework of general equilibrium theory. Accordingly, they missed that Mises's argument made substantially different assumptions about how markets work.[42]

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[40] This is one of the claims Mirowski makes about the development of economics after the 1940s. See Mirowski, *Machine Dreams: Economics Becomes a Cyborg Science*, 77-80.

[41] Of course, the neglected part of Mises argument is the question of whether it would be possible to assign such accounting prices without a system of exchanges. What would they be based on, after all? In the mathematical framework of general equilibrium theory, they would simply express the relationship between all commodities, given a set of endowments and the stock of industry.

[42] Recovering the substantially different, conceptual frameworks and evaluating which one is more plausible is the essence of the "revised" version of the Socialist Calculation Debate. Lavoie, "A Critique of the Standard Account of the Socialist Calculation Debate."

The Austrians did not waste time responding to the arguments proffered by the socialists. In particular, Friedrich Hayek became the most prominent defender of the idea that the market was a mythic entity whose movements could not simply be replaced by an economic model. He published a series of revised and expanded versions of Mises's argument.[43] However, the precise nature of the Austrian response has been contested. At the time, the socialists read Hayek's argument as a retreat from Mises's extreme position. To them, it seemed that Hayek had conceded that socialism was logically possible and instead argued that it would be *practically* infeasible.[44] The practical difficulties mostly concerned the possibility of collecting and processing information at a central location. As Hayek put it in his 1935 article, "Individualism and the Economic Order," "The mere assembly of these data is a task beyond human capacity"; but even if it could be accomplished,

> the magnitude of this essential mathematical operation will depend on the number of unknowns to be determined. The number of these unknowns will be equal to the number of commodities which are to be produced. […] the order of magnitude [for these unknowns] would be at least in the hundreds of thousands. This means that, at each successive moment, every one of the decisions would have to be based on the solution of an equal number of simultaneous differential equations, a task which, with any of the means known at present [1935], could not be carried out in a lifetime.[45]

Focusing on this part of Hayek's argument prompted the socialists to come up with what came to be known as the Lange-Lerner-Taylor solution. This solution asserted that the socialist planning board could easily resolve Mises's calculation problem by ordering its various managers

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[43] The most important entries can be found in the collection of articles from 1948. Friedrich A. Hayek, *Individualism and Economic Order* (Chicago, IL: University of Chicago Press, 1948).

[44] The alternative reading is that Hayek proposed an alternative vision of the market as a "laboratory of discovery" that is perpetually in disequilibrium. The question how the equilibriating tendency works is a question how the coordination of plans is actually achieved. This is unanswerable through mathematical modeling because the models (at the time) assumed that all plans have already been coordinated (i.e., everyone already knows everything about everyone else's position and makes decisions in line with this perfect knowledge). This alternative reading suggests that Hayek accused the socialists' response of simply begging the question that Mises posed.

[45] Hayek, *Individualism and Economic Order*, 165.

to fix accounting prices on the basis of a trial and error procedure.[46] If it turned out that the prices were too low, causing a shortage in consumer goods, the planners could raise the prices. If they are too high and a surplus emerges, the planners can lower the accounting prices. Rather than simply distributing resources according to Barone's equation, they envisioned the socialist planning board as personifying the Walrasian auctioneer who clears the market and sets prices. In the process of setting the prices, the planning board solves the equations of the Barone model by trial and error, ultimately finding the equilibrium solution that clears the market. The socialists accepted the epistemic function of prices as a common unit of measurement to compare the relative use of factors of production. But they insisted that the calculation the market provided could be taken over by economic models. The resulting, synthetic prices could then be used just like real market prices, resolving the problem of aggregating, updating, and re-distributing all information. The activities of the socialist board here are modeled on a primitive algorithm to discover an equilibrium distribution through a systematic trial and error process. How closely they were thinking about markets as solving optimization problems and how clearly this paved the way toward a vision of the market as a computer becomes visible in a retrospective quote by Oskar Lange, who noted decades after the debate had ended:

> Were I to rewrite my essay [on the possibility of socialism] today, my task would be much simpler. My answer to Hayek and Robins would be: So what's the trouble? Let us put the simultaneous equations on an electronic computer and we shall obtain the solution in less than a second. The market process with its cumbersome *tâtonnements* appears old-fashioned. Indeed, it may be considered a computing device of a pre-electronic age.[47]

After the formulation of the Lange-Lerner-Taylor solution, the debate raged on for several more years, with rebuttals from Mises and Hayek, each followed by counterattacks, notably by

[46] Rothbard, "The End of Socialism and the Calculation Debate Revisited," 53.
[47] Oskar Lange, "The Computer and the Market," in *Socialism and Economic Growth*, ed. Charles Feinstein (Cambridge: Cambridge University Press, 1967), 158.

Joseph Schumpeter, who argued that capitalism was going to evolve naturally into socialism.[48] But the debate never much moved past the original exchanges: neoclassic socialists continued to treat the Austrian responses as further attempts to contest the practical feasibility of their trial-and-error solution. In the aftermath of the debate, the mainstream of economics registered one practical argument as decisive. In line with Walras's original formulation, the Barone formalization assumed a static market with just one time point. This obviously did not correspond to the situation a real socialist planning board would have to contend with.[49] Responding to the search for equilibrium via Lange's trial-and-error model, Hayek wrote: "With given and constant data, such a state of equilibrium could indeed be approached by the method of trial and error. But this is far from being the situation in the real world, where constant change is the rule."[50]

In a real economy, production processes would evolve dynamically, with each stage shaping the next. Accordingly, it did not suffice to solve the static equations over and over again. Absent a dynamic analysis that could reconstruct the transformations of one stage into the next, economists had no means to address the question of how the socialists would practically determine the right setup of prices—the trial and error method might just lead to larger and larger disequilibria if it did not occur close to the equilibrium. Other potential flaws of socialism, such as the inefficiencies of bureaucracies and the problem of incentives to produce efficiently, also lay outside the purview of economic models. The mainstream of economics thus concluded that the neoclassic socialists rebutted Mises's impossibility argument, rendering the success of socialism a practical

[48] Who made the more compelling arguments and what these arguments were in the first place has been contested ever since Lavoie, "A Critique of the Standard Account of the Socialist Calculation Debate."; Rothbard, "The End of Socialism and the Calculation Debate Revisited."; Cottrell and Cockshott, "Calculation, Complexity and Planning: The Socialist Calculation Debate Once Again."
[49] Lavoie, "A Critique of the Standard Account of the Socialist Calculation Debate," 44.
[50] Friedrich A. Hayek, "Socialist Calculation: The Competitive `Solution'," *Economica* 7, no. 26 (1940): 131.

question. The question as to whether it was indeed feasible had to wait until a dynamic analysis could be provided. The aspiration of economists to act as socialist planners were held in check mainly by practical problems, and the difference between a socialist planning board and a market was one of degree, not in kind.[51]

To subsequent generations of economists, Hayek had formulated a *practical* challenge that might be answered if the appropriate tools became available: explain how the dynamic information processor of the market actually works to then replace it with a central planning board that can use the model to emulate the market.[52] Once economists gained the tools of control theory, linear and dynamic programming, and game theory, they came into possession of mathematical tools that made it possible to model the dynamic evolution of markets from one situation to another and potentially address the Hayekian challenges. Of course, after the 1940s, such socialist ambitions could not be voiced any longer, and so the aspirations for centralized planning disappeared behind more ambiguous concepts like "programming" and "optimization." Even though these tools are used to plan the use of resources from a central location to optimize outputs within a system of uses, the concepts sounded more attractive to the military, which combined a deep commitment to command-and-control hierarchies and centralized planning with enthusiasm for decentralized markets and "freedom"—a contradiction that no one was particularly concerned about.[53]

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[51] Lavoie, "A Critique of the Standard Account of the Socialist Calculation Debate."; Rothbard, "The End of Socialism and the Calculation Debate Revisited," 54-55.
[52] To the extent that contemporary economics ever refer to the debate, they largely continue to advance the standard reading. For example, consider the overview of modern economics intended for a generalist audience and written by a Chicago economist: Filip Palda, *The Apprentice Economist* (Lexington, KY: Cooper-Wolfling, 2013), 234-37. The original reading was developed by Lange himself Oskar Lange, "On the Economic Theory of Socialism: Part One," *The Review of Economic Studies* 4, no. 1 (1936); "On the Economic Theory of Socialism: Part Two," *The Review of Economic Studies* 4, no. 2 (1937). See fn. 20 above for more information on the readings of the debate.
[53] I owe this observation to Mirowski's discussion of the connection between economics and the military between the 1930s and 1950s. Mirowski, *Machine Dreams: Economics Becomes a Cyborg Science*, 255-6.

Though the Socialist Calculation debate was a relatively short intermezzo, its most important themes carried forward, in particular the idea of the market as a supreme information processor and that it might be possible to emulate its workings. When sociologists, anthropologists, and political theorists speak of economics today, they usually refer to economics' fondness for mathematical formalisms in order to evoke the odious specter of neoliberalism and its ideas of the atomized, rational man. But it must not be forgotten that it was the *socialists* who first extolled the virtues of perfectly competitive markets as represented by large mathematical models. And they did so because the perfectly competitive market could be *modeled*. Even central pieces of neoclassic economics thus have a sheen of socialism. For example, Kenneth Arrow, who together with Debreu provided the mathematical proof for the welfare effects of the general equilibrium, considers himself to be a "cautious socialist" and has worked on issues of state planning.[54] Behind much seemingly sterile economic formalism, thus stands the hope that by cracking the code of the invisible hand, you might be able to replace it's caprice with an enlightened planner.

But, alas, at the end of the calculation debate, the math was not good enough yet to replace anything. However, the tools of dynamic analysis, of computational economics, and information economics were within reach. Once they became available, everything changed—or more specifically, market design burst onto the scene. As a recent observer put it, "The stalemate between Hayekians and market socialists over the best way to coordinate the actions of a large number of people lasted until the union of game theory and information economics in the 1970s."[55] Two of the most prominent market designers, William Vickrey and Vernon Smith, had explicit connections to members of the Cowles Commission. But more importantly, the market designers start

[54] C.f. for example Kenneth J. Arrow, "A Cautious Case for Socialism," *Dissent* 25, no. 4 (1978). Another example is Leonid Hurwicz, who was part of the Cowles Commission.
[55] Palda, *The Apprentice Economist*, 178.

from the same assumption as the socialists: the idea that markets are algorithms that solve optimization problems by processing *information* and that these markets can be represented in mathematical models. The question was simply: How exactly do these markets work?

It is possible to distinguish two different schools of market design that articulate slightly different responses to Hayek.[56] Both developed roughly in the 1970s, but their institutional roots go back to the 1950s.[57] The first type of market design was the largely theoretical, highly abstract tradition of “mechanism design,” which is based on game theory. Economists will usually identify this school as market design proper. But in terms of practical applications, mechanism design is not the most successful form of market design.[58] A second, “experimentalist” school has been far more successful. But since members of the experimentalist school often rely on game theory and mechanism design, the difference between the schools is largely conceptual. It refers to a difference in the basic responses to the Hayekian challenge and the analytical approach they take to the problem of designing a market.

The creation of “mechanism design” goes back to the work of William Vickrey at Columbia University. In a series of papers from the 1960s, Vickrey responded to work by Abba Lerner, one of the market socialists from the Cowles Commission. These papers dealt with a problem that had already concerned the socialist calculation debate: how the social planning board would ever be able to aggregate the information necessary to solve the calculation problem. Vickrey

[56] Mirowski develops a taxonomy of three schools based on three different ways to conceive of information and markets in economics. Philip Mirowski and Edward Nik-Khah, *The Knowledge We Have Lost in Information: The History of Information in Modern Economics* (Oxford, UK: Oxford University Press, 2017), 126. I take over this taxonomy, but only discuss two schools here. The third “Walrasian” tradition as developed at the Cowles Commission is only of historical interest.
[57] Guala, "How to Do Things with Experimental Economics," 4.
[58] During a conversation with a market designer, I learned that contemporary mechanism design is internally divided into theoretical and an applied side. The former is cerebral and academic, its protagonists hardly visible outside the confines of academia, and the latter is more politically visible, but focused on simpler mechanisms.

considered a different version of this problem. During the socialist calculation debate, the main concern had been how all local knowledge could be collected and aggregated. With the advent of computers, a solution to this problem seemed to be within reach. But Vickrey saw an even more basic problem along the same lines: people might not want to provide the information the planning board needed.[59] If the government wanted to gather information from companies at a central location, they would have to contend with the possibility that these companies might *lie*. Strategic reasons can make it rational for companies to withhold or distort crucial information.[60] To Vickrey, it was clear that the market could somehow get actors to reveal their true beliefs. This was crucial for the creation of prices that reflected true scarcity. Vickrey was now interested in how this process could be modeled, i.e., how this property of truth-revelation could be recovered analytically. Here, he made a crucial move. Already in the 1960s, he considered whether there were *auction* designs that could incentivize companies to reveal their information to the government agency.[61] In other words, he introduced the idea that the institutional context of decision-making might shift the incentives rational agents might face and that you might be able to evaluate the "incentive compatibility" of different institutional structures in this way. Several economists, most prominently Robert Wilson and Michael Rothkopf, generalized these ideas from specific allocation problems to a more general set of auction types. They also created a tight link between game theory and information economics by introducing the notion of uncertainty into game theory; that is, they

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[59] Lerner had proposed ways for a government to use "counterspeculation" to create the correct incentives. William Vickrey, "Counterspeculation, Auctions, and Competitive Sealed Tenders," *The Journal of Finance* 16, no. 1 (1961): 8.
[60] The problem of mendacity is one of the core problems of information economics. Consider, for example, its implication for the efficiency of the "markets for lemons." George A. Akerlof, "The Market for "Lemons": Quality Uncertainty and the Market Mechanism," in *Essential Readings in Economics*, ed. Saul Estrin and Alan Marin (London: Macmillan Education UK, 1995 [1970]), 488.
[61] William Vickrey, "Auction and Bidding Games," in *Recent Advances in Game Theory*, ed. M. Maschler (Princeton, NJ: Princeton University Press, 1962).

designed games for agents who had to figure out how to value commodities relative to their beliefs about other players' beliefs. [62]

Initially, these attempts to determine optimal decision-making under uncertainty had nothing to do with market design. The economists wanted to develop consulting advice for oil companies who tried to improve their bidding strategies in auctions for oil tracts. The idea was to help players act "more" rationally to improve the ability of the market to aggregate information (and for the companies to make profits). However, the attention to the impact of different institutional frameworks on the role of uncertainty in strategic interactions soon led to an important insight: different market environments work differently, and the institutional framework influences how close they get to the theoretical ideal. This soon gave rise to a new line of analysis that came to be known as mechanism design.

This discipline asks: How can a set of rules be designed that structures the strategic interaction in such a way as to incentivize agents to reveal the private information (and create an efficient outcome)?[63] The theory of mechanism design poses this question as a meta-game between a player who wants to act on the basis of the private information (principal) and the other players who hold it. The principal proposes a rule structure (as well as a strategy), and the other players can choose to accept or reject it. The question is: Which rules would players agree to, assuming that they would go for a solution that would enable a strategy that would be optimal for them? To answer this question, the economist makes assumptions about utility, existing information, and the distribution of these two elements over a set of different players' "types." The concept of a player

[62] They also created a closer connection between (Bayesian) game theory and information economics, crucial for the development of market design. The introduction in one of Rothkopf's articles describes this connection concisely: Michael H. Rothkopf, "A Model of Rational Competitive Bidding," *Management Science* 15, no. 7 (1969).
[63] Tilman Börgers, *An Introduction to the Theory of Mechanism Design* (New York: Oxford University Press, 2015), 2.

“type” is the crucial bridge between information economics and game theory. It allows the game theorist to take into consideration how actors’ beliefs about other actors’ beliefs influence their decision-making. But it avoids the infinite regress of possible beliefs about beliefs about beliefs by pre-specifying a finite list of types, i.e., bundles of beliefs. Players uncertainty always refers to the type of the other players, which turns a multidimensional spectrum of possible beliefs-about-beliefs into a one-dimensional concept.

Nonetheless, the question of which sets of rules players in this meta-game would agree to is immensely complicated because many games might have more than one equilibrium (some of which might not involve truth telling as a winning strategy), and the set of possible games seems almost infinite. Much theoretical work has therefore focused on narrowing the set of possible games on a level of generality. Most famous is Vickrey’s “revelation principle,” which states that a mechanism designer can always restrict themselves to “direct” games (games in which all players reveal their type independently and simultaneously) that are incentive compatible (you have an incentive to report your “type” truthfully) and individually rational (expected utility is at least 0).[64]

Barring further details, mechanism design has two features that provide a powerful response to the Hayekian challenge. First, the game theoretical framework solved one of the most basic problems of the Socialist Calculation debate: the resulting market models were not static, but based on strategic decisions that could take beliefs about the world, uncertainty, and previous decisions into consideration. This promised a more realistic account of market *processes* as systems of iterative, strategic bargaining under uncertainty.[65]

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[64] Ibid., 33-36.
[65] Incidentally, control theory can be used to solve problems in mechanism design. This will become important later on. Thomas A. Weber, *Optimal Control Theory with Applications in Economics* (Cambridge, MA: MIT Press, 2011), 207/8.

Second, mechanism design enabled a curious inversion of the Hayekian challenge that proved extremely important for the success of market design. The Austrian argument was that real markets do things that socialist planning boards cannot do. They aggregate information faster and more reliably than any known mathematical model ever could. One piece of this argument was that the socialist collection of information would suffer from incentive problems: people would not want to reveal the true situation of supply and demand to the central planners because it would not necessarily be in their interest. Game theory revealed, however, that markets suffer from very similar incentive problems. In some situations, they create incentives for "adverse selection," i.e., the strategic misrepresentation of information. Real markets, in other words, produce all kinds of problems that inhibit the wonderful information processor Mises and Hayek had envisioned. Now, the mechanism designers had found that particular institutional configurations could resolve these problems. The mathematical models revealed which rule structures would lead market participants to behave in ways that would fulfill the promise of the markets that Hayek and Mises had envisioned. They could invert the Hayekian challenge: it is not only that socialist planning based on economic models can replicate the price mechanism of real markets, but the models do, in fact, work *better* because real markets often do not behave as reliable information processors. It is important to see that this involves a kind of ontological bait and switch: under Mises and Hayek, the market worked *like* an information processor, but since computers did not exist yet, the imagination retained the sense that such an information processor was somehow a theological entity—fundamentally different from a mathematical model and ungraspable. With the invention of computers, this idea reversed: the computer is the image of the true market; as such it is knowable, and to the extent that the models do not represent reality, it is reality that is at fault.

The ontological transformation of the market changes the optics of market design significantly: if mechanism design is *not* a matter of replacing markets with models, but a matter of making markets more *like* the models (as they are already at their "true" core), then we are not dealing with a socialist attempt to impose a unifying logic on social life. Instead, mechanism design is simply an attempt to *fix* a natural phenomenon that has been inhibited by a variety of "distortions" by the social process.[66] The conceptual move thus allows us to obscure the socialist tendencies that animate market design. But it also goes one step further. Now, economic engineering is not only a possibility, but a distinct need. Since markets do not work by themselves, the engineer must help them to realize their true nature. Market designers could now bolster their claim to political power by pointing to the constantly expanding empirical work that showed how real markets defied the classic equilibrium models.

The insights into the purifying characteristics of institutional design now enabled the economists to enter political processes as engineers for the first time. They offered their help to governments and suggested that they could replace regulation and bureaucracies with auction markets. After a series of more limited interventions, several mechanism designers came together at the Federal Communications Commission (FCC) to design auctions for spectrum licenses. Though the results of this design enterprise were ambiguous and the role of game theoretical market designers contested, the auctions were celebrated as the definitive success of mechanism design.[67] Yet, closer

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[66] That is in fact how market designers usually present their enterprise—as an attempt to help markets work as best as they can, e.g. Kominers, Teytelboym, and Crawford, "An Invitation to Market Design," 541.

[67] Their success was ambiguous because not all congressional goals were realized, most notably the requirement to distribute the licenses among a variety of companies. Labaton and Romero, "Wireless Giants Won F.C.C. Auction Unfairly, Critics Say." The role of market designers has been contested in the literature, with some scholars claiming the auctions represented an implementation of the theoretical blueprints. Guala, "Building Economic Machines: The F.C.C. Auctions." and others claiming they were largely a political construct Mirowski and Nik-Khah, "Markets Made Flesh: Performativity, and a Problem in Science Studies, Augmented with Consideration of the F.C.C. Auctions."

inspection reveals that the record of success is not as rosy as economic engineers like to paint it. It turned out that the game theoretical approach had practical shortcomings that powerfully limited its practical role in the construction of markets, including for the FCC. Today, “mechanism designers” typically do not get involved in real processes of market design, but publish abstract, mathematical papers that hardly ever become relevant outside the discipline.

The biggest problem is the theoretical abstraction of the mechanisms, which creates a problematic distance to empirical markets.[68] Since mechanism designers search for highly general features of efficient markets, their work mainly deals with a small set of stylized auction formats. A handful of formal criteria differentiates these different auction types. For example, we can ask whether they are open or closed, or whether they allow sequential or simultaneous bids. But while these differences matter very much for the mathematical features of the models, they do not map very well onto the real world. The translation from theoretical model into a system of rules that can actually regulate market action is therefore difficult and uncertain, which introduces room for error. To give an example, Auction design traditionally distinguishes between “private” and “common” information. But this does not correspond to a world in which processes of understanding are highly differentiated and information circulates through complex networks. Information can thus be shared between different people, it can be understood differently, and its relevance can change over time. Even if the designers have significant power over the institutional structure of the market setting, enforcing a clear bifurcation in common and private information would be almost impossible.

[68] Guala, "Building Economic Machines: The F.C.C. Auctions."; Mirowski and Nik-Khah, "Markets Made Flesh: Performativity, and a Problem in Science Studies, Augmented with Consideration of the F.C.C. Auctions."

Another problem is that the strict mathematical framework of game theoretical models forces designers to consider only one potential complication at a time.[69] One model would determine the best rule structure for a situation in which goods have complementarities, another the best structure for a situation in which there are knowledge asymmetries, and still another the best structure for situations of uncertainty. But the designers are unable to model what the best structure would be if all problems existed simultaneously. Relaxing the assumptions of game theoretical frameworks too much multiplied the potential solutions the designer would have to consider. Accordingly, the market designers advocate for a trial-and-error design process that gradually adjusts the mechanism and tries alternative proposals successively.[70] But the complications associated with minor modifications lead to a variety of different market design proposals and general disagreement about the best way to reconcile them. Accordingly, market designers end up with too many different alternative specifications to try them all out, and no model captures the resulting market process as a whole. In other words, the extreme abstraction and mathematical rigor of mechanism design creates a gap between the formal models and real-market environments that cannot be easily bridged within the confines of the methodology. These problems almost became devastating during the first real-world attempts to construct markets for the FCC.[71]

In practice, mechanism design frequently joins hands with a second approach that is broader and more applicable to real-market environments.[72] Though it builds on mechanism

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[69] Anna Alexandrova, "Connecting Economic Models to the Real World: Game Theory and the Fcc Spectrum Auctions," *Philosophy of the Social Sciences* 36, no. 2 (2006).
[70] John McMillan, "Market Design: The Policy Uses of Theory," *The American Economic Review* 93, no. 2 (2003): 8-10. Since most work in economic sociology has looked at mechanism design, this might explain the strange insistence by Callon and others that market design has to be understood entirely as a form of in-vivo experimentation. Callon, "Civilizing Markets: Carbon Trading between in Vitro and in Vivo Experiments.".
[71] Mirowski and Nik-Khah, "Markets Made Flesh: Performativity, and a Problem in Science Studies, Augmented with Consideration of the F.C.C. Auctions."
[72] Kominers, Teytelboym, and Crawford, "An Invitation to Market Design," 543. Economists rarely distinguish experimentalist market design from game theoretical approaches because experimentalists so frequently draw on

design, it ultimately offers a different response to the perceived challenges of the Hayekian argument against the socialists. This type of market design developed in the experimentalist tradition of economics starting sometime in the 1970s.[73] Experimentalist economists such as Vernon Smith, Charles Plott, and Stephen Rassenti from the University of Arizona and Caltech developed the first "designer markets." What initially started as an attempt to test economic theory in laboratory experiments (behavioral economics) quickly developed a constructive side that became the experimentalist school of market design.[74] In the 1970s, Caltech and the economics department at the University of Arizona were the leading institutions for experimental economics. Later, the approach was further developed at other institutions.[75] Characteristically, economists in the experimentalist tradition have a close connection to system operations research and engineering rather than experimental social sciences such as psychology.[76] They are able to combine different mathematical modeling traditions because the driver for the evaluation of analytic statements is the experiment. This methodology allows economists to "build" microeconomic systems and then manipulate their conditions until stable mechanisms emerge that can be ported into other settings.[77]

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mechanism design. I am taking the distinction between the two different schools from Mirowksi and Nik-Khah. C.f. *The Knowledge We Have Lost in Information: The History of Information in Modern Economics*.

[73] The lineage of this tradition can be reconstructed from a "witness seminar" in which eleven leading figures of experimental economists came together and reflected on the emergence of their field. The book-length transcripts of this seminar were published as Andrej Svorenčík and Harro Maas, eds., *The Making of Experimental Economics* (New York: Springer, 2016). The eleven experts hailed not just from the American but also the German and Dutch schools of experimenta economics. They were Frans van Winden, John Ledyard, Jim Friedman, Charlie Holt, Vernon Smith, John Kagel, Betsy Hoffman, Reinhard Selten, Charlie Plott, Al Roth, and Stephen Rassenti. Here, too, we detect connections to the Cowles Commission and the socialist calculation debate, reverberating through time. Smith, for example, explicitly considers the "Hayek hypothesis" in early papers, though he reverses its meaning in the way outlined above. Vernon L. Smith, *Papers in Experimental Economics* (Cambridge, MA: Cambridge University Press, 1991).

[74] Guala, "How to Do Things with Experimental Economics."

[75] Alvin Roth from the University of Stanford is the most famous contemporary market designer in this tradition and frequently provides commentary on the nature of market design as a unified approach.

[76] Roth, for example, got his PhD in operations research and not economics. Stephen Rassetti completed his PhD in the engineering department.

[77] Francesco Guala and Luigi Mittone, "Experiments in Economics: External Validity and the Robustness of Phenomena," *Journal of Economic Methodology* 12, no. 4 (2005).

The distinctive shift in the nature of market design is already visible in the early collaborative work of Charles Plott, David Grether, and his graduate student, Mark Isaac, a group of economists at Caltech.[78]

During the 1970s, the group was interested in public choice problems. These problems concern the issue of how procedural features of bureaucratic decision making (e.g., the structure of committees, voting rules, preset agendas, practices of negotiation, etc.) influence decision outcomes. In a series of papers that dealt with airline deregulation, they studied such problems for the allocation of airport landing slots.[79] Prior to deregulation, scheduling committees assigned these slots to airlines. The committees were staffed by representatives of the airports' airlines who gained votes based on the size of the airline. Since the committees' decisions tended to lead to capacity and access problems for airlines, the Civil Aeronautics Board asked the economists to evaluate the efficiency of the committee method.

Grether et al. analyzed the committee's process and came to the conclusion that the method should be abandoned entirely. But they did not stop there. Instead, they argued that the committee might be replaced with a new kind of auction for landing slots. The group had arrived at this conclusion through several steps. Initially, they merely tried to evaluate the existing method. They started by modeling the work in the committees as a "cooperative unanimity voting game without side payments."[80] In other words, they applied game theory to reproduce the decision-making process in the scheduling committee. They effectively took advantage of the fact that game theory

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[78] Svorenčík and Maas, *The Making of Experimental Economics*, 50-51.
[79] The original report to the Civil Aeronautics Board was not published officially, but circulated informally among economists. D. M. Grether, R. M. Isaac, and C. R. Plott, *Alternative Methods of Allocating Airport Slots: Performance and Evaluation* (Civil Aeronautics Board and Federal Aviation Administration, Polinomics Research Laboratories, Inc.: Pasadena, 1979). A much abbreviated version was published a few years later: David M. Grether, Mark R. Isaac, and Charles R. Plott, "The Allocation of Landing Rights by Unanimity among Competitors," *The American Economic Review* 71, no. 2 (1981).
[80] Ibid., 167.

offers a way to rigorously model social processes with multiple time points. When they tried to estimate the models, they found that there was no available data on past voting behavior. Accordingly, they created empirical data with laboratory experiments that implemented this basic game. They tinkered with the rules until they could reproduce outcomes of past decisions at similar committees. Once they were reasonably sure that they had created a valid baseline, they began to manipulate individual elements of the rules for the game until they saw where the resulting allocations would become more efficient. In the end, they summarized the manipulations into a novel institutional structure that optimized efficiency along a variety of dimensions.[81]

In their proposal, the assignment of slots to airlines would not simply follow the rule of the highest bidder. Instead, they invented a complex calculation that translated a structure of bids into a structure of allocations. This auction would be repeated over time. What makes this paper so interesting is the fact that they designed a novel auction format inductively and custom-tailored it for a specific problem. The method also allowed them to show exactly how differences in the construction of institutional rules could affect the effectiveness of the market along a variety of dimensions. This presented a departure from the game-theoretical approach to market design, which only considered a limited set of esoteric auction structures and only one type of efficiency. The experimentalist approach allowed economists to design for a variety of different goals customers could choose from. And since the interfaces for the experiments had to be custom-built for different allocation problems, the market designers no longer assumed “a” or “a few” different kinds of markets. Rather, they began to see markets as mechanisms that solve *specific* problems, each potentially different from all others. The need to set up experiments required the economists

[81] For example, committee level vs. system level; responsiveness to changing circumstances; long-run dynamics; susceptibility to collusion.

to figure out how they could design the situation in the laboratory to conform to the assumptions of economic theory. This went a long way to close the gap between theory and practice and solved the biggest problem of the game theoretical account: To set up an experiment, the economists always had to create the mechanism in full. Accordingly, the custom-tailored experiments had to consider the desired market process as a whole rather than just individual aspects of it. These features meant that any exercise of market design was now closely related to practical problems of implementation.[82] It could solve the practical problems for a variety of desired outcomes. The methods' flexibility and versatility made it much more useful to political processes that typically searched for solutions for very specific allocation problems. The experimental framework allowed designers to develop custom-tailored mechanisms whose robustness could be tested, specified in terms of institutional rules, and potentially be ported to other settings on a case-by-case basis.[83]

The groups early work drew on the experimentalist framework that Vernon Smith had developed in the pursuit of a good way to test theory. When Smith moved to Caltech, their approaches merged, and they moved from questions about the efficiency of bureaucratic processes to the design of market mechanisms. Together, they conducted laboratory experiments to test propositions about institutional structures and then used the rule structures of the experiments to propose new market mechanisms.[84]

[82] Of course, STS has long and correctly held that the transportation of an experiment from the laboratory into reality is extremely tricky and does not allow for easy generalization. To work in reality, the designers need to contend with less control, different scale effects, interferences, etc. I am not suggesting that the laboratory experiments are the markets that operate in reality. I am merely tracing a fundamental difference in the specification of the designer markets, which then changes how they are conceived.
[83] Francesco Guala, *The Methodology of Experimental Economics* (New York: Cambridge University Press, 2005).
[84] Summarizing these early connections for the public choice problems, Plott said during the Witness Seminar: "The next encounter [with experiments] was again shadowed with Vernon. This is around 1969, 1970, and I was interested in the mathematics of axiomatic social choice theory and voting. These are public goods environments. And I realized that one could take Vernon's idea about induced preferences and induce them in a much broader economic environment. In that sense I began to test things that were evolving out of voting theory and out of cooperative game theory without side payments, which is much different from the bargaining problem. […] Then Vernon came to

The next crucial development in this collaboration was the introduction of computers to the experimental setting. Still responding to problems with the auction design of airport landing slots, Stephen Rassetti and Vernon Smith created custom-tailored software interfaces to structure how players in the simulated slot auctions could interact with each other.[85] This led to a shift in the understanding of the designer markets. While the previous experiments had treated the market as synonymous with the exchanges between individuals under a given set of rules, the introduction of software now turned the *market mechanism* into a *computational* algorithm.

Initially, the strategic interactions between individuals could be understood as analogous to a computer. Now the market actually moved into the computer. The software as market can perform various dynamic tasks in the processing of the information that it collects from participants of the game. In the airport problem, the software treated the inputs of all bidders as a combinatorial set-packing problem and used an algorithm to find the best combination of slot allocations.[86] With this move, the market becomes an entity in its own right, an information processor that exists over and beyond the activities of individuals. Characteristically, after the introduction of computers, market designers began to talk of their laboratory constructs as “smart markets.”[87]

An interesting consequence is that part of the market does not work like a market at all. While the trading process itself is a simple algorithm and can be described using tools of calculus (e.g., Lagrange multipliers), the software can draw from a variety of algorithms to search for globally optimal solutions. Examples are ‘neural networks’, ‘genetic search’, or ‘simulated

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Caltech where he began to get more focused on markets and market institutions.” Svorenčík and Maas, *The Making of Experimental Economics*, 30.

[85] Stephen J. Rassenti, Vernon L. Smith, and Robert L. Bulfin, "A Combinatorial Auction Mechanism for Airport Time Slot Allocation," *The Bell Journal of Economics* (1982).

[86] Ibid., 403-4.

[87] Mirowski and Nik-Khah, *The Knowledge We Have Lost in Information: The History of Information in Modern Economics*, 185.

annealing'.[88] These algorithms proceed on the basis of principles that have no direct relation to the way economic interactions are thought to generate efficient allocations. Accordingly, the computer-human hybrid markets operate unlike anything that existed before.

This final development leads to a new response to the Hayekian challenge. Let me recapitulate. The Austrians had argued that a board of socialist planners would not be able to emulate the work of the market. Each production process uses a variety of resources at different and constantly shifting quantities (because output levels are changing). Only the market can optimize the selection of production processes because it generates prices that make a simple calculation available to entrepreneurs. This simple calculation aligns their activity with everyone else's. But the market could also not simply be emulated by a mathematical model because these models had a variety of shortcomings.

The mechanism designers had responded that the Austrians had it the wrong way around: dynamic system analysis revealed exactly how the market produced the feats the Austrians so loved. But the markets often did not actually allow the alignment of plans because people might have reasons to strategically misrepresent information. The price would then be "polluted" by a variety of factors that prevented the allocation function of the market. Accordingly, institutional structures need to be put into place that push the market process back on the right path. Experimentalists now went a step further.[89] They began by noting that most allocation problems are

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[88] In fact, these techniques have rarely been used in electricity systems because their operation is less comprehensible to an external observer. ISOs have relied on more traditional linear and quadratic linear programming techniques. They generate only approximate solutions, but errors can be easily detected and resolved in secondary analyses. Zhifang Yang et al., "Fundamental Review of the O.P.F. Problem: Challenges, Solutions, and State-of-the-Art Algorithms," *Journal of Energy Engineering* 144, no. 1 (2017).

[89] Though Vernon Smith has more recently developed the argument that there are two types of rationality – constructive and emergent. While designer markets are the outcome of constructive rationality, emergent markets are markets that evolve in response to practical challenges without conscious interference. This reconciles "real" with "designed" markets. Vernon L. Smith, *Rationality in Economics: Constructivist and Ecological Forms* (Cambridge, MA: Cambridge University Press, 2007), 24-42.

actually set-packing problems familiar from combinatorics (e.g., find the most valuable combination of items for the backpack that do not violate the volume restrictions). However, these problems could differ drastically between domains and, depending on the number of variables and constraints, require very complex algorithms to be solved. To arrive at one of many different equilibria, agents had to adjust their selections constantly and on the basis of complex calculations. Having deciphered the logic of the market qua optimization algorithm, it was unlikely that these calculations would occur automatically. The mysterious process that Mises and Hayek described therefore only worked if a rigid institutional environment *minimized* agents' role in the market. Pure institutional design is not sufficient, as game theorists had held. Instead, the cognitive limitations of real human beings must be considered by offloading some of the computational complexity of the market onto software. The software processes simplified user inputs and thus reduce the requirements for the agents—sometimes to the level of "zero-intelligence"—until the sets of incentives are simple enough that the equilibrium can be guaranteed by the system of strategic interactions that characterizes the human part of the market.[90] This, in turn, requires that the human-computer systems must be carefully designed, monitored, and adjusted during their operation. The response to the Hayekian challenge was thus: it is true that a socialist planning board would not simply be able to replace the market with a mathematical model. But a socialist planning board could create the computational and institutional infrastructure in which the market would play out in such a way that the goals of the centralized planners could be perfectly realized.[91] Without a

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[90] E.g., Dhananjay K. Gode and Shyam Sunder, "Allocative Efficiency of Markets with Zero-Intelligence Traders: Market as a Partial Substitute for Individual Rationality," *Journal of Political Economy* 101, no. 1 (1993).

[91] In some ways, this vision was presaged by the Arrow-Debreu model of general equilibrium that contains a "dummy" agent that sets the prices for all goods in the Walrasian decision situation. To fit the mathematical structure inherited from game theory to the problem, it was necessary to assume agents that only choose what they purchase/produce. They could not set the prices dynamically. Accordingly, the mathematical structure of one of the most central pieces of economic writing in the neoclassic tradition contains a centralized planner who sets the prices in response to market movements. In economics textbooks, this is referred to as an "institutional assumption."

board of benign planners, however, most markets will not behave the way Hayek and Mises envisioned.

In sum, then, we have arrived at the following picture of market design. It aims to create synthetic market processes that follow the logic of an algorithm that solves a particular optimization problem. To this end, the socialist planning board does not have to collect all information in a central location. Instead, the board can simply model economic behavior as a dynamic game where actors use information about others to plan their moves. Calculating the outcomes of games under different institutional configurations, they can then reverse engineer the circumstances under which the resulting endpoint has a desirable equilibrium. In the next step, the market designers devise ways to enforce the conditions of the game, such that the benefits of the invisible hand will ensue. The experimentalists provide the key tool for enforcing the games' structure: they reconceptualized markets as computer-person hybrids, where the computer takes over much of the calculation required by agents. Since the agents can only act in very limited ways and the requirements for rational behavior are low, the likelihood of error declines. The computer revolution of the 1990s had finally created the tools to hand economists the keys to the offices of the socialist planning board. The professions influence on regulatory and governmental processes ensured that they would use them. The next step is how we should think about the conditions for the success or failure of these synthetic market environments.

Andreu Mas-Colell, Michael Dennis Whinston, and Jerry R Green, *Microeconomic Theory*, vol. 1 (New York: Oxford University Press 1995), 511.

4.4. Addressing the Problems of Centralized Planning

In the last section, I reconstructed the core tenets of modern market design. We have seen that it is a form of social engineering. The designers seek to create market processes that work according to a theoretical blueprint. These blueprints specify how strategic interactions between individuals aggregate into an equilibrium distribution with desirable properties. This process is conceptualized as an algorithm that searches for a solution to an optimization problem. In the experimentalist tradition, the market qua information processor becomes an entity in its own right, partly removed from the activities of individual participants. It is "software" that aggregates, processes, and distributes information from agents who engage in particular strategic interactions. Described in this way, market design appears as a form of *centralized planning*. Centralized planning is the attempt to organize an economic process from a "synoptic" position to conform to an idealized model of the social process. This is precisely what market design is attempting to do: by designing institutional rules and software architectures that structure the economic interactions, the designer creates, monitors, and controls a social process in accordance with a mathematical model. This provides a very general criterion for the success of market design: market design succeeds if the designers are able to guarantee a continual match between the way the market process operates and the way the model conceptualizes it. Specifically, they must be able to get agents to behave in ways that match the calculative logic of the algorithm, i.e., the agents must act on the basis of calculations that are consistent with the algorithm of the blueprint. Analytically, we can distinguish two different aspects of this task. First, the market designers must be able to create an initial match between the market process and the blueprint. The designers have to build infrastructures, software, institutional rules, etc. that configure the market process. Since the logic of search algorithms in both linear and dynamic programming techniques is deterministic, the market process has to take place in a closed social system, i.e., the interactions have to follow the logic of the blueprint exclusively. Analytically, such a system can be conceptualized in terms of a hierarchy of levels.[92] Each level is characterized by properties that do not exist at the lower level.[93] For example, the activities of two people who are trying to strike a contract are constrained by the legal rules that establish what these contracts can look like. The institutional structure constrains the process that unfolds on the lower level. This constraint is enforced by an entity that establishes the formal procedure through which the contract is negotiated, e.g., the software platform where the exchange takes place. The relation between levels can be characterized as a control structure. A higher level imposes constraints on a lower level. It must be able to observe what is going on at the lower level and must then be able to intervene in the system to enforce the constraints.[94] In other words, the first step in market design can be understood as an attempt to set up a hierarchical system in which a higher level (institutional rules, software) exercises control over a lower level (activities between individuals).

After the market starts, the designers then need to monitor the process and make sure that it continues to conform to the blueprint. To perform this task, the designers need to create tools for control and surveillance. This second step means that market design essentially envisions feedback-control systems.[95] Figure 4-1 depicts the generic structure of such a system. The market

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[92] These levels are largely *analytical* constructs—that is, the levels can be specified at various different degrees of resolution and in relation to different inputs and outputs. I take the following framework from Leveson, whose safety engineering framework captures exactly the logic of market design. Interestingly, the system-theoretical framework Leveson proposes has both disciplinary and methodological affinity with the market design project. Nancy Leveson, *Engineering a Safer World: Systems Thinking Applied to Safety* (Cambridge, MA: MIT press, 2011).

[93] In that sense, the levels have emergent properties. Such "emergent" properties of a set of components are related to constraints upon the degree of freedom of those components from a higher level. "Emergence" is a term of observation. It refers to the fact that some concepts can usefully only be applied at one level but not the other. The shape of an apple can be explained in terms of cells, but it cannot be applied at the level of cells. Ibid., 63.

[94] Ibid., 66.

[95] I will later show that the kind of dynamic system analysis that control theory enables was indeed central for the development of electricity market design.

process receives inputs (e.g., resources, demand) and has to generate certain outputs (desired allocation outcome). To make sure that the system operates according to the plan, the higher levels in the system need to control the lower levels so they operate within parameters.

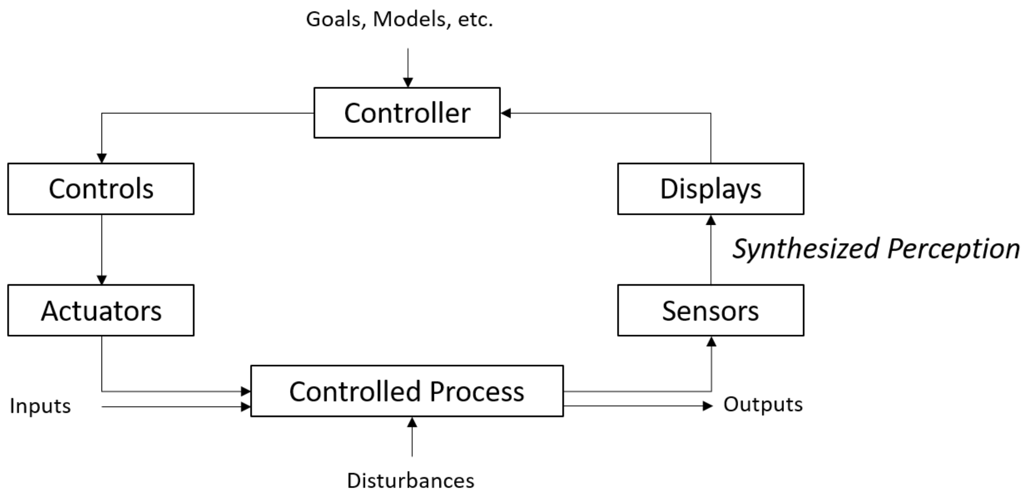

Figure 4-1 – Synthetic Feedback-Control Loop

An effective control structure has several different components. First, the controller must have a specific goal (e.g., the market must always reach equilibrium). Second, they must be able to intervene in the process they seek to control. Engineers refer to such means of intervention as "actuators." Third, the operators must have a model of the system, i.e., an abstract, theoretical understanding of the process that tells them what data to collect and how to understand it (the blueprint). And fourth, they must be able to observe the system, i.e., be able to collect the data that is necessary to determine whether the goals are met. In more complex systems, computers are typically interlaced with this process. Sensors collect data that is then processed by software and displayed in a summary fashion to the controller, creating a synthesized perception. Similarly, the actuators are controlled via software interfaces.[96] If all four conditions are met, the controllers can

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[96] Each of the steps in this control loop takes time. Accordingly, there is always some lag between the emergence of a problem, the activity of the sensors, recognition by the controller, and the correcting response. These lag times can become extremely relevant in tightly coupled systems.

identify disturbances that prevent the process from turning inputs into the desired outputs. In sum, then, market designers seek to create the market process by designing socio-technical systems that enforce the ongoing match between blueprint and market process through a hierarchy of levels and continual feedback-control loops. This constitutes a form of centralized planning because the hierarchy of levels sets up a centralized controller who ensures the match between model and market process. Now, to evaluate any particular instance of market design, it is important to establish what determines the specific requirements for that control structure. We can then ask under what conditions market designers can meet these requirements. To gain some traction on the issue and gain some theoretical leverage, I will now compare market design with other forms of centralized planning.

History is rich with utopic experiments of centralized planning. The Soviet collectivization in the 1930s, the villagization in Tanzania in the 1970s, and the failures of scientific agriculture are just some of the more devastating examples.[97] Since centralized planning is a feature of large corporations, and since we are once again in a period of corporate consolidation, many other examples from governmental and corporate contexts could be cited.[98] As far as I can see, the multifaceted literature identifies four fundamental reasons why centralized planning fails. These play out in a myriad different ways across different settings, but they usually come back to one of the four basic problems of centralized planning.[99] Some refer to problems that derive from the

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[97] James Scott studies this in his landmark study, *Seeing Like a State* James C. Scott, *Seeing Like a State - How Certain Schemes to Improve the Human Condition Have Failed* (New Haven: Yale University Press, 1998). The scholarship on each of these experiments is too vast to be summarized here. I am going to focus on the most important theoretical objections that have been raised.
[98] For a fascinating take on centralized planning within large-scale corporations that begin to absorb entire branches of the market, c.f. Leigh Phillips and Michal Rozworski, *The People's Republic of Wal-Mart: How the World's Biggest Corporations Are Laying the Foundation for Socialism* (Brooklyn, NY: Verso, 2019).
[99] See, for example, the highly critical account of Alec Nove, *The Economics of Feasible Socialism Revisited*, 2nd ed. (London, UK: HarperCollins Academic 1991). It is partly inspired by the failures of some attempts to implement centralized planning in the UK, e.g., as explored through problems with labor unions and the NHS.

processes to be controlled; others have to do with the bureaucracy that does the controlling. I will begin with two problems that have to do with the nature of economic processes.

As James Scott observed, centralized planning requires that the social process becomes *legible* to the planner. Since bureaucracies can most easily control processes that admit quantification, centralized planning is characterized by standardization. By changing the social process in such a way that it becomes amenable to standardized measures, different parts of the social process can be summarized and compared at a central location. This, in turn, makes it possible to administer the social process. By reducing a vastly complex social reality to a few comparable measures, this reality becomes amenable to control. For example, the collectivization of the Soviet countryside between 1930 and 1934 began with the imposition of a standardized system of measurements and a single accounting system for all tracts of land. Instead of an infinitely complex configuration of family lots whose boundaries were constantly shifting, the Bolsheviks set about creating large, hierarchical, state-managed farms whose cropping and procurement patterns were centrally mandated and whose population was, by law, immobile.[100] By imposing legibility, the social process is simplified to a degree that enables central administration.

Scott argues that these attempts to make social life legible are doomed to failure because they repress local knowledge that is crucial to cope with problems on the ground. Individuals do their work in contexts that are characterized by idiosyncratic conditions. To deal with these conditions, they develop situated and embodied knowledge.[101] Disrupting work processes through acts

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[100] Scott, *Seeing Like a State - How Certain Schemes to Improve the Human Condition Have Failed*, 209.
[101] James Scott develops this argument powerfully, but it can be found in anarchist as well as libertarian writing as well, ibid., 6. It also includes the insight that the presumed algorithmic logic of economic reasoning excludes components of economic judgment that go beyond mere calculation. Any local decision will have practical, ethical, political, and speculative elements that cannot be reduced to price calculations (e.g., where should the generator be located in the factory when people do not want their office to be next to it, etc.). These issues can sometimes be translated into price calculation, but not without changing their character.

of simplification therefore engenders vast inefficiencies. This problem extends in both directions: general solutions to local problems (e.g., as developed in the laboratory or for other contexts) do not easily fit to local contexts. And local solutions to contextual problems cannot be aggregated and generalized. Accordingly, the attempt to impose legibility on the basis of an abstract schema onto a larger social process creates substantial inefficiencies and disruptions.[102]

This, in turn, creates a substantial discrepancy between the interests of the farmers and the centralized planners. The example of Soviet collectivization illustrates this point. Forcing peasants to move away from the plots they had cultivated for generations and expecting them to meet centrally mandated quotas went against the logic of their farming practices. This, in turn, prevented people from fulfilling the quotas, which created a fundamental antagonism between the planners and the peasants. This led them to circumvent the plans of the bureaucracy, which created further inefficiencies and kicked off a dangerous cycle of repression and evasion. The argument has a philosophical underbelly that is useful for the discussion here: The problem is not merely that the bureaucracy looks at social life with an insufficient level of granularity; the problem is that the strategies to make social life measurable and quantifiable assume that all information has a "thing" character that can easily be transmitted. In reality, information is highly contextual and can therefore not be aggregated into statistical measures: only the people on the ground know exactly how a particular piece of land can be used productively, what helps, and what does not. The meaning

[102] This argument has been made for a variety of contexts. For example, it has been used to argue against the popular idea of "legal transplants." Pierre Legrand, "The Impossibility of 'Legal Transplants'," *Maastricht Journal of European and Comparative Law* 4, no. 2 (1997). The argument for legal transplants was that legal rules constantly travel between different systems. This suggests that the connection between a legal structure and society is less strict than assumed. Accordingly, legal systems may be transplanted wholesale to other countries. Alan Watson, *Legal Transplants: An Approach to Comparative Law* (Athens, Georgia: University of Georgia Press, 1993), 95. The counterargument is, of course, that "legal rules" are interpreted in vastly different ways in different contexts and that this interpretation has to grow slowly out of dealing with local problems. Simply transposing one framework into another context will wreak havoc because it will not be attuned to the fabric of social life and not be embedded in a culture of interpretation that facilitates the match between legal rule and social problem.

of information is tied to specific practices of problem-solving.[103] The same piece of information can mean two different things in two different contexts of production. It can therefore not be aggregated into statistics and processed by a centralized organization.[104] Though the socialists at the Cowles Commission did not recognize this at the time, Hayek made essentially the same argument during the Socialist Calculation debate.[105] A centralized planner who effectively represses local knowledge by imposing a different structure of legibility will create inefficiencies and antagonisms that breed informal structures that circumvent and undermine the formal structure.

Folded into this first argument about the nature of information is a second objection about incentives. As we have seen, the attempt to impose a schematic order on the social process creates inefficiencies because it represses local knowledge practices. Based on a schematic understanding of the social processes, the centralized bureaucracy is then bound to level unrealistic demands at social actors. For example, the administrators in the soviet system were often wholly uninformed about what was possible for farmers and what was not. They did not know much about soil conditions, plant life, weather, or historical experiences with different farming practices. Often, planning occurred without an attempt to acquire this specific and localized knowledge. The bureaucrats mandated quotas of grain that left the peasants nothing to survive on. The class of essentially unfree laborers who had nothing to gain from their exploitation were thus actively pitted against the system, which led to further inefficiencies. On the other side, the bureaucrats had their own interests, which were not aligned with those of the peasants. Noting their resistance, they imposed endless

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[103] Though, of course, the epistemic framework of Hayek's philosophy shifted over time. Mirowski and Nik-Khah, *The Knowledge We Have Lost in Information: The History of Information in Modern Economics*, 66-73; Andrew Gamble, "Hayek on Knowledge, Economics, and Society," in *The Cambridge Companion to Hayek*, ed. Edward Feser, Cambridge Companions to Philosophy (Cambridge: Cambridge University Press, 2006).
[104] Friedrich A. Hayek, "The Use of Knowledge in Society," *The American Economic Review* 35, no. 4 (1945): ?
[105] I am now drawing on the "revised" reading of the socialist calculation debate, which suggests that the protagonists of the two schools misread each other.

repressions that made the situation worse.[106] When the bureaucrats could not deal with the problems, they gained incentive to lie and withhold information themselves. This gave rise to practices of structural hypocrisy—the ideal plan became little more than a charade, masking an alternative system of adjustments, corruption, and crypto-capitalist exchange relations.[107] In sum, the first argument is that centralized planning is impossible because the information required to make local decisions cannot be aggregated or standardized, nor can local problems be solved with knowledge practices that are developed away from these local problems. The attempt to do so leads to inefficiencies that breed alternative social arrangements below the radar of the centralized bureaucracy.[108]

At least at first sight, these objections do not seem to apply to market design. Market design is an attempt to constrain the *form* of economic action but not its substance—that is, it combines centralized planning with decentralized decision-making. While market designers do seek to standardize the parameters of action and the incentives that guide behavior, they do not enforce substantial decisions. In that sense, they are similar to urban planners who structure how people navigate the city by imposing a grid structure on the streets. But they do not determine the path that any particular individual has to take. They structure options for behavior rather than prescribe behavior. Similarly, market designers would not create fixed output decisions for farmers. Instead, they would seek to create an institutional structure in which the interaction between farmers and

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[106] Scott, *Seeing Like a State - How Certain Schemes to Improve the Human Condition Have Failed*, 211-17.

[107] These kinds of problems are also well-known from the literature on organizations, particularly the ecological tradition, which views formal and informal structures as the product of gradual evolution rather than intentional planning. In the interplay between formal and informal structure, a variety of pathological developments can fester that undermine the goals of the organization. Stephen Linstead, Garance Maréchal, and Ricky W Griffin, "Theorizing and Researching the Dark Side of Organization," *Organization Studies* 35, no. 2 (2014); Diane Vaughan, "The Dark Side of Organizations: Mistake, Misconduct, and Disaster," *Annual Review of Sociology* 25 (1999).

[108] This argument resonates with economic sociology more broadly because we constantly look for ways in which the social mechanisms differ that integrate economic action in different domains. Our pragmatist working assumption is that the coordination of social life is intrinsically local and contextual.

customers is guided by several basic rules of calculation and decision-making. The idea is that enforcing a particular logic of interaction is sufficient to arrive at an optimal allocation in the aggregate. Individuals are then free to address problems as they face them on the basis of their situated knowledge.

Market design also avoids the main incentive problems of centralized planning because markets individualize risks and rewards of individuals' decisions. Producers compete with each other based on output decisions that they make themselves. If they make the wrong substantial choices, they are punished with losses. If they find ways to innovate and solve problems, they are rewarded with profits. Since the risk of failure lies in the market, the oversight regimes also have an incentive to reveal them—unless they become systemic.[109] These are just the standard reasons economists offer why markets are superior to centrally administered systems. But over and beyond this, we have seen that market designers are tirelessly working to identify how institutional rules structure incentives. The whole point of mechanism design is to understand how the context within which self-interested behavior occurs can create incentives to withhold information, lie, or forgo activities that would occur in the ideal market of economic theory. Market design is incentive design.

The discussion of the two objections draws out the fundamental difference between market design and other forms of centralized planning. Market design only shapes the form of economic action, but it does not enforce particular, substantial decisions. In other words, it leaves individuals

[109] Of course, this leaves room for much bureaucratic inefficiency and obfuscation. Max Weber already knew that all bureaucracies have a penchant for secrecy. Max Weber, *Economy and Society - an Outline of Interpretative Sociology* (Berkeley, CA: University of California Press, 1978), 990-4. If a bureaucratic structure becomes unable to perform its task for some reason, bureaucrats gain powerful incentives to hide their failings. In addition, there are various reasons why bureaucrats may become ambivalent about their tasks. Paul S. Adler, "Perspective—the Sociological Ambivalence of Bureaucracy: From Weber Via Gouldner to Marx," *Organization Science* 23, no. 1 (2012).

to make local decisions as they see fit and only ensures that they aggregate in the way the mechanism requires. This potentially enables market designers to combine the advantages of centralized planning—the ability to specify a clear goal and exercise control to align the different activities in the market in pursuit of this goal—with the advantages of decentralized decision-making, which include the ability to apply local knowledge to local problems and reap the benefits of good decisions and pay the costs of bad decisions.

But the difference between form and substance that informs the opposition between market design and centralized planning is more elusive than might at first be apparent. After all, what exactly does it mean to only constrain the "form" of economic behavior? At what point does the attempt to "structure" economic decision-making interfere with actors' ability to make the kinds of decisions that are reasonable in their local context? And how much "structure" is actually required to realize the algorithm of a given blueprint? The task of the control structure is to make sure that the process takes inputs and processes them in such a way that they generate a particular outcome. Depending on the nature of the social process it seeks to control, this may require more or less constraints from the higher levels of the control structure.

The considerations thus point us to a central tension that undergirds market design. Its success depends on the ability of market designers to allow economic actors to develop local solutions to problems they are facing. At the same time, market designers must ensure that these activities aggregate in such a way that they are compatible with the algorithm that solves the optimization problem at the heart of the market. This requires some measure of control over individual choices. The crucial question is, how much control do you have to exercise over the content of specific economic decisions in order to ensure that the form is consistent with the algorithm that aggregates the choices? What features of different allocation problems and blueprints shape how much control is necessary?

From what we have said so far, we can hypothesize at least a few factors that will be important. Given that market designers must allow substantial decision-making but ensure that these decisions aggregate according to the static rules of a blueprint, anything that exacerbates the tension between these two requirements will present obstacles to market design. First, the *diversity* of local contexts of action will be important. If the blueprint is supposed to control social processes that work very differently across the domain of the market mechanism, more control is necessary, which is going to leave less room for free, individual decision-making. Conversely, the rigidity of the blueprint matters: if the logic of action that is compatible with the blueprint is very narrowly defined, more control is necessary and less room for decentralized decisions will ensue. In both cases, the design process could collapse back into the problems of centralized planning: by trying to displace local knowledge, the process would self-sabotage. Conversely, if the problems faced by actors in local contexts are largely comparable or if the blueprint is very flexible, the two sides become more compatible.

Another factor that is important is *change*. If we are dealing with an economic system where decentralized decisions lead to innovation and change, the logic of interaction between market players will change. The higher the rate of change, the more easily the process will run up against the static logic of the blueprint. If the centralized planners enforce against change and thus curtail the necessary innovation, they will once again incur the familiar problems of centralized planning. Conversely, if they allow innovation, they have to find a way to adjust the blueprint and the oversight regime to the ongoing changes. The challenge is then to define the different kinds of social processes that are required to implement the feedback-control loops that organize the interplay between the levels in the hierarchy of the system. We thus gain a theoretical statement about the condition for the success of market design. Market design succeeds if the control that it exercises over local social processes leaves room for actors to make decisions that are appropriate to the problems they face. We gain the impression that the degree of control required depends on the diversity of social contexts that need to be unified under the market mechanism and the rate of change that animates problem-solving in these local contexts.

With these observations, we can now move to the second set of objections against centralized planning. These objections are directed against the nature of the bureaucracy that must implement the plan. The first argument is that centralized bureaucracies are too slow to dynamically process all the information required for the planning task. In particular, they are unable to make the dynamic adjustments that are necessary to respond to unexpected needs and problems that decentralized economic action may encounter.[110]

In principle, the use of computers resolves this problem. It is true that there are lag times between collection of data, processing, and use of actuators to change the social process. But the possibility of creating *virtual* market environments enables market designers not only to reduce the complexity of market processes, but also make it possible to collect, analyze, and disseminate disaggregated information close to real time. Even extremely complex systems of nonlinear equations can be solved closed to real time with a variety of approximation algorithms.[111] If a market

[110] This has often been taken to be the classic argument of the socialist calculation debate. It can be attributed to some of Mises's and Hayek's writings and has been used over and over again. Von Mises, *Economic Calculation in the Socialist Commonwealth*, 109; Hayek, *Individualism and Economic Order*, 187. For a contemporary version: Rothbard, "The End of Socialism and the Calculation Debate Revisited," 56-57.

[111] Since this response hangs entirely on computational power, contemporary socialists advance the same argument. C.f. Cockshott and Cottrell, *Towards a New Socialism*. Others make the argument that large companies like Amazon and Wal-Mart already use these computational techniques for their internal processes of centralized planning. C.f. Phillips and Rozworski, *The People's Republic of Wal-Mart: How the World's Biggest Corporations Are Laying the Foundation for Socialism*.

actor has to change his or her mind or there is an instance of "irrational" behavior at some point in the market process, this information can be accommodated and incorporated nearly instantaneously. A real-world example for such dynamic adjustment is Uber's ability to continually optimize the distribution of cabs to consumers even if consumers have the chance to cancel their order before pickup. So, the speed of information processing seems like an outdated argument. However, this response assumes that market design *can* actually internalize the entire synthetic market into one software environment. If this is not possible because crucial features of the market mechanism (or factors influencing it) remain outside the software interface, it becomes an open question as to whether the design can be implemented in such a way that all relevant information aggregates and disseminates fast enough. A similar argument applies to the oversight structure: whether it is possible to observe all problems fast enough depends ultimately on the complexity of the changes that need to be logged and responded to. It also depends on the speed with which they need to be accommodated.[112]

Another objection claims that centralized planning fails for organizational reasons. In order to process all information about the myriad economic activities, the centralized bureaucracy will require a complex division of labor with a variety of different departments. The highest departments will then be too far removed from the lowest offices to communicate effectively—they will have different priorities, cultures of decision-making, and interpretative frameworks to make sense of incoming information. Accordingly, there will be misunderstandings, misalignments, and lost information along the way as different departments begin to make decisions that impact each other. Similarly, large bureaucracies are not well suited to adapt to new situations. They cannot quickly

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[112] In the world of High Frequency Trading, for example, regulation practically breaks down because the trades occur at a speed and with quantities of information that make it near impossible to reconstruct the rationales underlying it fast enough to detect and prevent fraudulent behavior.

reorganize information flows and paradigms of decision-making in response to changes in the market environment.[113] Whenever the requirements become too high, career bureaucrats have reason to hide or ignore existing problems.

This objection seems to hinge on the assumption that centralized planning controls the substance of economic decisions, e.g., the bureaucracy decides how much coal has to go to a particular factory to produce a particular amount of iron, which becomes input for another company. This would indeed require a number of planning offices to match the complexity of different production processes. In that case, we would end up with a complex and internally differentiated hierarchy of control structures that might all suffer from lags, information loss, miscommunication, etc. But in synthetic markets, economic decisions remain with the economic actors. Market designers do not enforce a substantial plan for decentralized production processes. Instead, they merely impose constraints on the form of economic interaction, i.e., the parameters of exchanges between people. This renders the task of oversight much simpler than the task of a centralized planning office. Aided by computational tools that allow them to observe any part of the economic process at will and with the ability to standardize economic interactions through the design of interfaces, the designers merely need to make sure that market actors do not violate the *rules of interaction* that will lead to an equilibrium based on individuals' best economic judgments. This means that the bureaucracy can offload much of the computational complexity onto computers and

[113] With reference to centralized planning, this argument has been made in Nove, *The Economics of Feasible Socialism Revisited*. They are familiar from the research on organizational mistakes, misconduct, and disasters. C.f. Vaughan, "The Dark Side of Organizations: Mistake, Misconduct, and Disaster."; *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at N.A.S.A., Enlarged Edition* (Chicago, IL: University of Chicago Press, 2016 [1997]); Linstead, Maréchal, and Griffin, "Theorizing and Researching the Dark Side of Organization."; Zhike Lei, Eitan Naveh, and Zhanna Novikov, "Errors in Organizations: An Integrative Review Via Level of Analysis, Temporal Dynamism, and Priority Lenses," *Journal of Management* 42, no. 5 (2016).

individuals in the markets. Ideally, this might lead to a highly centralized bureaucratic structure with just a few control feedback-loops.

Nonetheless, this second objection suggests a further hypothesis about successful market design: market design is successful if the centralized bureaucracy can monitor and control the structure of market interactions. It will fail, however, if the complexity of the control task overwhelms the capacities of a hierarchical division of labor. An important question is how complex the control task is and at what point the bureaucracy becomes unable to deal with it. This depends, in turn, on the question of how much control you need to exercise over the form of people's economic interactions to obtain the results required by the blueprint.

In sum, we have gained a couple of basic insights about market design that will structure the subsequent investigation. First, it is a form of centralized planning. Market designers seek to create market processes as an algorithm that solves an optimization problem. The algorithm is implemented in an interplay between software and the strategic interactions between market participants. The interactions are guided by institutional rules that configure the incentives economic actors face within the market environment. If everything goes according to plan, the interactions between market participants aggregate into a global distribution that has desirable equilibrium properties, such as Pareto optimality or allocative efficiency. Market designers have to set up the institutional structures that engender these market processes and subsequently ensure that the match between blueprint and market process obtains going forward. They can either change the blueprints to adapt to the social process or they can change the rules that guide the institutional process. The design enterprise can be understood as the attempt to set up a hierarchy of levels of control that control and structure the market process. These levels of control set up feedback loops that allow them to then monitor the ongoing match between market and model.

The condition for the success of this enterprise is that market designers give room to individuals to freely solve local problems while also ensuring that their interactions follow the rules specified by the blueprint. In other words, the space of activities that are acceptable within the parameters of the blueprint must be large enough to fit the local requirements for efficient task performance. This, in turn, requires control structures that can implement the institutional structures as planned, observe market behavior, and control it if it deviates from the plan or change the institutional structure if is beneficial. We also got the impression that the success of this depends on the complexity of the task to observe and enforce a particular logic of interaction, which itself has to do with the diversity of social context and the rate of change.

Before closing, it is important to point out that this investigation assumes the perspective of economists and approaches designer markets as if they are closed, technological systems—after all, we are trying to determine to what extent these aspirations hold true. This means that we will ultimately end up with an account of the conditions for the success or failure of market design that stresses systemic factors. The crisis, for example, will appear as a consequence of design failures. Such a "system" perspective may not be unproblematic, however.[114] Usually, such a perspective is applied to research on the failure of technological systems, such as meltdowns, airplanes crashes, fires, etc. After the financial crisis of 2007–2008, several sociologists considered a normal accident theory (NAT) explanation of the mortgage meltdown. Though initially predisposed to this strategy, Charles Perrow, the father of the NAT perspective, ultimately rejected this approach.[115] In a

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[114] The systems framework by Leveson usefully transcends the old debate between Normal Accidents and High Reliability Organizations because it does not distinguish between inherently accident prone and inherently safe system. Leveson, *Engineering a Safer World: Systems Thinking Applied to Safety*, 63.

[115] See e.g., the afterword in Charles Perrow, *Normal Accidents: Living with High Risk Technologies* (Princeton, New Jersey: Princeton University Press, 1999 [1984]). See also his discussion of the U.S. power grid, including a discussion of Enron's involvement in California's Energy Crisis in *The Next Catastrophe: Reducing Our Vulnerabilities to Natural, Industrial, and Terrorist Disasters* (Princeton, NJ: Princeton University Press, 2007), 211-47.

collected edition that deals with the 2007–2008 financial crisis, he writes: “I believe that system accidents exist and have explored a number of them; I just do not think that this disaster, and perhaps all financial disasters, are system accidents.”[116] His main point is that explanations at a system level are appropriate for accidents where failures of different components begin to interact in ways that no one anticipated. Since such accidents are based on unpredictable interactions, they can always occur, regardless how much everyone in the system tries to prevent them. In contrast, financial crises like the one in 2008—and certainly the California electricity crisis—involve deliberate attempts by people to circumvent and break rules.[117] In such cases, the crisis derives from malfeasance and should therefore be explained from an *agentic* perspective—partly because it is possible to ascribe clear responsibility to one or several actors who abuse their power and fail the system they are supposed to serve.[118] He argues that system features, such as tight coupling and nonlinear complexity, are merely *tools* that help irresponsible parties to bring down the system. The analysis should therefore focus on power and interests of guilty parties rather than just system features (or neo-institutional factors such as ideology or culture).

The thrust of Perrow’s argument is that a systemic perspective might displace the guilt of those who bring down the system with criminal behavior. This is an important consideration. But as we have seen, the categories of guilt and innocence do not carry with the California crisis because the system was set up in such a way that it becomes impossible to arbitrate the root causes in terms of an ultimate culprit. More importantly, an agentic point of view would miss what is special to economic engineering. The whole *point* of economic engineering is to manipulate the

[116] "The Meltdown Was Not an Accident," in *Markets on Trial: The Economic Sociology of the U.S. Financial Crisis: Part A* (Bingley, UK: Emerald Group Publishing Limited, 2010), 310-11.
[117] *The Next Catastrophe: Reducing Our Vulnerabilities to Natural, Industrial, and Terrorist Disasters*, 234-40.
[118] "The Meltdown Was Not an Accident," 311-12.

choice architecture of humans in such a way that they behave as the theory requires. Accordingly, forms of malfeasance become an indicator of design problems—they are deviations from desired behavior that the design was supposed to ensure. The designers were trying to create a system within which the attempts by individuals to make profits become the means by which the system achieves dynamic equilibrium. Nonetheless, Perrow's point is a useful reminder that there is an important difference between regular and economic engineering: the designers are not setting up the conditions for a causal mechanism between inanimate elements. Instead, they are setting up a framework within which actors can freely relate to each other on the basis of plans, intentions, hopes, beliefs. It is the attempt to establish a framework for intentional and substantially *free* action *as if* it could be seen as a cog in a system of inanimate elements. Whether or not this is reasonable is, in some ways, the core question of this dissertation.

With this caveat, we can now move closer to the empirical case and ask: What exactly does electricity market design aim to do, how did the California system implement these aims, and why did it fail?

5. The California System

5.1. Introduction

I have argued that market design is a form of centralized planning. Designers seek to create market processes that operate like algorithms that solve optimization problems. This requires control structures that constrain the market process into continual alignment with their blueprint. On the one hand, institutional and computational infrastructures need to configure the incentives that structure the market process. On the other, a centralized monitoring regime needs to be in place to observe whether the market process converges on the blueprint. The crucial tension that undergirds the intellectual enterprise is the need to allow some measure of autonomous decentralized decision-making while ensuring that these decisions aggregate as the blueprints require. Whether this is possible (and if so, under what conditions) depends on the problem that needs to be solved and the nature of the algorithm. Accordingly, it is now time to apply this analytical framework to the case and ask: What exactly are electricity markets supposed to do and how did the California system meet the challenge?

This chapter begins by outlining how the electricity industry operated prior to deregulation. This will clarify the challenge market designers had to meet. I will show that they had to create a market process that would be able to find the "security-constrained, optimal dispatch" of generators relative to aggregate demand in the system for the short and long run. In other words, the market has to find the cheapest combination of generators to meet the demand for electricity at all nodes of the grid. This task had to be performed in advance of real-time operations. Since electricity grids need to be in perfect balance from moment to moment, a system operator manages the real-time operation of the system based on command and control principles. Market designers thus had to figure out how to create financial markets for *future* obligations to deliver electricity. The crucial question was how these financial markets would be integrated with real-time grid management, and particularly, how much coordination they would manage before the system operator took over.

After explaining the task and challenges for electricity market design in some detail, I will then show how California responded to these challenges. I explain how a system of sequential forward markets for a variety of different services created approximate schedules for the supply and demand of electricity at given time points as well as a simplified set of locations in the network. The system operator would then implement these schedules in real time and disaggregate the fictional network locations over the real nodes within the system.

Since the system was rather complex, I first provide an overview of the design's skeleton. Next, I fill in details, and finally, I provide a fictionalized example that walks the reader through a typical trading day in the markets and shows how the different components work together.

The purpose of this chapter is not merely to prepare the ground for the subsequent exploration of the reasons the system broke down. It will seek to show what it means to say that the California markets were an instance of market design. By revealing how the complex design corresponded to technical challenges, it becomes possible to appreciate the degree of planning involved. This helps to correct a view that some research on the energy crisis expresses. Particularly legal and journalistic accounts sometimes describe the market design as fundamentally naïve. For example, one observer writes: "The market system provided for [the utilities] to purchase power was not only dumb, it was horribly incomplete. In particular, long-term contracts for the delivery of power were prohibited and replaced with an ineffectual and underutilized market for future delivery."[1]

Another commentator, writing about the first price spikes during the summer of 1999, notes: "The summer of 1999 offered the first proof that the conflicts between the CPX and ISO—and the gaming of energy providers—had turned the California Plan into a mockery of deregulation."[2] From the perspective of these accounts, California's energy markets failed because the politicians did not "truly" deregulate the markets.[3] Since these accounts treat the creation of the markets as yet another instance of the 1990s' obsession with deregulation, they focus on the political process that led to the creation of AB1890, the bill that paved the way for restructuring. This is problematic for two reasons.

First, as I will show in detail in the next chapter, the political process does not account for the most important structural flaws in the market design. The market design was flawed, yes, but not for the reasons that the literature tends to focus on, nor was the design naïve. Second, they overlook the fact that the political process—while important—was only part of the processes that guided restructuring. Far more elements of the California system go back to technical decisions in the WEPEX and TAC working groups. These took place far away from the California Assembly and the political skirmishes in Sacramento.

To correct the impression that the California markets were somehow obviously flawed and the product of a botched attempt at deregulation, it is important to develop an appreciation for the

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[1] Ross M. Miller, *Paving Wall Street - Experimental Economics & the Quest for the Perfect Market* (New York: John Wiley & Sons, Inc., 2002), 266.
[2] Walsh, *The $10 Billion Jolt: California's Energy Crisis: Cowardice, Greed, Stupidity and the Death of Deregulation*, 114.
[3] Ibid., 25-26; Harvey Wasserman et al., "Power Struggle: California's Engineered Energy Crisis and the Potential of Public Power," *Multinational Monitor* 22, no. 6 (2001).

technical rationale behind the California system. This is the task of this chapter. I am now going to outline the challenge posed by electricity market design. In the second section, I will then reconstruct how the California system of 1998 addressed these challenges.

5.2. The Challenges of Electricity Market Design

The electricity industry is made up of four components: production, transportation, distribution, and consumption. Early in the twentieth century, a "utility consensus" emerged and governed the industry for the better part of the century. The state would regard the industry as a natural monopoly in exchange for control over the rates that the monopolies could charge their captive customers. Vertically integrated utilities thus received the right to rule over large service territories where they operated all four components of the industry. They produced and delivered energy to end users whose consumption they metered. Public Utility Commissions (PUC) would then sanction the rates that utilities were allowed to charge. These rates were designed to capture the cost of production and allow utilities a reasonable return on their investments.[4]

The decision to restructure the industry was a decision to abandon the utility consensus. The plan was to break up the monopolies and replace them with competitive markets for the trade of energy. To this end, the four segments of the industry would to be separated. There would be markets for the production and consumption of electricity, while transmission and distribution would remain monopolies operated by neutral entities. To understand the difficulties this plan posed, I will discuss the four segments in turn.

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[4] Hirsh, *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System*, 4-5, 11-15. The philosophy that guides rate negotiations is also sometimes called the "regulatory compact." I will not use the term here.

The production segment consists of different generators that produce electricity. During the 1990s, most plants in California relied on generators that spin turbines to induce an electric current. Depending on the generator, the rotation of the turbine shaft is sustained with heat from fossil fuel, fission reaction, or water pressure. The shafts spin an electromagnetic field around a conductor to induce an electric current. This current is then released into the grid.[5]

Though the basic mechanism for the creation of electricity is simple, different generators have vastly different operational characteristics. While some may have to run for hours or days to come online and achieve efficient output levels, others can produce efficiently within a few minutes. The time that generators need to come online is referred to as the "ramp rate" of generators. Some produce a steady output over long periods of time, and others produce vastly different levels of energy from one hour to the next. The degree to which generators can produce steadily is also called their "intermittency." On the production side, the electricity system thus contains a variety of different kinds of generators with different operating characteristics.[6]

Every electricity system needs a balanced mix of generators because the system must be able to respond quickly to fluctuations in demand that occur over the course of the day as well as the year. This has to do with two characteristics of electricity.

First, as long as electric cars and new battery technologies do not allow efficient storage, electricity needs to be consumed as soon as it is produced. Production and consumption of electricity thus occurs almost instantaneously. If you switch on a light in Chicago, a generator somewhere along Lake Michigan produced the energy a fraction of a second earlier. A shift in demand,

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[5] Power plants usually contain several generators that are dispatched separately. For accounting, managerial, and regulatory purposes, these plants are treated as units. Joskow and Schmalensee, *Markets for Power: An Analysis of Electrical Utility Deregulation*, 46.
[6] Biggar and Hesamzadeh, *The Economics of Electricity Markets*, 46-49.

therefore, requires an instant shift in supply as well. The electricity system is thus a system of constant, dynamic adjustment.

Second, end users do not adjust their usage relative to available supply—consumers simply use energy when they need it. This means that demand is "inelastic" in the short- and middle-term. The patterns of use change throughout the day as well as the year; most people use more energy when they come home from work than when they are asleep. They use more during a hot summer day than on a moderate spring morning. Accordingly, the system can experience substantial fluctuations in demand that are not responsive to the existing supply.

Together, the two characteristics of electricity require that there is a mix of generators that can flexibly serve the highest as well as the lowest level of demand in the system.[7] Specifically, there needs to be "baseload" plants that produce a constant output for the level of demand that is always present (e.g., nuclear with high fuel efficiency but low flexibility), intermittent or "cycling" plants that serve intermediate fluctuations (older coal- and oil-fueled plants with some flexibility, high operating costs, but relatively high fuel efficiency), and "peak" plants that are only reached a few hours in a year (low fuel efficiency, but high flexibility).[8]

The optimal mix of generation assets does not just meet the existing demand at all times; it also minimizes the *cost* of energy production. The cost structure for power plants is complicated. There are fluctuating input costs, maintenance costs, personnel costs, and a variety of fixed costs of investment. A third factor that matters for the composition of generators is safety requirements, which impose redundancy requirements. If there is not enough energy in the system, the frequency drops the alternation of current that moves energy. If it drops too far from the U.S. standard of 60

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[7] This is the reason the basic characteristics of an electricity system can be summarized in a load-curve, which shows the level of demand for all hours in the year.
[8] Joskow and Schmalensee, *Markets for Power: An Analysis of Electrical Utility Deregulation*, 47.

cycles per second, generators will switch off because they are unable to produce output at lower frequencies. This will reduce the frequency in the system further, which will lead to more generators disconnecting. Soon, the chain reaction can cause cascading blackouts that can bring down the system. To prevent this catastrophic event, the system always needs to meet certain safety standards. The existing capacity must exceed the peak demand by a safety margin.

In addition, a mix of generators with different response rates is necessary. While some generators must nearly run constantly, others must be able to come in and deliver energy in quick bursts before shutting down again. A few generators must always stand ready to provide emergency "ancillary services," essentially capacity that can come online quickly in case other services fail. These services are mainly differentiated by the time they require to come online. A special ancillary service is "blackstart capability," i.e., power plants that can start without electricity of their own in case there is a blackout. Finally, there must be sufficient capacity in the system to allow generators to switch off for safety and maintenance purposes.[9]

The next issue is how to operate and expand the system in the most effective way. In the short run, the system must use the available generation capacity to meet all demand in the system at the least cost. This is also referred to as the "unit commitment problem." Since generators must run for different periods of time to come online and produce energy efficiently, operators constantly need to consider when to start a generator and "commit" its resources to the grid. This decision depends not just on the ramp rates of different generators, but also on their operating costs.

Since the inputs vary, the operating costs do too: hydro plants have zero-fuel costs since they simply use the energy released by falling water; natural gas or internal combustion engines,

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[9] Stoft, *Power System Economics*, 19.

however, have costs that fluctuate with the market value of natural gas and oil. Another difficulty is the presence of non-convexities in the cost curves of generators, i.e., more output does not necessarily mean a higher cost. This makes it more difficult to determine when to commit a generator because the operator needs to figure out how long the generator will operate at efficient levels and whether this will offset the cost at other levels.

Perhaps the core problem of operating the electricity system efficiently is finding combinations of generators that optimize these commitment decisions for different time horizons and input costs. The solution to the unit commitment problem finds the most cost-efficient combination of generators for a given time frame while also providing the necessary redundancies.

Over longer time frames, the available capacity needs to be expanded to keep the mix of generators up-to-date with the development of demand. Here, it is important to note that generators have vastly different capital costs: building a hydroelectric dam can take years and is extremely capital intensive, while natural gas turbines can be built quickly and cheaply. In the 1990s, the most balanced type of generator was the steam electric plant, in which water is heated to produce steam that drives the turbine. Such generators can run on a variety of different fuels, which changes their cost structure.[10]

When planning expansions to the existing generators, it is necessary to consider not only how they relate to the existing mix but also *where* to place them relative to the position of demand. Due to the potentially long time frames that are involved in the construction and connection of new power plants, the expansion is also riddled with uncertainties: it is unclear how the costs of

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[10] The economics of generators have shifted since then, partly because of technological advances in renewable technology, partly because of changes to input costs. I am confining my discussion to the situation that the market designers faced in the late 1980s and early 1990s. For an overview of current trends and dangers, see Varun Sivaram, *Taming the Sun: Innovations to Harness Solar Energy and Power the Planet* (Cambridge, MA: MIT Press, 2018), 59-68.

inputs are going to change over time (consider just the possibility of oil shocks), and innovations can undercut the rationale for a particular type of investment (for example, renewable technology can make baseload plants unprofitable). Finding and operating a mix of generation facilities to meet aggregate demand in the system at all times is thus a complex task that the regulated utilities used to perform for their respective service territories. These tasks are complicated further by the need to send all energy through a shared network of transmission lines.

The grid consists of a high-voltage transmission system and a local distribution system. The dual system is necessary to minimize the amount of energy that is lost in transportation. The high-voltage transmission lines deliver electricity from generators' switchyards to the substations of local distribution systems. From there, a network of low-voltage lines transports the energy to end users, where it is metered and consumed.[11]

Having a high- and a low-voltage system helps to minimize waste. Transmission lines have *resistances* that convert some of the energy into heat.[12] How much energy is lost from this conversion depends on the length and material of the transmission line as well as the strength of the electric current. An electric current is the rate of flow of electric charge past a point.[13] By stepping up the voltage, the current *decreases* and line losses are minimized. Though the analogy is incorrect in important ways, you can imagine the current a bit like a river: high voltage is equivalent to

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[11] In practice, the difference between transmission and distribution is not always clear cut. Depending on the point of view (technical, accounting, managerial, regulatory), a line may be classified as either transmission or distribution. Nonetheless, for the purpose of market design, the difference is relatively straightforward.
[12] In A/C systems, the current faces not just resistance but impedance, which follows from the resistance of the material and the phase difference between current and voltage that is created by certain elements' opposition to changes in current or voltage (inductance and capacitance).
[13] Electric current (I) is measured in ampere, which is calculated as resistance divided by voltage. The power that is being transmitted is calculated as current times voltage ($P = IV$). Voltage (V) is the potential difference in charge between the two points and is measured in volts. It describes how much work (joules) is necessary to move a unit charge (coulombs) between two points.

a river with a wide riverbed, while low voltage corresponds to one with a narrow bed.[14] In both rivers, the same amount of water (i.e., power) will pass through at a given point, but the narrower the riverbed the faster the water will flow. The faster it flows, the more it pushes up against the mound and erodes it. By stepping up the voltage and reducing the current, the transmission system decreases transmission losses because it reduces the force with which the current "pushes" against the material. But high voltage is dangerous to humans and not useful for most machines. Accordingly, a distribution system is necessary that steps the voltage back down and delivers the energy to consumers over a more fine-grained system of low voltage lines. The distribution system first serves large industrial users who need medium to high voltages, and then serves smaller end users, progressively stepping the voltage down further. Together, the two systems form the grid.

Finally, the consumption segment of the system consists of the different households and industrial enterprises that receive the energy from the distribution system. Their use must be monitored and billed. Large-scale consumers may also have contracts that make their load "interruptible," i.e., they allow curtailed consumption in case the system is in danger.

The difficulties of finding and operating the ideal mix of generation are exacerbated by the need to transport the energy via the grid. Transmission lines have thermal limits that determine how much energy they can transport. This means that a generator which might be best suited to meet demand at a given node, may not be able to reach that demand because the path is blocked. When the path from a generator to a consumer is blocked because the line carries too much energy, the network is said to be "congested." This is a conceptual fiction to describe a situation in which

[14] A/C currents are better imagined as a pulse. The A/C current periodically reverses direction and can be represented as a sinusoidal wave, where the x axis marks time and the y axis the positive and negative directions. In U.S. transmission lines electrons are pulsing back and forth at a rate of about 60 reversals a second (60 cycles per second, or hertz). The pulsation transports an electric charge between two points.

demand cannot be served by the most cost-effective generator because not enough transmission capacity is available. There can never *actually* be congestion in the sense of electrons that suddenly slow down. If too much energy were to be sent through a line, the current would first increase and then collapse, or the line would sag and rip. The sudden voltage drop would have cascading effects on the frequency outlined above.

Since such problems can have cataclysmic effects in the rest of the grid, they must be prevented. The metaphor of "congestion" therefore refers to *potential* bottlenecks in the system where not enough transmission capacity is available to use the most cost-effective combination of generators to service a load. To deal with this problem, generators must be stepped down and generators elsewhere in the system must take over. This means that the cheapest generator may not be able to serve demand at a given node. Instead, a more expensive generator has to take over to adjust for the limited transmission capacity.[15]

Finding the optimal set of adjustments during operation is a complicated problem because the capacity of transmission lines does not only depend on static limits of wires' material. It depends on the overall patterns of energy flows in the system. Electricity flows at about the speed of light on all available paths, roughly inversely proportional to the impedances it is facing. Since the grid contains many redundancies to reduce the impact of mechanical failures, the grid has many circular pathways built into it. In such "loops," the energy flows interact with each other and either increase or reduce the amount of transmission capacity that is available on any given line.[16] Line losses and "reactive" power flows further impact the available capacity.

[15] Stoft, *Power System Economics*, 374-81.
[16] Power flows can cancel each other out, thus increasing the available capacity on the line. This follows from the law of superposition.

This means that an adjustment to the mix of generators can create new limitations elsewhere in the system. In other words, any attempt to find the right combination of generators to serve existing demand must take into consideration how each combination of inputs impacts the power flows on all lines. Taking the complex interactions between flows of energy into account is also referred to as the "power flow problem."[17] The problem of economic dispatch is therefore not merely to find the cheapest mix of generation as a solution to the unit commitment problem. It also needs to find the combination of generators whose dynamic interactions maximize the amount of available *transmission* capacity while observing the capacity limits of the grid.[18]

The transmission system also complicates the search for the optimal mix of generators in the longer run.[19] Both generators and transmission lines must be maintained and updated. New generators and transmission lines must be added as demand grows, and they must be added at the right locations. The addition of generators and transmission lines must reflect how they would change the usage patterns of the grid and seek to optimize the power flows.

When additions are planned, the construction needs to take into consideration whether the plant would be able to serve demand where it is needed and what part of the load curve the plant would have to serve. Ideally, additions to the system do not only reduce the costs of system operation through efficiency gains and reduced input costs; they should also improve the security of the system and reduce *environmental* impacts.[20] Since each addition or subtraction of hardware

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[17] Part of this is done by equipment that automatically adjusts generation in response to fluctuations in the grid. Human interference ceased a few minutes before real time dispatch.
[18] There are voltage and stability limits on transmission lines that frequently change. They determine security limits to transmissions. Stoft, *Power System Economics*, 239.
[19] O'Neill et al., "Independent System Operators in the U.S.A.: History, Lessons Learned, and Prospects," 488.
[20] Particularly today, environmental concerns are paramount and drive the development of electricity systems. While California was a trailblazer in terms of environmental technologies since the 1970s, the development of renewable energies hat not yet reached the threshold that would pose special problems for market design. Today, this has changed. But since it was not central to market design in the 1990s, I will neglect the issue here and only come back to it in the conclusion.

affects the system as a whole, and since they involve vast capital expenditures as well as long periods of time before the assets can come online, the level of planning for the mid- and long-term is extreme.

In sum, then, the electricity system is a vast network of interlinked machines that must work in tandem to maintain a constant frequency of 60 cycles per second. The output of all operating generators must be adjusted to meet the demand at all nodes in the system. This process needs to take the complex power flows in the grid into consideration and account for generators' different operating characteristics as well as changes in input costs. The long-term growth of the system requires updates, maintenance, and additions that match the development of demand in the system as well as the existing mix of generators and transmission lines.

The complex network effects posed substantial challenges to market designers who wanted to deregulate the production side of the electricity industry.[21] In order to take over the coordination from the utilities, the markets had to be structured in such a way that they would find the optimal mix of generation and then operate it efficiently. The markets had to attract the right investment at the right locations in the long-term, and they had to find solutions to the unit commitment problem in the short-term.[22]

But how would the markets be able to account for the complex nonlinear dependencies between energy flows on the transmission system and the output of all generators relative to the aggregate demand? Since markets would not be fast enough to manage the second-to-second balancing of supply and demand, a centralized system operator had to manage the system in real time.

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[21] In the 1980s and 1990s, market designers had substantial disputes about several basic questions concerning the structure of the system. I am going to discuss some of them in later chapters, but here, I focus on the system as it was designed for California. For a quick overview of the most important debates, c.f. O'Neill et al., "Independent System Operators in the U.S.A.: History, Lessons Learned, and Prospects," 489-90.
[22] Joskow and Schmalensee, *Markets for Power: An Analysis of Electrical Utility Deregulation*, 25; 35.

How could the markets be integrated with the work of the system operator? How much coordination could markets accomplish and how much would the system operator have to do? I will now explain in detail how the California system addressed these questions and how a control and monitoring structure ensured the smooth operation of the system.

5.3. California's Electricity System

Very basically, the California system created a set of forward markets for the delivery of energy. In these markets, utilities, power marketers, generators, and various energy service providers bought and sold wholesale energy. In the aggregate, these processes would create schedules of financial obligations to produce and consume energy at different locations in the system. The system operator would use this information to coordinate the real-time dispatch of the system. It would then settle the financial obligations on the basis of the actual consumption by end users. Meanwhile, end users could buy their electricity in retail markets. In what follows, I will reconstruct this basic system in detail and explain how it responded to the technical challenges.

The first question market designers had to determine was how markets could be integrated with the work of the system operator.[23] The system operator forms the functional core of any electricity system. In California, this entity was CAISO. It had wide-ranging authority not just over the grid, but over all parts of the technological system, including the generators. It adjusted inputs to the grid to meet aggregate load while resolving transmission constraints, compensating for losses, and implementing various reliability services for emergencies.[24] Since markets could not

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[23] Peter Cramton, "Electricity Market Design: The Good, the Bad, and the Ugly" (paper presented at the System Sciences, 2003. Proceedings of the 36th Annual Hawaii International Conference on, 2003).
[24] The details can be found in the last version of the 1998 Tariff for the ISO, filed with FERC: "California ISO, ISO Tariff, Version 7," 82 FERC 61,327 (1998), Sections 2.1-2.5.

aid the system operator in real time, the designers created electricity markets as *financial* markets that operated *prior* to the real-time dispatch. All market activities thus occurred in anticipation of future energy flows.

Market participants did not trade "real" energy, but financial obligations to deliver energy at specific locations at future points in time. The temporal separation between markets and system operation creates a clear division of labor: the markets prepare the real-time dispatch by finding approximate solutions to the unit commitment and setting incentives for investments. The system operator takes the results of the market process and implements them, adjusting for the fluctuations that occur in real time.

The next question was how much coordination the markets could take over, how they would do that, and how the required market process could be enforced by an institutional and organizational infrastructure that hosts the market process. Since the answers to these questions are complicated, I am going to proceed in three steps. First, I will reconstruct an outline of the temporal and geographic architecture of the markets as well as the control structure that implemented it. Then, I will discuss in detail the market mechanisms for the different product markets and the organizational structures that implemented them. Lastly, I will provide a fictionalized example of a trading day under ideal conditions. I will now begin to discuss the basic structure of the system.

California's wholesale markets for electricity were organized as a cascade of interlinked forward markets. Forward markets concern the delivery of some good in the future. In some of California's markets, buyers and sellers traded bilateral contracts for the delivery of electricity at various future dates. In other markets, auctions created matches between buyers and sellers and resulted in contractual obligations. While some contracts referred to delivery in the next year or month, others established delivery obligations for the next day or hour.[25] Figure 5-1 depicts the timeline of the different markets.

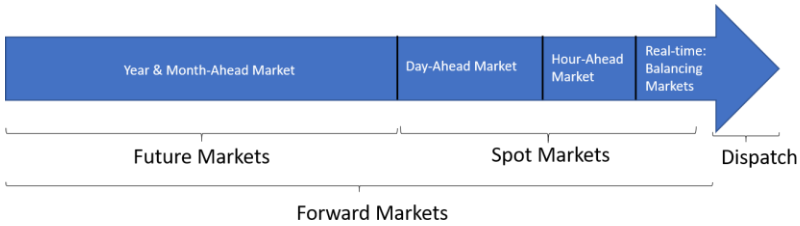

Figure 5-1 – Temporal Structure of Forward Markets

Though all markets in figure 5-1 are forward markets because they are cleared prior to dispatch, the day- and hour-ahead markets, and the real-time markets were usually referred to as "spot markets" because they operated close to the moment of dispatch. The purpose of these sequential markets was the creation of increasingly more refined dispatch schedules that solved the unit commitment problem, i.e., the least-cost order for generators to meet aggregate demand.

To understand the rationale of the market mechanism, it helps to consider a market without transmission constraints for a single time point. Assume we are in the day-ahead market for electricity. In this market, buyers and sellers trade energy that will be delivered at a particular hour the next day. Both sides will have an idea of how much energy they will need or how much they will be able to produce at that future point in time. If you assume an ideal market environment, where everyone acts rationally and has perfect information, the market will converge on a solution to the unit commitment problem for the next day. Buyers will buy from the cheapest supplier.

Suppliers, who compete with each other, will have a strong incentive to offer their energy at marginal cost. In such a market, buyers will always go to the cheapest offer. When that energy is used up, they will go to the second cheapest, and so on until all demand is met. In equilibrium,

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[25] "Report on January 9, 1997 Direct Access Working Group Workshop on Communications and Data Systems," Box 30, Folder 108a, *CPUC*, 2-8.

supply and demand will be in balance, and we will have found the ideal mix of generators to supply all demand at least price.

For the simplest case, a perfectly competitive market with perfect information and rational actors will converge on a distribution of contracts that solve the unit commitment problem. If the markets meet these requirements, they thus work as an algorithm that finds the optimal combination of generators to meet the demand of the next day.[26]

Now, since the markets were not about the present moment but the future, the simple logic has a wrinkle. The information about supply and demand on the next day may be inaccurate. Actors face "uncertainty" in the economic sense. Note that economists do *not* typically refer to the Knightian sense of uncertainty as a situation where the range of future outcomes themselves are not known and probabilities cannot be assigned. Instead, they refer to uncertainty as a situation where the actors only know a probability distribution of future states of the world.[27]

Accordingly, the activities in the forward markets are premised on inaccurate information—the future is not entirely known at the time these markets take place. To guarantee the correct results, the markets must be designed in such a way that market participants can fine-tune their obligations as new information becomes available. This is the reason the California markets employed a cascade of forward markets.

As time progressed and the delivery date for a given quantity of energy came closer, another market became available to augment the obligations from the previous market. For example, if a utility buys 10 MW/h for a given hour on the next day, they can adjust these obligations in the hour-ahead market on the next day; once the intervening time has elapsed, day-ahead energy turns

[26] James G. Kritikson, "California Electricity Market Primer," prepared for the CalPX Board of Governors (February 2000), R400.010, Box 18, Folder 12, Electricity Oversight Board Subject Files, *CSA*, 8.
[27] Hal R. Varian, *Microeconomic Analysis*, 3rd ed. (New York: Norton & Company, Inc., 1992), Chapter 11.

into hour-ahead energy.[28] If they find out that they will actually need more or less energy, they can buy or sell energy for the dispatch hour. The structure thus allows buyers and sellers to plan for the future. They can hedge against price risks that might affect the real-time price, and they can gain certainty about the delivery of the energy they bought or sold ahead of time. If everyone uses the markets, the aggregate result will be a more and more accurate plan for production and consumption of energy at a given future date.

For the logic of mutual improvement to work, market actors must have incentives to improve on previous trades. Otherwise, the earlier markets might lock in structures of obligations that are widely inaccurate for later markets. To ensure that the markets improve on each other, California used a two-settlement system. In such a system, obligations from each market are settled *separately*. For example, if A sold 10 MW/h to B for the next day, this contract was settled at the strike price. If it turned out that the obligation anticipated the real-time correctly (A produced 10 MW/h, B consumed 10 MW/h), no adjustment had to take place. But if the actual delivery or consumption did not match up with the contract, adjustments had to be made to reflect the differences. The seller would either have to purchase additional energy if they delivered less than promised, or sell additional energy if they delivered more than promised. This deviation from the forward contract was settled separately and at the price of the subsequent market.[29] This way, the price *risk* of incorrect anticipations always remained with the party who made the mistake. This

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[28] Nonetheless, substitution in time was limited. The energy deliveries established by a long-term contract may be tied to conditions (e.g., same delivery location, same buyer, periodic repetitions of deliveries, etc.) that made it impossible to trade the contract in one of the subsequent markets. Only the products in the spot markets were designed to be close substitutes. This is important for the assessment of market power and the incentives that define the linkages between the markets Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 100-05.

[29] "California ISO, ISO Tariff, Version 7," 82 FERC 61,327 (1998), Section 11.2.4.1. This system makes sure that buyers and sellers have exactly the same incentives in the real-time market as in the forward market because each set of transactions is settled separately.

created incentives to avoid mistakes and improve schedules as new information became available.[30] Ignoring for a moment how exactly the designers made sure that the actors in the markets would behave rationally and hold perfect information, the system of sequential markets with a two-settlement system enabled a progressive refinement of approximately correct dispatch schedules for aggregate demand. This system also set incentives for the construction of new generation: if there is much demand in the forward markets, companies that want to invest in new generation can sell their projected output in advance and thus gain certainty about their ability to sell the output. Similarly, by indicating who can achieve high prices, the market learns where generation capacity is scarce, which produces incentives for new investments.

The cascade of forward markets describes the core of the California system. A hierarchical control structure implemented the sequence. In the longer time frames, wholesale buyers and sellers had the choice between several different marketplaces. Each marketplace was operated by a so-called "scheduling coordinator" (SC). The SC acted as broker (or acted on its own behalf), standardized the contracts, and enforced the conditions of settlement and billing required for the two-settlement system. They would then submit the results of their market activities to the ISO according to the information standards the ISO had imposed (e.g., identifying the physical resources that would serve demand, financial information about the supplier, etc.). Some scheduling

[30] In bilateral markets, situations exist, in which a producer of energy and a user of energy are linked only indirectly. A trader who does not participate in the real-time market has a contract with the user and a contract with the generator. Producer and consumer automatically participate in the real-time market because all actual energy flows are ultimately accounted for in this market. Since the trader is not himself consuming or producing any energy, the risk of a deviation between forward and real-time market must be shifted to the generator and the consumer. To this end, the trader must have a deal with the generator about deviations, and they must have a contract with the buyer about deviations. These deviations must then be related to the relationship between user and producer. Contracts-for-difference achieve this goal. Each bilateral contract with the trader establishes an obligation for the counterparty to pay the contract quantity times the difference between the contract price and the real time price. A contract between producer and consumer establishes the same obligation between them. This isolates the trader from the price risk of the real-time market and shifts it to the producer and consumer. C.f. Stoft, *Power System Economics*, 213-4.

coordinators enforced these conditions via their software interface; others collected it by hand and passed it on to the ISO. After the forward markets concluded and the schedules were submitted to CAISO, the system operator implemented the schedules as closely as possible. The CAISO observed the electricity system in real time and adjusted the financial schedules as necessary to deviations that occurred in real time. After the energy had flown, it received the results from metering all consumption and settled the difference between the schedules and the real consumption according to the real-time price. Since the CAISO trades were settled separately as well, the structure of subsequent settlements enforced the incentives that linked the sequential forward markets to each other. Though I have not discussed the specific nature of the market mechanism yet, it should be clear that the resulting structure was highly centralized: the scheduling coordinators implemented their local market processes and passed the information on to CAISO, which ensured the match between the market activities and the real-time operation of the grid.

The market system was not just differentiated by time, but also by geographic reach. This had to do with the technical characteristics of the grid. CAISO was not responsible for the entire network. Within California, there were four additional "balancing authorities" that corresponded to the territory of a couple of municipalities. They had opted out of restructuring and continued to manage their grids autonomously.[31] In addition, California was tied into the Western Interconnection, which included parts of Mexico, Canada, and eleven Western States.[32] A variety of balancing authorities managed these parts of the grid outside California. Since most states around California

[31] These four balancing authorities were: Los Angeles Department of Water Resources (LADWP), Imperial Irrigation District (IID), Turlock Irrigation District (TIDC), and the Sacramento Municipal District (SMUD).
[32] During the crisis, the Interconnection was under the oversight of the Western Systems Coordinating Council (WSCC). WSCC was renamed into the WECC (Western Energy Coordinating Council) in 2002. It is an independent agency that reports to NERC (National Electric Reliability Council) and is responsible for compliance and enforcement of NERC's security standards. It coordinates the bulk electric transmission system in the Western Interconnection. Effectively, it establishes standards for the interrelation between the different system operators in the Interconnection and enforces them.

had not yet deregulated their systems, most of these balancing authorities were simply the service territories of regulated utilities. From a technical point of view, CAISO was one of 35 balancing authorities in the Western Interconnection.[33]

Electricity thus moved through a system that was vastly larger than the area controlled by CAISO. The electricity markets had to contend with this technical reality. Since the stability of California's grid depended on its ability to import and export energy from adjacent balancing authorities, the markets had to make room for transactions that transcended the state. But since the system operator could only control resources within the state, and since it used markets to procure these resources, some of the markets had to have a more limited geographic reach. Accordingly, the markets that were closer to dispatch were geographically restricted, while the earlier markets were not, leaving room to account for imports and exports.

The bilateral forward markets traded contracts for electricity within the entire Western Interconnection. Companies could buy and sell energy at any location in the different balancing areas—typically at one of several trading hubs of the West. As soon as energy was scheduled at a location within California, this energy could also be traded in California's centralized auction markets. The main auction markets were operated by the Power Exchange (PX) and CAISO. While the PX operated a day- and an hour-ahead auction for energy, the CAISO operated a real-time ("imbalance") market that was used to price real-time deviations from the schedules of the forward markets. These markets formed the core of California's market system, but they only allowed trades at a few locations within California.[34] These "locations" were fictional abstractions. They did not reflect the physical reality of the transmission system, which was a complex structure of

[33] Today the WECC contains thirty-eight Balancing Authorities.
[34] "Electricity Markets of the California Power Exchange—Annual Report to the Energy Regulatory Commission," July 30, 1999, George Sladoje Personal Archive, 14-19.

lines, circuit breakers, switches, transformers, meters, and other hardware. To simplify the trading process, the model only represented those parts of the transmission system that were historical sources of congestion. Specifically, the model split California into three zones. The first zone, NP15, corresponded to PG&E's old service territory. SP15 corresponded to SCE's old service territory. The zones were linked via the major transmission line "Path 15," which was frequently congested.[35] The third zone, ZP26, referred to a large area in central California. Energy could be scheduled to either of these zones or one of the 26 scheduling points where California intersected with the other balancing areas. From these scheduling points, energy could travel into California as imports or out of California as exports. Figure 5-2 represents the locational structure of the market model. The three zones are marked in black, and the scheduling points are marked by white dots. The red lines mark transmission lines. In principle, forward energy could be sold at a different price at each node of this model. In practice, however, only the three zones tended to have different prices.[36] If a company outside California wanted to sell energy into California, it first had to set up bilateral contracts to deliver the energy to one of the scheduling points in California.[37] From there, it could then sell the energy into the other markets—except in CAISOs real-time markets, which required that the seller have physical control over the asset. The geographic structure allowed markets to allocate energy across the Western Interconnection optimizing the mix of generation across the entire region, but it also ensured that energy that was traded close to dispatch belonged to resources that could be controlled by CAISO.[38]

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[35] "California Electricity Market Primer," 5.
[36] "California Electricity Market Primer," 4.
[37] The out-of-market trades for real-time operation in CAISO are the exception. Otherwise, the rule was: "Traders wishing to sell or buy in the PX market from remote locations arrange to make or take delivery of their energy at these points." See "California Electricity Market Primer," 3.
[38] The improvement on schedules through the imbalance markets, particularly how the resources were selected, is explained below.

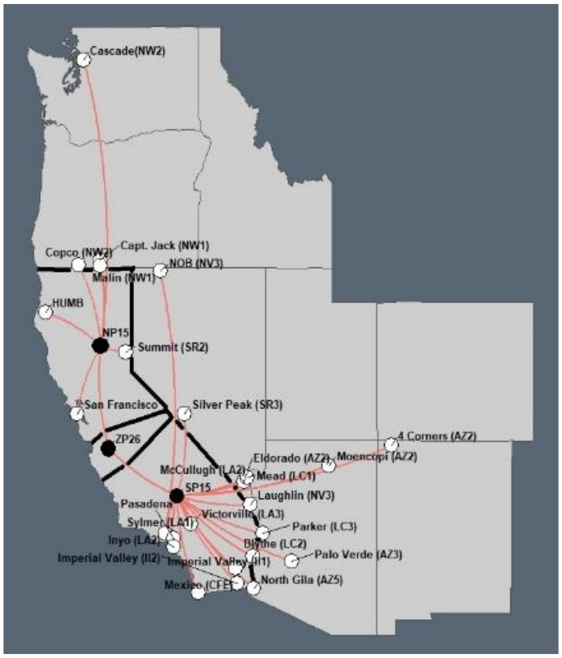

Figure 5-2 – California's Simplified Network Structure

In sum, California's markets were differentiated by time and geographic reach. The sequential structure allowed market participants to arrive at iteratively refined schedules and pushed the system toward a solution to the unit commitment problem. The different geographic structures of the markets made sure that the system could import/export energy, while also ensuring that the PX and CAISO markets dealt with resources that could be controlled from within California and could therefore be used for real-time grid management.[39]

Finally, the system was divided into a wholesale and a retail level. There was one major technical reason for this distinction. End users usually did not have the necessary equipment to learn about wholesale prices in real time. They simply used energy and paid at the end of the month. In order to create competitive wholesale markets with elastic demand, it was therefore necessary to split the production and the consumption segment of the industry. The retail markets

[39] This requirement was the target of several of Enron's games. Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 145-61.

covered the sale of energy to end users over the distribution network, while the wholesale side covered transactions in the high-voltage transmission system. Consider the retail level first. The utilities and other ESPs sold energy to end users through the local distribution network. They sold delivery contracts to end users, metered their consumption, and billed them. Most retail customers either had contracts with flat prices for kw/h of energy, or a simple peak/off-peak tariff.[40] In other words, retail customers typically only knew at the end of the month how much money their electricity had cost, and this energy was priced by simply multiplying the total monthly use with a flat tariff. End users could be individual households, or they could be community aggregates such as neighborhoods, universities, cities, or districts. Retail sellers, so called Energy Service Providers (ESPs), made money by selling energy more expensively to the end users than what they purchased it for in the wholesale markets.

Before the retail markets went live in 1998, the CPUC launched an $80 million public information campaign to inform consumers that they would be able to choose a new supplier when the market opened. When the markets opened, a variety of ESPs entered the new market.[41] But despite a promising start, not many small commercial and residential consumers decided to switch over from their original utilities. Accordingly, the retail markets never really got off the ground. This had partly to do with the fact that AB1890, the law initiating restructuring, had implemented not only a retail freeze until 2002, but also a 10 percent rate reduction for small commercial and residential customers.[42] This made it hard for new entrants to compete meaningfully with the incumbent utilities, so customers had little incentive to switch. At the height of retail competition,

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[40] Borenstein, "The Trouble with Electricity Markets: Understanding California's Restructuring Disaster," 196.
[41] By 2000, there were thirty-four ESPs. Retrieved from 01/01/2000 version of the Power Exchange website, archived through ArchiveX.
[42] Lambert, *Energy Companies and Market Reform: How Deregulation Went Wrong*, 150.

only about three percent of retail customers had contracted with an ESP.[43] During the crisis, many users even switched back to the utilities because the rate freeze prevented the utilities from imposing the high wholesale prices on the end users. California's retail markets thus continued to operate largely as before: customers simply used electricity as they always had, without much regard for the new competitive market place. The utilities ended up serving about 88 percent of California's aggregate demand. Since the retail markets formed a largely static structure, they remained relatively unimportant for the day-to-day operation of the California system.[44] Most business took place in the sequential wholesale markets. Since the utilities had to purchase their energy in the PX, these spot markets became the de facto center of the wholesale markets.[45] Here, a variety of buyers and sellers came together to trade electricity for direct consumption in industrial contexts or for resale in the retail markets. Three classes of players existed in the wholesale markets. First, there were *producers* of electricity. These were entities that owned generation assets in California or in the Western Interconnection. Producers formed a diverse group of state and private actors. On the private side, it included a large group of independent power producers who owned small but efficient fossil fuel and renewable energy plants as well as the energy companies that had purchased the in-state fossil power plants from the three incumbent utilities. These energy companies were Duke Energy, Southern Energy, Calpine, AES, Houston Industries, NRG, and Thermo Ecotek. Outside California, a variety of vertically integrated utilities could sell into the California

[43] Joskow, "California's Electricity Crisis," 376.
[44] Nonetheless, the structure of the retail markets formed an important backdrop to the wholesale markets. Though the retail side was linked only indirectly to the wholesale markets, the system had been developed with the idea of a highly competitive retail market in mind. In such a competitive retail market, customers would have distributed evenly across a variety of ESPs. In that case, the financial integrity of the utilities would have had less systemic importance. In addition, the must-buy requirement would not have been as detrimental. They would have had to buy much less energy out of the PX, and the ESPs were not forced to procure their energy there. With competitive retail markets, the PX would not necessarily have been the most central location in the wholesale markets.
[45] See, for example, comparative transaction volumes in the PX, "Electricity Markets of the California Power Exchange, June 1999," 21.

markets. Public entities included municipalities, such as the Sacramento Public Utility District and the Los Angeles Department of Water Resources, and Public Power Authorities like the Bonneville Power Administration. Since the municipalities had not handed control over to CAISO, they could buy energy from the grid or sell excess energy from their own production. Irrigation districts and factories also sometimes sold power to the grid. When the crisis hit, the prices soared so high that it sometimes became more profitable for factories to shut down their production and sell the output of their (oil) generators to the grid.

The second class of market participants were buyers who sold the energy to end users or consumed it themselves. The most important buyers were the three utilities because they satisfied most demand in California. The law that had established deregulation contained a "must-buy" clause that forced the three utilities to procure all their energy in California's auction markets. Discounting old long-term contracts and generation from their own sources, the three utilities effectively satisfied 90 percent of their daily power needs in the PX and CAISO markets.[46] Besides the utilities, some industrial "direct access" customers also participated in the markets to buy bulk energy for consumption in production processes. The last group of buyers were the increasingly smaller group of ESPs who tried to sell energy in the retail markets. Outside California, several utilities also occasionally bought power from California. During the crisis, when the prices soared everywhere in the West, exports from California increased when the ISO started to implement price caps, and higher prices could be obtained in other parts of the Western Interconnection.

The third class of market participants were power marketers. Power marketers did not own generation assets and did not consume electricity. Instead, they made profits by buying and selling energy between locations or time-points—that is, they were speculators who benefited from

[46] Borenstein, "The Trouble with Electricity Markets: Understanding California's Restructuring Disaster," 199.

arbitrage opportunities that existed between the different markets (either by location or by time). This had two functions: On the one hand, they were supposed to increase the liquidity between the different market places that scheduling coordinators ran. They would also identify price differences between the markets with different temporal horizons and eliminate them, thus improving the efficiency of the various market linkages. This, in turn, helped the markets to converge on a solution in the search for the economic dispatch. The power marketers were thus a tool of information distribution and convergence between the different marketplaces, helping the overall process to operate with perfect information.[47]

It is important to note that the market design intended to limit the role of power marketers in the forward markets outside CAISO. They were supposed to help buyers and sellers find hedges and improve the markets' liquidity. As such, they had been conceived as purely financial players and were not supposed to enter the markets that the ISO used to balance the system. These markets were developed as "physical" market places where sellers had to control the generation assets whose outputs they sold (see above). The point of this restriction was to ensure that CAISO would have operational control over the physical assets that were sold in its markets. The forward markets outside the CAISO, in contrast, were financial markets whose obligations would enter CAISO's system as just an approximation to the actual dispatch structure in real time.[48]

The group of power marketers included financial trading firms like Enron or Calpine, but also unregulated affiliates of the three big utilities. Not all members in this group acted exclusively

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[47] There were several other functions that they played apart from improving the search for the ideal unit commitment: they could act as financial intermediaries hedging price risks for consumers, they could manage energy purchases for disaggregated buyers, help with congestion management, as well as the provision of ancillary services. Stoft, "What Should a Power Marketer Want?" 36.
[48] Borenstein et al., "Inefficiencies and Market Power in Financial Arbitrage: A Study of California's Electricity Markets," 10-13.

as power marketers. Some of the companies that owned generation assets also had wholesale trading desks and some power marketers had affiliate companies that owned generation assets. The LADPW, for example, had a wholesale trading desk despite being a municipality with generation assets. Usually, large holding companies unified corporate entities that could fall into either of these groups. In particular, each of the three utilities had parent companies that also ran subsidiary trading organizations. Such "unaffiliated subsidiaries" confronted the utilities as sellers in California's markets. Despite these connections, the power marketers formed a distinct group of market participants because their only goal was to move financial obligations around to make money. This group of players developed most of the manipulative schemes that undermined the functionality of California's market mechanisms.[49]

The three types of players could now interact with each other in a variety of different wholesale markets. Scheduling coordinators (SCs) operated each market and served as intermediaries between buyers and sellers. Between 1998–2000, there were around thirty such SCs that ran different types of markets. Most SCs worked as brokers and facilitated bilateral contracts between buyers and sellers.[50] Such contracts would establish an obligation to deliver a quantity of energy at a particular location at a future point in time or for a period of time in the future. As outlined, these could differ with respect to time frames and geographic reach. Contracts could refer to dates that were several years ahead to about a week in the future. In the Western Interconnection, most wholesale energy trades took place through longer bilateral agreements. In California, short-term contracts with delivery between one and seven days prevailed. Though there were a variety of SCs in California, the most important SC was the PX.

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[49] Sheffrin, "Empirical Evidence of Strategic Bidding in the California Iso Real-Time Market."
[50] Many of them also simply acted on their own behalf, selling energy from affiliated producers.

All SCs had the same function: they generated financial obligations between buyers and sellers and aggregated them into balanced schedules. A balanced schedule was a table that showed how all buyers were going to be served by all sellers. Imports, exports, production, and consumption needed to cancel each other completely. These schedules were submitted to CAISO, where the operators tried to implement them as closely as possible in real time.[51] To deal with deviations that occurred in real time, CAISO used a real-time market to buy and sell resources that it could use to implement necessary schedule revisions. The resulting market structure is outlined in figure 5-3. The figure shows how wholesale sellers and buyers engage with each other in different bilateral and auction markets. When the SCs have completed auctions and bilateral agreements, the SCs send their schedules to CAISO, which used its submarkets to run the grid in real time.

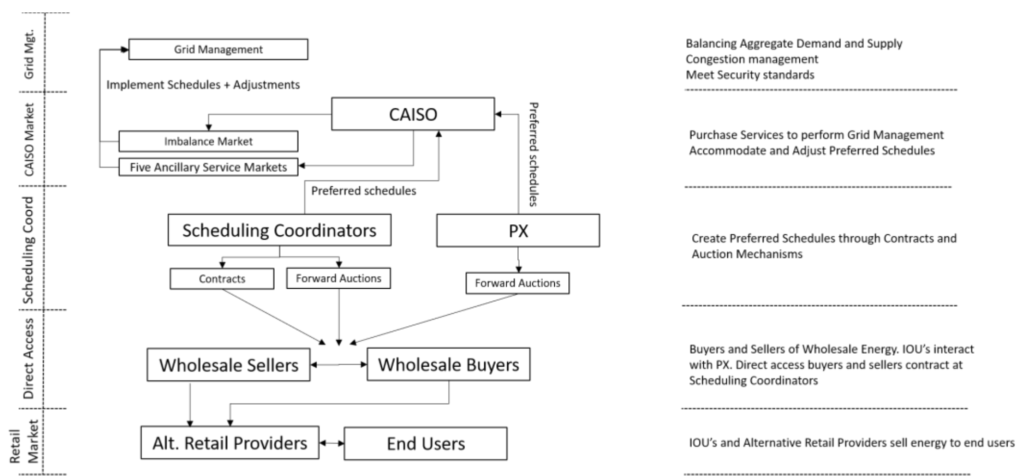

Figure 5-3 – California's Market Structure

The basic logic behind this setup was the following: The temporally differentiated markets would find approximate solutions to the unit commitment problem. The broader geographic markets made sure that this solution included resources from the Western Interconnection as a whole,

[51] CAISO, *Annual Report on Market Issues and Performance*, (CAISO: Folsom, CA, June 1999), http://www.caiso.com/Documents/1999-2000AnnualReportonMarketIssuesandPerformance.pdf, last accessed: 03/16/2020, Chapter 2.3.

while the more limited markets in California ensured that CAISO would be able to physically control the resources in real time. The power marketers were supposed to discover price differences between the SCs and the sequential markets. Resolving those price differences through arbitrage trade would allow the system as a whole to converge on an increasingly accurate solution to the unit commitment problem. Their trades would spread information among market participants and increase the competitiveness of the markets, thus increasing liquidity and the pressure to sell at marginal cost rates. In the end, these results are submitted to CAISO, which uses its own, restrictive markets to buy and sell supply that is needed to make real-time adjustments. Finally, the difference between actual and financial energy flows are settled retrospectively, completing the two-settlement system.

So far, I have described how markets with different temporal and geographic reach hang together. I have also explained how different market participants interact in these markets and how the resulting schedules are submitted to the CAISO. To implement this architecture, the designers relied on a control structure with several different levels. Retail customers who bought energy from utilities and ESPs represent the lowest level in the hierarchy. The CPUC and the CEC oversaw these retail markets. The CPUC regulated the retail markets and the way the local distribution system was managed by the utilities and municipalities. In particular, it enforced the rules regarding the contractual relationships between retailers and customers. The CPUC and the CEC, in turn, were overseen by the California government. Wholesale markets occupied the next higher level. Here, the utilities, the ESPs, and “direct access” customers purchased wholesale energy from producers and power marketers. The entities that organized, monitored, and controlled these wholesale markets were the SCs. They oversaw the transactions and facilitated and implemented billing and settlements.[52] Above the wholesale markets was CAISO, which evaluated the outputs of the markets in terms of the technical requirements and then implemented the resulting schedules in real time. CAISO's monitoring units monitored not just CAISO's spot markets but also the transactions of the scheduling coordinators as they were submitted to CAISO's software infrastructure. FERC oversaw CAISO as well as all scheduling coordinators. FERC, in turn, was accountable to congress. Each organization could be split into further levels and different responsibilities, but this picture gives a first orientation for the way the California system was set up in terms of monitoring and control. Each level imposed constraints on the lower level, enforcing the market mechanism that would solve the unit commitment problem and set the incentives for the correct investments. As figure 5-4 indicates, CAISO was effectively the entity that executed centralized oversight of the wholesale markets. While the SCs managed their respective transactions, all data ultimately had to be submitted to CAISO, which implemented the schedules, operated the system in real time, monitored energy consumption, and provided the final settlements. Its monitoring units had the most comprehensive view of the system, and its operating room had the most control over the system's resources in California. Hence, we have now reconstructed how the markets related to each other and how they were differentiated by time and space.

[52] Some of the activities of wholesale market participants were monitored not just by CAISO and FERC, but also by the CEC and the CPUC. The CEC was a policy and planning agency responsible for managing regulatory issues connected to the maintenance and expansion of generation and transmission capacity. It conducted research relevant for the expansion of the system and was responsible for the analysis of proposals to build additions to the existing infrastructure.

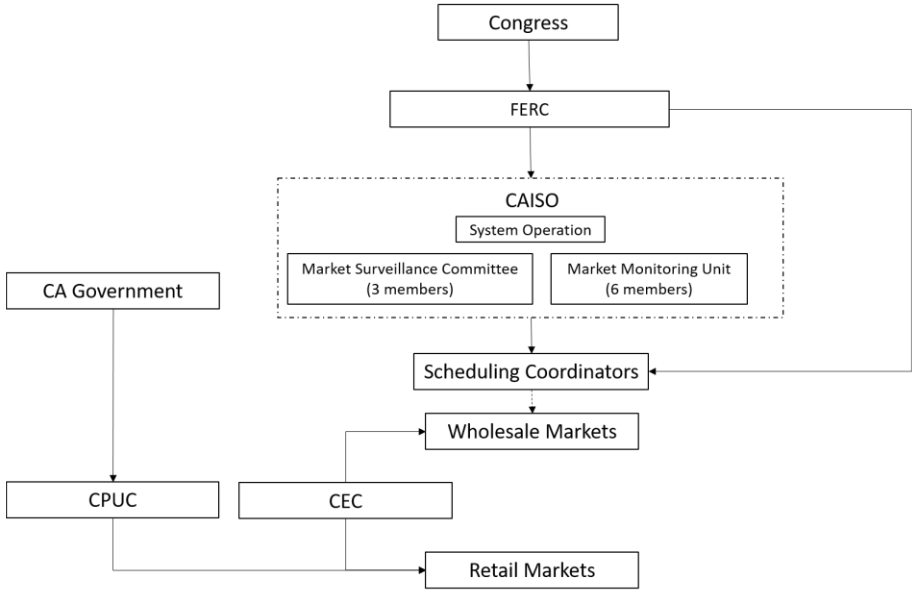

Figure 5-4 – California's Control Structure

The picture is almost complete, but we are still missing a few more pieces.[53] First, we have not yet discussed how the markets took transmission capacity into consideration. As I have outlined in the previous section, the optimal dispatch of generation requires that transmission constraints are taken into consideration. Second, we have not accounted for the fact that the optimal dispatch does not just require pure energy, but a variety of additional services are required to maintain security standards as well. This necessitated a variety of submarkets that operated partly sequentially, partly in parallel to each other. Lastly, I have only provided the roughest idea of how the basic market mechanism actually worked and how it was implemented. The answers to all three questions hang together, so it is necessary to increase the complexity of the discussion somewhat. The closer the moment of dispatch, the more structure was imposed to enforce the correct market process. As less and less time remained until the schedules had to be accurate, there was

[53] The following discussion is reconstructed from the detailed descriptions in the submissions of the California Independent System Operator Market Surveillance Committee in *FERC* ER98-2843, Chapter 2 of the annual report of CAISO from 1999, and the detailed descriptions of "Reports of the Market Surveillance Committee Meetings," R400.006-R400.007, Folder 1-12, Box 12, *CSA*.

less and less room for market imperfections. Accordingly, the basic pricing mechanism changed. Similarly, most of the markets for reliability products were short-term markets and the attempt to include transmission capacity into the market was also limited to short-term transactions.

The easiest way to understand how the different markets hang together is to differentiate them by product and then show how transmission capacity is included as we get closer to dispatch. Figure 5-5 lists the different sub-markets that take place at different time points.

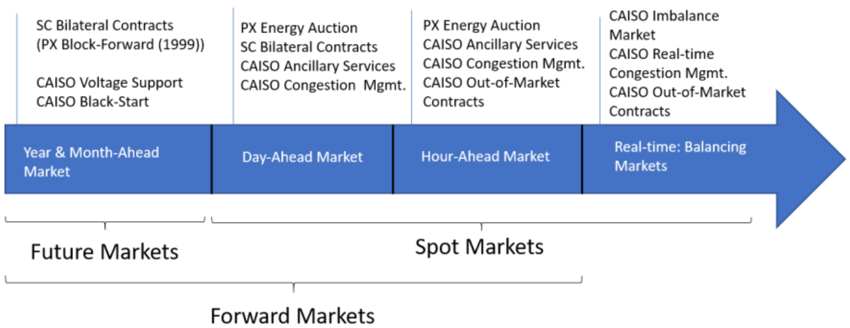

Figure 5-5 – Temporal Structure of California's Energy Markets

In the year and month before dispatch, customers could mainly buy bilateral contracts for firm and non-firm energy. Firm energy is energy that which will always be delivered. Practically speaking, this is energy that is backed up by capacity reserves. If a generator cannot deliver this energy, another backup generator will. Non-firm energy is interruptible, i.e., it is not covered by reserves and might be scaled back by the system operator.[54] Firm/non-firm energy were the main products sold across the different energy markets. They represented practically all bilateral contracts and constituted most of the trade volume in the system as a whole. Nonetheless, there were a few other products that could be traded in the long term: In 1999, the PX launched a "forward market" where utilities could buy blocks of capacity for delivery on all days of the week for a

[54] The main difference between firm- and non-firm energy is whether or not CAISO must procure replacement reserves to prevent the curtailment of firm energy.

given month. This product was meant to help utilities find long-term contracts for a piece of their daily baseload. For reasons yet to be discussed, this market remained marginal throughout the PX's existence. The ISO also introduced a yearly auction for firm transmission rights (FTRs) in 1999, which entitled the bearer to congestion revenues if they could not send their capacity on a particular line.[55] This market was designed to hedge the price risk of high transmission capacity costs. It could also be used to indicate where expansion to the transmission grid were necessary. In addition, the ISO bought two special ancillary services, Voltage Support and Black-Start, through long-term contracts.[56]

All of these products were functionally important, but did not constitute large markets. Bilateral contracts for firm and non-firm energy dominated the longer time frame frames before dispatch. Apart from administrative rules established by FERC, the contract markets were not specifically designed. The block-forward markets and the FTR markets were designed as centralized auctions to ensure that enough buyers and sellers would come together to guarantee competition and to make information centrally available to all participants.[57] Restrictions only began to apply as the results of these markets fed into the PX/CAISO interfaces, where they needed to meet technical requirements. Until we reach the day-ahead market, there were thus relatively few restrictions on the markets, and merely the presence of power marketers and scheduling coordinators ensured

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[55] FTRs are essentially hedges against congestion and work like swaps, while transmission capacity rights are used to establish the redispatch under congestion, assigning the transmission capacity to those generators for whom it is most valuable.

[56] Most generators require energy from the grid to get going. Black-start capability is a generators' ability come back online even if it cannot draw on any external energy. Voltage support is a service necessary to deal with voltage drops that occur as power flows from generators to load. It can be counteracted by the injection of "reactive power" into the grid. Reactive power has special physical characteristics and can be provided by capacitators as well as generators. For generators, the cost of providing reactive power is mainly the opportunity cost of not providing regular power. "Report on Market Issues in the California Power Exchange Energy Markets, prepared for the Federal Energy Regulatory Commission by the Market Monitoring Committee of the California Power Exchange," August 17, 1998, *FERC* ER98-2843, 4-5.

[57] I am not going to cover these auctions in detail here because they did not belong to the initial set-up in 1998.

that the market process met the conditions of rational trades, perfect information, and perfect competition. Nonetheless, since the markets were small and far removed from the moment of dispatch, the amount of control over the contract structure and individual transactions was limited.

But as we arrive at the day-before dispatch, the main markets are located in the "spot" markets of the PX and CAISO. These markets were closely related to the tasks of the system operator and operated with different rules than the bilateral markets of the other SCs. Since they constitute the core of the system, it is important to consider their structure and products in detail.
The PX ran two principal auctions for firm/non-firm energy. In these auctions, buyers and sellers traded energy for delivery in the next hour (hour ahead) or the next day (day ahead).[58] Both auctions were "two-sided" and generated a single market clearing price. In a two-sided auction, both buyers and sellers of energy submit bid schedules that indicate how much energy they wanted to buy or sell at different locations for each hour of the day. These schedules consisted of "single-price" bids. For each hour, a company would submit a curve that indicated how much they would be willing to sell or buy a given quantity of energy for. This meant that the generators had to condense their complex considerations in terms of the best way to operate into a simple supply curve. Once everyone had submitted their step-functions, the PX's auction software aggregated them into a downward sloping demand curve and an upward sloping supply curve. It effectively stacked the different bid quantities by price to generate these curves. The intersection of the curves then determined the market clearing price.

The mechanism to arrive at the single-market clearing price provided incentives for generators to bid their true marginal costs. It followed the basic structure of a Vickrey auction and was

[58] In 1999, the PX also introduced Block-Forward Markets, where utilities could buy energy for longer time periods.

based on the “revelation principle.”[59] The clearing price was set equal to the last offer necessary to meet aggregate demand, but quantities would be sold in ascending order: the cheapest generator would get to serve the most demand, and so on, until all demand was met. Since all generators received the same price, and since they could sell more if they bid lower than others, they had an incentive to go as low as possible—i.e., to their marginal costs. In other words, the cheapest generator would be able to sell most at the price of the most expensive generator necessary to meet the last MW/h of demand. The result of the auction would be a schedule that told everyone how much they would be producing or consuming and how much they had to pay or would be paid. Like all SCs, the PX generated a balanced schedule.[60] In the hour-ahead market, the auction would be repeated and companies got a chance to adjust the schedules from the day-ahead market.

The centralized auction format had several advantages. By fixing the temporal horizon of the markets (hour-ahead, day-ahead), the PX enforced the consistency of a company’s calculations: they would all operate against the same temporal horizon of decision-making. Further, by enforcing a standardized product and creating a centralized market for it, they ensured that the markets would be liquid, i.e., there would always be many buyers and sellers, exchanging standardized obligations. The must-buy requirement for the utility furthered the competitiveness of these markets. Lastly, the PX and CAISO published information on the outcomes of the auction and the demand in the system, thus ensuring perfect information and players’ ability to act rationally. With three-month delays, the PX also published anonymized information on bidding behavior

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[59] It was a multi-unit auction with complementarities, which created several problems for the Vickerey format, c.f. Natalia Fabra, Nils-Henrik von der Fehr, and David Harbord, "Designing Electricity Auctions," *The RAND Journal of Economics* 37, no. 1 (2006): 23-46. The pure Vickery auction is a sealed-bid, second-price auction and thus has a slightly different structure.

[60] This included imports, exports, and transmission losses. “CAISO Annual Report on Market Issues and Performance June 1999,” R401.006, Box 7, *CSA*, Section 2.4. (Henceforward CAISO Annual Report 1998).

that allowed companies to better understand how clearing prices had been created, further teaching them how to behave rationally. Lastly, since the auction took place via the software interface of the PX (which also connected to the CAISO markets), the bids always conformed to the basic structure required for the auction mechanism, and the monitoring units could observe in real time how the different players in the system behaved. The day-ahead markets were thus tightly controlled systems whose rules and interfaces were set up to enforce the rationale of perfectly competitive markets.

PX's day-ahead schedules, combined with the schedules of all other SCs, provided the baseline for CAISO's management of the grid. To perform its management functions, CAISO operated several auctions of its own, each for a different product. The most important market was the real-time energy market, also called imbalance market, which provided energy for instructed and uninstructed deviations from the last schedules created by the markets (i.e., the hour-ahead schedules). This market provided the resources for CAISO's core activity. To adjust the system to changes in consumption (load), transmission constraints, and unforeseen contingencies, the system operator monitored all power flows and adjusted them by incrementing ("incing") and decrementing ("decing") generation assets. This activity was so central to everything the system operator was doing that the operators had created a jingle around it. In honor of the CEO Jeffrey Tranen when he left in 1999, the staff enacted a musical loosely based on Mary Poppins. One of the songs had the following chorus:

> Just a stack full of dec bids helps the frequency go down,
> The frequency go down, the frequency go down.
> Just a stack full of dec bids helps the frequency go down.
> In the California way.[61]

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[61] O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 219.

The imbalance market generated prices for energy resources that the ISO could use to "inc" and "dec" resources. Since this balancing activity took place in the minutes before dispatch, the ISO only accepted bids from sellers who had direct control over their generation assets. This explains the limited geographic reach of these markets, and practically excluded power marketers who did not own the generation whose outputs they sold.[62] In contrast to PX's markets, the imbalance market was not a two-sided auction. In the hour-ahead market, market participants would submit so-called "supplemental energy bids" to the ISO. These informed the ISO how much a generator was willing to increase or decrease their output at a given price. The ISO then stacked the bids up and selected them in increasing order of their prices as it needed them. This created a resource stack the operators could draw on, while still setting incentives to bid as low as possible. Much of this system was automatic: every hour, the Balancing Energy and Ex-Post Pricing (BEEP) software computed the supply stack using the bids for that hour. This would result in a set of energy quantities from different resources, ordered by price. Within that hour, the system then used energy from this bid stack to correct energy imbalances every ten minutes. It selected resources in the bid stack not just based on price but also based on the technical characteristics of the resources (time delay, ramp rate, etc.). Every ten minutes the computer would use updates on system conditions to select resources from a stack of so-called "supplemental energy bids." Scheduling coordinators collected these bids from their market participants in one of the forward markets. The CAISO operators would check the BEEP computations and then approve the dispatch correction. The price for the resources would not simply be equal to the supplemental energy bids. Instead, it was calculated on the real-time energy bid of the marginal unit dispatched in the ten-minute interval

[62] One of the manipulative strategies was designed to find a way around this restriction. Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 148.

(again, to incent least-cost bids). CAISO then paid or charged these ten-minute prices for the dispatched increments or decrements, respectively.[63] In addition, every hour the BEEP software calculated a quantity-weighted average of the ten-minute prices as the hourly real-time ex post energy price. All random fluctuations or "uninstructed deviations" from schedules, by loads or generators, were settled at the hourly ex post price. In other words, if companies diverged from their approved schedules by producing more or less than they had promised, they would be charged or paid at this average ex-post price. This price was an average to incent producers to submit schedules that were as accurate as possible. This system made sure that the ISO always had resources it could draw on to adjust the system and that any uninstructed deviation, i.e., any deviation from the schedules not approved by the CAISO, was priced by the market. At the same time, the system incentivized lowest-cost bids and accurate schedules. The structure of the markets meant that players had two different ways of entering the real-time markets for firm/non-firm energy: They could submit supplemental energy bids through their scheduling coordinators, or they could take a passive position in the market by diverging from their schedules.

Apart from the imbalance auction, there were two other important mechanisms to procure firm/non-firm energy. First, the ISO had created a special class of Reliability-Must-Run contracts (RMR contracts) that made it possible to force generators to produce either energy or ancillary services in so-called "load pockets," i.e., areas where the structure of transmission usage did not allow any other generators to serve demand. When such contracts were invoked, generators were not paid according to the market price, but according to a preestablished contract price. This was supposed to deal with situations when transmission constraints removed all substitutes for a given

[63] These dispatched quantities are called "instructed deviations" and are dispatched by the ISO to meet the systematic and predictable variations from the schedule mentioned above.

generation asset.[64] The RMR contracts made sure that generators without competitors would be unable to increase the market clearing price above competitive levels. When generators were called to provide energy on RMR contracts, they bid the RMR capacity at a zero-dollar price into the forward markets and were paid separately. Their zero bids drove down the market clearing price and thus adjusted the price to the existence of this separate contract market.

Lastly, the ISO had an out-of-market mechanism. If the imbalance market did not provide the necessary energy to serve demand, operators could strike bilateral agreements in the last few minutes before dispatch. Though the out-of-market purchases were supposed to follow the market clearing price, the operators could move beyond that price. Though these markets also allowed competitive forces from outside California to depress imbalance prices, they were really meant as a sort of last resort if everything else failed. Accordingly, these markets became important during the crisis when they turned into a last resort for the desperate operators—and an El Dorado for power marketers, who could ask practically arbitrary prices from them.

Apart from the imbalance market, the ISO also operated four "ancillary" markets. The products sold in these markets served essentially as contingency reserves.[65] For each of these services, the ISO bought the right to call on generators to provide particular types of outputs within specific time horizons. The ancillary services thus served as standby capacity that the ISO could call on in case of contingencies not anticipated, e.g., line failures, generator outages, etc. The four different types—spinning reserves, non-spinning reserves, regulation, and replacement reserves—

[64] There were two main types of RMR contracts called "contract A" and "contract B." They created different kinds of problems for the other markets. The RMR structure was reformed several times, c.f. "Report on Redesign of Markets for Ancillary Services and Real-Time Energy, prepared by the Market Surveillance Committee of the California ISO, March 25, 1999," *FERC* Docket ER98-2843, 18-26.
[65] "CAISO Report on Management Assertion Relating to Ancillary Services Management, Balancing Energy and Ex-Post Pricing, and Congestion Management Systems, May 27, 1998," R401.005, Box 6, Folder 4, CSA, 3-5.

all refer to resources that can come online quickly to deal with emergencies. Spinning reserves can come online within ten minutes of being called; non-spinning reserves take thirty minutes, and replacement reserves take longer than that. Regulation refers to automatic generation control—generators automatically notice if there are tiny load fluctuations on the grid and change their output to “regulate” the frequency. Regulation has the highest quality of these services because it is fastest and technologically most demanding. The other services decrease in quality the longer the time horizon—the non-spinning reserve is a less demanding service than a spinning reserve. A generator that can provide a high-quality service can usually also provide a lower-grade service. For each service, the ISO ran separate auctions whose interfaces were integrated with the day- and hour-ahead auctions at the PX. After each day- and hour-ahead market cleared, the market participants entered a separate market where they could sell any or all of the four ancillary services. The interface asked them to specify how much capacity of each service they had available and how much energy they were willing to sell, using that capacity. The markets were then cleared sequentially, based on the capacity bid component only, from the “higher quality” to the “lower quality” services: first regulation, then spinning, then non-spinning, and finally replacement reserves.

Again, the auctions were single sided. The ISO established how much of each service it needed for the next day or hour. The required amount depended on the anticipated discrepancy between scheduled and real-time production/consumption and the balance of firm/non-firm energy. Accordingly, the estimate was based on security standards as well as information from the day-ahead and hour-ahead markets. After determining the required quantities, CAISO ordered the bids by price and set the market clearing price to the marginal unit necessary to clear the market for the first service. If a unit was awarded capacity in this market, any bids from the unit to supply services in subsequent markets were adjusted to account for the capacity awarded to the unit in a previous market. In other words, if a unit was selected for a particular service, it could not also provide a lower quality service in the next market. Conversely, higher quality capacity not selected in one market moved over into the next, where it was then bought as lower quality service.[66] Generally, generators could decide to offer ancillary services in addition to, or instead of, energy. If their firm-/non-firm energy was not bought, their ancillary services might be. Conversely, if their ancillary services were not needed, they could sell the energy in the imbalance market. If the ancillary services were drawn on, they were paid according to the imbalance market price on top of the premium they received by selling them as ancillary services. This had the advantage that the generator would get paid twice: once for the supplemental energy, once for the ancillary services. But since the ancillary services would not be drawn on before the imbalance energy was used, the decision to sell as ancillary service ran the risk of not being selected to run. The complicated structure of the ancillary services had to do with the fact that most of the services were standby capacity that could usually be sold in the energy markets. To ensure that the most effective generator would be available to meet the demand in the system, the markets had to be structured in such a way that an effective generator always had an incentive to bid into the regular energy markets. If it was efficient to use them, the market price had to be sufficient to attract them. But if they were not necessary, they needed to have incentives to enter the ancillary markets. The complicated way in which they could be paid twice but might not be chosen struck a balance between these two requirements.

[66] The structure of the ancillary markets as outlined here was only valid in 1998. It created significant problems and was reformed multiple times. Since my purposes here are expository, I will not account for the changes, but relate them later in the dissertation when they are relevant. C.f. "Report on Redesign of Markets for Ancillary Services and Real-Time Energy, prepared by the Market Surveillance Committee of the California ISO, March 25, 1999."

Finally, the ISO also operated an implicit market for transmission rights that interacted with both the hour- and the day-ahead market at the PX.[67] Recall the problem of transmission congestion. If it turned out that the market's dispatch schedules violated transmission constraints, the schedules had to be adjusted to put the system back into balance. Generators that would ordinarily sell their output had to be backed off and other generators whose transmission to the customers was not blocked had to step up their production. Congestion is thus a conceptual fiction that indicates a discrepancy between the market schedules and the physical flows of energy: there is not enough transmission capacity to implement the schedules the markets have produced. In principle, such congestion can occur anywhere in the physical grid—the real network that consists of thousands of buses and lines connecting them. Since such congestion depends on the global patterns of all inputs and outputs, it can change at any moment. Given the complexity and temporal instability of congestion patterns, the system operator needs to resolve congestion in real time on the basis of software that monitors all power flows and adjusts the system as necessary. However, some sources of congestion occurred frequently enough to be predictable. Such congestion could therefore be represented in a simplified network model and resolved through a market for transmission capacity. As outlined, the PX and CAISO markets did not use a complete network model for the market, but a simplified representation that aggregated the network into several "zones" and twenty-six scheduling points where the grid intersected with the rest of the Western Interconnection. The CAISO thus had a two-stage system to deal with transmission constraints.

If the day- or hour-ahead market generated schedules that violated transmission constraints between the zones of the simplified model, market participants entered CAISO's implicit market

[67] Based on "CAISO Report on Management Assertion Relating to Ancillary Services Management, Balancing Energy and Ex-Post Pricing, and Congestion Management Systems, May 27, 1998," 24-33.

for transmission rights. Here, the congestion represented by the zonal model could be resolved. Once the market had taken care of such "interzonal" congestion, the ISO would merely have to deal with the remaining "intra-zonal" congestion on paths not represented in the market model of the network. The resulting congestion management had several steps.

When CAISO received the day-ahead schedules, it used a simplified DC power flow model that simulated the feasibility of the combined schedules on the network paths that characterized the zones.[68] If there was no congestion, the ISO accepted the schedules and the transportation costs were zero. But if there was, the ISO would conduct an implicit, day-ahead auction for transmission rights. See figure 5-6 for a schematic representation of the different steps.

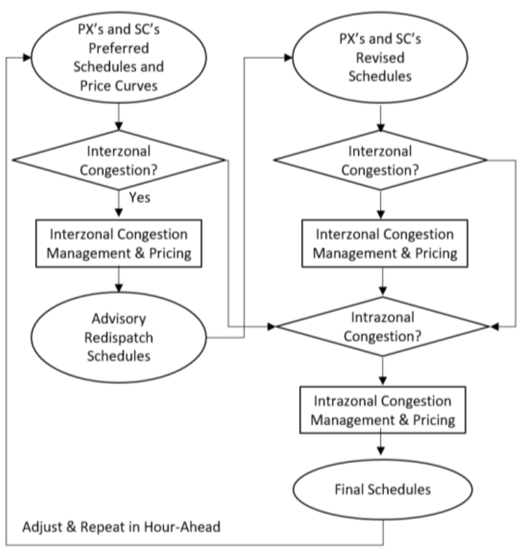

Figure 5-6 – California's Congestion Management

To participate in this auction for transmission capacity, the traders submitted "Schedule Adjustment Bids" (SABs) with their day- or hour-ahead energy bids in the PX. These bids indicated how much more or less the traders were willing to sell from each supply resource or buy at

[68] Paul R. Gribik, George A. Angelidis, and Ross R. Kovacs, "Transmission Access and Pricing with Multiple Separate Energy Forward Markets," *IEEE Transactions on Power Systems* 14, no. 3 (1999): 867.

each delivery zone or scheduling point if the market clearing price were to change as a result of congestion.

For example, assume a generator in zone 1 wants to sell a quantity of energy at $10/MW to a load in zone 2. If the link between zone 1 and 2 becomes congested, the generator would either have to buy replacement energy in zone 2, or it would have to buy transmission capacity. Traders are willing to pay for transmission to the extent that they can still make a profit on the underlying energy transaction. The bids express this ability to profit, and the ISO determines who would benefit most from the capacity.

The congestion management software (CONG) would use the schedule adjustment bids as an indication of the value that transmission had for the different market participants. In determining the redispatch that was necessary to relieve the congestion that would result from the schedules, it set the price of transmission capacity to the highest value someone would place on it (i.e., to the marginal value for the user with the highest opportunity costs). It would then organize the redispatch around this preference ordering. Hence, those who valued the transmission most highly would get transmission while others would be compensated for redispatch. This calculation also included counterflow trades and resulting payments that would increase available transmission. Specifying the "right" adjustment bids was easy. To determine profitable trades, traders simply had to specify at what level of price difference between their location and any other location they would want to buy transmission or change their schedule.

In the next step, the system operator submitted the "advisory redispatch schedule" as well as the prices for transmission service to the scheduling coordinators, who had an option to adjust their schedules in response (though they could not adjust their price bids). Based on the revised schedules submitted by the coordinators, the ISO used the same procedure to determine the final day-ahead schedule and zonal prices. These zonal prices were used as market clearing prices by the PX for all PX suppliers and customers and the zonal price differences were charged to all scheduling coordinators (including the PX) as a transmission usage charge applied to all interzonal power flows. The scheduling coordinators could adjust their schedules up until one hour before dispatch, provided these changes could be affected with adjustments to resources that had already been scheduled in the day ahead market. The ISO then ran the same congestion management system again and finally locked the schedules in. Following the finalization of the hour-ahead schedules, the ISO took over and implemented the schedules in line with the operating requirements of the grid. It used the imbalance market that relied on the hour-ahead adjustment bids to resolve the remaining intra-zonal congestion as well as settle deviations from the hour-ahead markets. For the remaining congestion, it would use the full network model to make sure that no remaining congestion would affect the reliability of the system.

The point of this two-stage system was relatively straightforward. The complexity of power flows made it impossible for the market to take all interactions between inputs into consideration. But it was still desirable to reflect transmission constraints in the market because these constraints impacted the optimal dispatch structure. By using a simplified network structure with only a few locations, the markets could include the main sources of congestion in the trading process. This helped to improve on the optimal dispatch the markets estimated. And by pricing scarce transmission capacity, the markets indicated where new additions to the grid were necessary. Since the traders only needed to specify adjustment bids, and since there were only a few locations, including the transmission constraints did not make the calculation of profitable trades much more complicated for traders. It was also easy to disseminate the information to all market participants, and the markets did not fragment into too many locations.

The second stage ensured that the system would always remain reliable operation: Based on the full model of the network and a real measure of all power flows, the system operator would redispatch all resources and thus prevent a situation where too much energy might be scheduled to flow on a particular line. The price of these unpredictable adjustments would then be charged to the system as a whole. With the two-stage system, the market could thus help as much as possible with the allocation of transmission capacity and minimize the adjustments that had to be socialized and implemented in real time. Though the transmission capacity markets required a tight information exchange between the SC's and the ISO's spot markets, it ingeniously integrated the operation of markets with the tasks of grid management. Markets effectively procured firm and non-firm energy, all reliability services, and transmission capacity.

The system operator used this information to optimize the operation of the grid in real time. The auction mechanisms that operated in the short-run created incentives to sell resources at marginal cost. It standardized products, provided the same information to everyone, ensured adequate numbers of competitors, and sent signals where new generation and transmission assets were necessary.

This completes the picture of the California's markets. To recapitulate: The system consisted of intricately linked markets that fed into the task of system management. SCs were responsible for creating balanced schedules and submitting these schedules to the ISO. In the longer term, bilateral agreements prevailed. The closer you moved to dispatch, the more important the markets at the PX and the CAISO became. The highly structured, centralized day-ahead markets generated schedules for the next day, which went through compatibility checks by the ISO. If the schedules were not feasible in terms of the simplified network model, the ISO performed congestion management. Based on the day-ahead schedules, it acquired ancillary services. The hour-ahead markets refined the resulting commitments.

Once the final revisions were locked in, the ISO implemented the schedules as closely as possible, adjusting them relative to the full network model and the contingencies of real-time operation. The imbalance market was used to buy these adjustments. The two-settlement system and the software interfaces ensured that each market improved on the other and created increasingly accurate schedules for the moment of dispatch. The wholesale markets were competitive because buyers only make profits in the retail markets if they find cheaper wholesale rates than they are charging on the retail level. This made them price-responsive. Suppliers were competing because there was usually a variety of sellers who could serve any particular market. The resulting schedules therefore reflected an approximate solution to the least-cost-dispatch problem: the cheapest generators sold the most output, then the second cheapest, and so on until all demand was served. The arbitrage business of the power marketers made sure that the solution transcended any individual SC market and converged on a global solution because they found price differences between market places, locations, and time-points. By arbitraging them, the price differences disappeared and pushed the market to a global solution. This way, the interaction between the three groups of market participants generated schedules that the CAISO could use and that tended to solve the unit commitment problem. High prices indicated where new generation is necessary; congestion indicated where new transmission investments should flow. As real time approached, the other markets made sure that the system operator received the resources to fine-tune the resulting schedules in a least-cost fashion. The integrated system of the different submarkets thus fed perfectly into the task of managing the system in real time. CAISO and PX continuously published information on the auctions, the demand, and various determinants of input costs. This ensured everyone had the same, complete set of information and understood the basis of everyone else's decisions.

The California system can thus be understood as a sophisticated attempt to fulfill the different goals of restructuring. The complicated interrelation between the different PX and CAISO markets should also indicate how much institutional design was necessary to implement the hierarchy of control that constituted the system. Before moving to the next chapter and asking why this sophisticated system failed, I am going to present a fictional example that walks the reader through an ordinary day in the life of a market trader. It shows how the market operated under ideal conditions and brings the somewhat formulaic description to life. The numbers are drawn from a dataset of bilateral energy trades between 1998 and 2000 as well as system information from the PX and CAISO.[69] I chose an arbitrary day in July of 1999, and then modeled the example on those contracts. This time frame shows the system at a moment when it operated close to capacity limits but was functional. Since bidder behavior in the CAISO and the PX was never published, I have to fictionalize the example. Nonetheless, the financial obligations are closely based on the contracts established by a real municipality.

5.4. Interlude: A Day in a Life….

Imagine you are working at the trading desk of a municipal utility in southern California. Your company has about 100,000 commercial and residential customers. To serve them, the city largely relies on energy from outside sources, secured through a diversified portfolio of long-term contracts. The utility buys most of its power from a coal plant in Utah, but it also receives

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[69] Published by the California Energy Institute, retrieved via ArchiveX. Contains hourly prices and quantities for PX and CAISO between 1998 and 2001.

hydropower from the Northwest, geothermal energy from the Salton Sea, and wind power from independent power producers outside Los Angeles. Apart from these external suppliers, the district also owns six natural gas plants that are used for times of peak demand. These plants have a total capacity of 262 MW and can come online in just 15 to 30 minutes. When not otherwise needed, this excess energy can be sold into the new California markets. Since last month, your utility has also decided that it no longer wants to just sell excess energy into the PX and the CAISO. Instead, it will also allow your office to engage in arbitrage businesses. You are now a bona fide power marketer as well as a producer of energy.

Your workday begins early because the day-ahead market in the Power Exchange requires participants to submit their bids by 7 AM the day prior to dispatch. Typically, you sort your bids out the evening before, but today you came in early. Every day, at 6 AM CAISO collects load forecasts for the next day and publishes them. Eager to make some money for the city, you go online and log onto CAISO's WeNet (later: OASIS), which compiles load forecasts, transmission outage and capacity status, market prices, and market result data from the past. You can even see anonymized bidding behavior in the PX and CAISO, published with a lag of three months. Using a website to conduct your business is still a new experience, but it is 1999 and one has to go with the times. As you look through the stats, you get a sense how much energy will be needed today. It is a hot day, and the anticipated load for the system is much higher than usual. It looks like there will be an aggregate demand of around 30,000 MW for some hours during the next day as well as today.[70] With that much load and low hydro reserves in the Northwest, it is very likely that older power plants need to come online. All this is pretty plain from WeNet's list of available generation capacity and your general knowledge of resources in the West, propped up with data on generators

[70] Based on logged demand curves in PX on 07/07/1999 and 07/06/1999.

that is published on a yearly basis by the CEC and the EIA. On a day like this, the older plants will push up the prices and will make it worth your while to sell your natural gas output. So, you might be able to make quite a bit of money if you sell some of it into the forward markets. You go to PX's new software interface—or call the 24/7 trading desk in Alhambra—and submit a portfolio to the day-ahead market.

Your plants are in Southern California, so you list your delivery location as SP15 in case there should be congestion. Your bids have to look like a step function, so you have to decide how much money you'll request for different output levels of your natural gas plants. Their maximum output is 262 MW, but running them at that level will be hard on the engines and probably require extra maintenance. So, you decide to ask for a few hundred dollars at output levels that push you to the capacity limitations. In the efficient output range, it costs about $23 to run your natural power plants because your last natural gas delivery was a steal. But you also have startup costs, and you need to send some people over there to get the turbines going. Since you only plan to produce for three hours after noon when the prices are likely going to be highest, you need to consider the cost of running the generator before it is connected to the grid. To represent these costs, you bid the power in at $35 MW/h. Normally, it would not make sense to include those costs because the market clearing price has been at around $30 per MWh in both the day-ahead and the hour-ahead markets. Since most generators prefer to sell their output, they bid only their operational costs into the market, which pushes the prices down. If you really needed to sell the energy, you would bid your energy into the market at that level to capture some of the sales. But since your plants are peakers, you are not desperate to risk losses and therefore bid your capacity at $35. Normally, you would not be able to sell your energy at that price. But yesterday, the day-ahead market cleared at $32 per MWh and demand was lower than today. Accordingly, you submit a load curve that represents your true marginal costs. It starts at $35 per MWh and then slowly moves up until you reach the capacity limit, where you give the curve a very steep incline. You submit the curve for three hours in the afternoon, when it is likely to be particularly hot. A few minutes later, at 7:15 AM, the PX has conducted the auction and determined the market clearing prices for each hour of the next day.

Unfortunately, it turns out that your calculation was wrong: in anticipation of the higher prices, more generators have submitted bids and the last unit required to meet the demand had a price of $31 per MWh at the necessary level of output. This clears the market and your natural gas turbines have not been selected. You notice that the market for 16:00 the next day cleared at a $45 per MWh and are extremely angry that you failed to submit a bid for that hour. Who could have known that the price would jump by more than $10 between two hours? The PX software asks you if you'd like to bid some of your capacity into the four ancillary markets, but you do not want to do that quite yet—the ISO has implemented a new protocol to clear the markets and the prices have been much too low recently. With the PX auction over, you have time until 10:00 AM to make some other trades for the next day. If you already had a schedule for today, you'd now be able to enter the hour-ahead markets. But since you did not trade yesterday, you are now limited to the bilateral markets until 10:00 AM when all day-ahead markets must submit their balanced schedules to the CAISO for congestion management.

You start to make some phone calls to other energy companies and realize that there is some cheap energy to be had from coal plants in Arizona. You strike a deal with the California company who owns this power plant and buy a bilateral contract for 200 MW/h of firm energy at

$29 per MWh that will be delivered at the Palo Verde substation at 4 PM the next day.[71] The utility frequently sells to the ISO and therefore has a license to act as a Scheduling Coordinator. It will add your trade to the schedule that it will submit to the ISO (your purchase cancels out their sale and the schedule is balanced). After hanging up the phone, you log the trade in your internal database. As you are considering your purchase, the phone rings and a trader from Enron's wholesale trading desk asks you whether you have any energy to sell into California. You offer them the contract you just purchased, but at a premium for $45 per MWh. After all, that is the market clearing price for the next day at 4 PM. The Enron trader immediately accepts. Strange! You notify the utility of the change of ownership, and they now add the transactions to the schedule. Right after you hang up, you call the Arizona utility and buy another 200 MW/h. The utility clearly has not realized the true value of its energy and you congratulate yourself for your acumen. However, you do not sell the new energy to Enron right away. Their willingness to buy the energy at a premium has made you suspicious. It looks like they know something you do not! Somewhere in California, you might get even more money than you got from Enron.

Once 10:00 AM comes around, the day-ahead markets are done and all scheduling coordinators submit their trades to the ISO. The ISO now compiles the information on the agreements to generate and consume power in California for the next day. This gives a complete picture of anticipated generation and production in California and will provide the baseline for CAISO's grid management. Since everyone has been trying to find the best offer and power marketers are eliminating price differences between different market locations, the resulting distribution already approaches a rough solution to the unit commitment problem: the cheapest generators serve most

[71] In reality, these contracts would run for more than one hour, but for the sake of the example, I am keeping things simple.

demand, followed by the second cheapest, etc. for all hours of the day. On the basis of its load forecast, the ISO now calculates how well these schedules cover the anticipated load. It uses this information to update the requirements for ancillary services. Between 10:00 and 11:00 AM, CAISO then conducts the auction for ancillary services and runs its intra-zonal congestion management software.

As it turns out, the combined schedules that all SCs have submitted will lead to congestion on the notorious Path 15 connecting southern and northern California. Since your energy from the plant in Utah will be imported at Palo Verde substation, the separation of the zones does not concern you yet. But the congestion forces some generators in Southern California to back off. Based on the schedule adjustment bids, the ISO notifies all participants of the congestion charges that would obtain if they stuck to their schedules. The charges correspond to the incremental value to the marginal user of the transmission interface. Some scheduling coordinators give their customers a chance to adjust their schedules before the ISO implements any congestion charges. If a generator finds that it is not worth their while to produce energy, they might prefer to make arrangements to back off. By 12, the SCs submit the revised schedules to the ISO, which then recalculates the schedules' compatibility with the network model. As it turns out, buyers and sellers were satisfied with their initial trades and the ISO adjusts the trades on the basis of the schedule adjustment bids, hence the market segmentation into two zones that you observe in WeNet. Those who were willing to pay the most for the limited transmission capacity on Path 15 produce at the agreed output level and pay the charge to the ISO. The congestion charges will be paid to the owners of the transmission assets (the utilities) as well as those who own financial transmission rights (FTRs) on those interfaces. Those generators who backed away from their obligation to produce are now forced to procure the missing energy elsewhere in the hour- or real-time markets. The adjustment makes sure that the most efficient generators use the limited transmission capacity and creates an incentive for the generators to find the cheapest replacement for their capacity in northern California.[72] Around 1 PM, the ISO is done with its calculation and sends everyone the resulting schedules as well as congestion charges. At 1:15 the zonal market clearing prices are published and the day-ahead market is over. You receive a telephone call informing you that your day-ahead import of 200 MW/h at Palo Verde has been approved. Since you had not participated in the previous day-ahead market, there is nothing left for you to do and you occupy yourself with other work.

On the next day, your contracts from the day prior allow you to enter one of PX's hour-ahead markets and modify your energy positions for that day.[73] Since your trade was logged with the ISO, it can be modified as an hour-ahead position in the PX. The changes had a negative impact on your positions, and you now have to do something about your 4 PM Utah-energy contracts. Since you don't want to use this energy, you now have to find a buyer. Ideally, you would also like to sell some of your natural gas output given that the day-ahead market clearing prices were far higher than usual. Since January of 1999, only three hour-ahead auctions take place during the day: one at 6 AM, one at noon, and one at 4 PM. Prior to these auctions, you can specify bids for the hours succeeding the auction.[74] Since you want to take advantage of the high prices in the afternoon and have a contract for delivery at 4PM, you aim for the noon auction. In the morning, you log into the market software and specify bid curves for your natural gas plants. You plan to offer the energy for three hours in the afternoon when the day-ahead prices are probably going to

[72] However, the ISO struggles with one problem these days—it has to obey the market-separation constraint, which states that interzonal congestion can only be resolved with resources from the scheduling coordinator. So, it cannot substitute energy from another SC's portfolio, limiting the degree to which the CAISO can optimize the use of existing energy. CAISO, "Annual Report 1998," 2.10.
[73] PX, Market Surveillance Committee, "Second Report on Market Issues in the California Power Exchange Energy Markets, prepared for the Power Exchange, submitted to FERC, March 9, 1999," *FERC* ER98-2843, 8-12.
[74] The noon auction refers to energy that will be delivered between 1PM and 5PM

be the highest: between 1 and 4 PM. By now, you suspect that the Enron trader who bought your first Utah-contract speculated for even higher prices in SP15 in the hour-ahead market. This makes sense because the segmentation into zones made some plants from northern California unable to deliver in southern California, and the system is close to its capacity limit. Since the PX generates a single market clearing price and you are very sure that the price will be above your marginal costs, you plan to submit your energy at the lowest possible price, hoping to sell all of it at a high market clearing price. So, you offer to sell your 200 MWh from Palo Verde at SP15 for $29 per MWh and your generator capacity at the intersection between your municipality and the CAISO at its true cost for $35 per MWh. In addition, you offer to sell 50 MW of capacity from your natural gas power plant into the Ancillary Service market—for the hour-ahead market, these bids are submitted simultaneously. You also submit some schedule adjustment bids in case it might be more profitable to sell energy in Northern California. These adjustment bids indicate the willingness of a generator to increment a supply resource if the price increases or to decrement a resource if the price decreases, and vice versa for demand and exports. If the sale price does indeed go up as far as you expect, selling your energy would be very profitable to you, so you submit adjustment bids that capture the difference between your production cost ($29 per MWh and $35 per MWh) and your anticipated earnings (around $45 per MWh). At noon, the PX closes the auction and calculates the result. Oh joy! It turns out that your anticipation was correct: the last generator required to meet load had submitted a marginal bid of $60.5 for the last MWh necessary to meet load at 4 PM. Since you are below this bid with a good chunk of your bid-curve, you get to produce at an efficient output level for all three hours and receive $60.5 for each MWh of this output. Again, the schedules are sent to the ISO, which conducts congestion management and ancillary service auctions. Since you sold all your energy in the hour-ahead market, your capacity does not qualify for these markets.

In the second iteration of its interzonal congestion management, the ISO determines that the price in SP15 is going to be even higher than you thought: $63 per MWh. It is now about 3 PM and you have one hour before the final dispatch. In principle, you now still have a chance to use PX's interface to bid some additional energy into the CAISO imbalance markets. Since you are producing at an efficient output level, you could push the engines a bit harder and sell some incs to the CAISO. As it looks right now, it would certainly need the extra energy given that there is likely going to be some deviation from the schedules in real time. But you wager that it is probably safer to run your units efficiently and log out of the market. You have made a handsome profit: since you bought the energy at Palo Verde for $29 per MWh, you made a profit of $36 on each of your 200 MWh. On the production from your own plant, you made about $30 per MW/h. If prices keep at this level for more than just a few days this year, it might become reasonable to plan for the construction of an additional natural gas peaker.… You go home and enjoy the warm summer day.

While you go home, the moment of dispatch arrives and the ISO implements the aggregate schedules, adjusting them with energy from the imbalance markets. Since the schedules were relatively accurate predictions of real-time conditions, this is done quickly—real-time energy adjustments only amount to about 5 percent of total market activities. At this time, the ISO also resolves congestion in the real network, using a complete power flow model to make sure that all parts of the physical network are working in line with security standards. Some minor interties in southern California are congested and require substitutions of generators in the west with some from the east. CAISO seeks to resolve the congestion at the lowest cost and with minimal adjustments to the final schedules. The costs for this service are socialized and settled at an ex-post price derived from the adjustment bids. Since the major sources of congestion have been taken care of, the markets provided schedules that approached the solution to the unit commitment problem and required only minor adjustments by the CAISO in real time. Another day comes to an end, and the system is buzzing with previously unknown efficiency. In Folsom, everyone feels like it has been smooth sailing today….

This example constructs an ideal case: it shows sellers who are constantly looking for ways to sell to the highest bidder and how this moves energy to the parts of the system where it is needed most, depressing prices to marginal cost of operation. Since the anticipation of high temperatures brings in a lot of bids, the overall price in the day-ahead market goes down. The system is already at capacity so the prices in the hour-ahead markets then go up. But everyone is still bidding their marginal costs. The transmission capacity markets run smoothly and leave little work to be done for the ISO. Despite the fact that the PX and the ISO dealt with a multitude of operational problems during the first two years of operation, constantly adjusting the tariff and the software and adding adjustments to the market logic, the example captures the operation of the system during the first two years. The behavior of market participants who deal with products in a variety of forward markets feeds seamlessly into the logic of grid management. Now, I will turn away from the fictional example and return to the empirical case to ask: Where did this design break down? How can we understand the energy crisis as a consequence of flawed system design? This is the topic of the next chapter.

6. The Structural Preconditions of the California Energy Crisis

6.1. Introduction

After the detour through the intellectual history of market design and the details of California's electricity system, I will now return to the crisis of 2000–2001. With a working knowledge of the market system and the designers' aspirations, we can examine where the California system went off the tracks. Specifically, I will identify the structural preconditions for behavior that violated the market mechanism.

While the analysis will deal with the details of the system, the overall argument in this chapter is straightforward. I will show that problematic behavior became possible where the market system did not represent crucial elements of the physical electricity system.

On the one hand, the market mechanisms did not incorporate the long-term planning horizons for the gradual expansion of the system. The temporal structure of the markets was unable to create incentives for the addition of marginal generators *in time* to prevent the emergence of behavior that undermined the system. On the other hand, the mechanism did not account for crucial features of generation assets and the electricity grid. These features were relevant for the technical operation of the system. In the words of economists, the system had many *externalities* that were not priced by the market. These externalities had to be provided by the system operator.

However, several design features created profit opportunities from the discrepancy between market mechanism and the requirements for system operation. These opportunities turned the market mechanism against the provision of the "externalities" that were required to operate the system reliably. The opportunities emerged under certain operating conditions and relative to the distribution of supply and demand in the system. Trades that undermined the logic of reliable system operation were ruled out. But companies developed games to circumvent the rules.

Depending on the operating conditions, the market process was thus in constant danger of turning against the system. This meant it deviated from the path to the market equilibrium the designers had hoped to create. By turning against the reliable operation of the electricity system, the market process violated the mechanism designed to find the economic dispatch of the system.

Since the structure of the market design created many opportunities to derail the market mechanism, it created substantial requirements for market oversight: a centralized regulatory agency would have needed to observe the market process and detect conditions under which the market mechanism would stop working according to the plan and begin working against the reliable operation of the system. It would then have to detect problematic trades, block them, and coerce the market process back into alignment with the desired mechanism.

These requirements were heightened by a second feature of the market design. It created complex interrelations between the different market settings. At each moment, market actors could act within dozens of different markets with different geographic, temporal reach, and different operational rules. This complexity increased the difficulties for the oversight of these markets substantially: a control structure would have been necessary to observe the dynamic interaction between the different market settings.

However, the existing control structure was woefully inadequate for the task despite a complex information infrastructure and centralized monitoring committees. In sum, the argument in this chapter shows that certain design features created incentives and opportunities to act in ways that turned the market mechanism against the reliable operation of the system. This generated high oversight requirements, which were not met by the control structure. Since the argument is rather complex, I will now outline the different sections in a bit more detail.

The analysis proceeds in three steps. First, I am going to provide an outline of three types of behavior that violated the market mechanism: the exercise of market power, illegal arbitrage businesses, and congestion games.[1] This first step establishes what the incentives for these three types of strategies were and how they derailed the market mechanism. I show that incentives for the exercise of market power existed whenever the available generation capacity became scarce. The arbitrage games became profitable when price differences between the forward and real-time markets emerged. The congestion games responded to incentives to predict power flows not anticipated by the market software. The games fed on the presence of market power and reinforced it. Whenever the problematic incentives emerged, the market logic no longer harmonized with grid management but began to oppose it.

In a second and third step, I then reconstruct what design features created the incentives and opportunities for the destructive market process. It is here that my argument begins to diverge from existing research. Most of the empirical studies isolate three principal design flaws as the root of the crisis: the regulatory decision to put limits on utilities' ability to hedge their positions with long-term forward contracts, the price freeze in the retail markets, and the requirement that utilities had to buy their energy in the PX. I argue that these decisions represent important *proximate* causes in the event chains that led to the price spikes and then the crisis. From the structural perspective, other features of the system appear decisive because they created the incentives that triggered the problematic behaviors as well as the opportunities to act on them.

In the second section, I show that the primary design flaws were the temporal logic of the spot markets, the decision to separate the markets from the process of grid management, CAISO's

[1] This part of the argument is not controversial. The different types of problematic behavior are well-known. Their prevalence and illegality are under dispute.

need to treat all SCs equally, an insufficient representation of the physical reality in the market system, and the ability of companies to assume several different roles in the market structure.[2]

The problematic temporal logic of the markets was the first flaw. It explains the emergence of market power. The forward markets were unable to incent the creation of excess capacity until the moment the capacity became necessary to meet demand. But at that moment, market power already derailed the logic of the market system and undermined the incentives to add new capacity.

The separation of markets into several different organizations and the provision to treat all SCs equally were the second and third fundamental flaws. These two provisions had two consequences. On the one hand, they increased the dynamic complexity of the markets substantially. Since many SCs were supposed to operate different marketplaces, the designers put a multitude of different operational rules and price mechanisms into place. These could lead to price differences, which made it more difficult for the overall market process to converge on a single optimal solution for the dispatch problem. But the incentives in any given market could also be influenced by the dozens of other marketplaces actors could choose from. The stability of any one market mechanism therefore depended on the exact coordination with all other marketplaces, which increased the requirements that had to be met for the market to operate as desired.

These difficulties were exacerbated by the equality provision because it prevented the ISO from optimizing the dispatch structure *across* schedules: it was only allowed to optimize dispatch schedules with resources in the portfolios submitted by the SCs. This increased the inefficiency of

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[2] Though not the dominant explanation for the crisis, this argument is not entirely novel. It follows, in part, arguments that Hogan and Smith have developed in articles and expert testimony. For example, c.f. Smith, Rassenti, and Wilson, "California: Energy Crisis or Market Design Crisis?"; William W. Hogan, "Electricity Market Restructuring: Reforms of Reforms," *Journal of Regulatory Economics* 21, no. 1 (2002). See also “FERC: Regulators in Deregulated Electricity Markets,” Committee on Government Reform, House of the Representatives, One Hundredth and Seventh Congress, First Session, August 2, 2001, 93-98. However, as far as I can see, no one has brought the different strands of argument into a complete explanation. Further, the system’s perspective, which ties the different strands together, has not yet been applied to the case.

the market process and made it harder for the different markets to converge. In turn, this created dynamic interactions between the price movements in different markets, exacerbating the complexity further.

The separation and equality provisions led to substantial differences between the SC's purely financial markets and the markets that the ISO used to balance the system. This created price differences between the CAISO and SC markets, which incentivized arbitrage trades. But though the products were equivalent from a financial point of view, they were not *technically* equivalent.

The financial products traded by the SCs did not account for a variety of technical characteristics that determined how, when, and where the generators could be used to produce the energy represented in the financial commodity. The technical differences between generators were not represented in the markets, but these differences were crucial for the technical work the operators had to do. So the CAISO imposed restrictions on trades in its own markets, but this did not relieve the incentives to realize the arbitrage opportunities. Sellers of energy thus developed a variety of games that contravened these rules. They were possible because of the fourth flaw.

The companies could play several different roles in the market. As scheduling coordinators, companies could manipulate schedules in the interest of entering the prohibited markets as sellers. The last flaw was the simplified representation of the grid in the market. This created discrepancies between power flows and their representation in the market. Since one could get paid to relieve congestion not anticipated by the market, the sellers gained incentives to identify the discrepancies and trade on them.

The second section thus shows how design features could create incentives to act in ways that derailed the market mechanism. It also shows that the design features that created these incentives generated high interactive complexity between the markets. This heightened the requirements for the oversight structure, which I examine in the third section.

In the third section, I show that the control structure was insufficiently developed to detect and constrain behavior that threatened to derail the market mechanism. The oversight regimes operated with significant lag, did not have clear goals, nor did they monitor the interdependencies between different markets. In addition, it suffered from insufficient enforcement capabilities. This, then, sets up the two questions for the second part of the dissertation: What drove the problematic design decisions? And why was there no effective control structure for a machine with high interactive complexity whose safe operation was paramount for the provision of one of society's most basic goods?

6.2. Three Types of Dysfunctional Behavior

In this section, I am going to outline how incentives for different kinds of problematic behavior emerged. In the next section, I will then trace them to structural features of the market design. Regardless of the complexity of the design, all electricity markets rely on the most basic mechanism of economics: if suppliers have to compete and consumers search for the cheapest offer, suppliers are forced to offer their generation at the lowest possible price to consumers. Discounting all the complications that derive from transmission constraints, limited cognition, uncertainty, imperfect information, product differentiation, operating characteristics of generators, diverging temporal horizons etc., this basic mechanism tends towards an equilibrium, in which the aggregate demand is served by the cheapest combination of generators. At the heart of any synthetic electricity market thus beats the mechanism of competitive pricing.[3]

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[3] Robert Wilson, "Architecture of Power Markets," *Econometrica* 70, no. 4 (2002): 1302-04.

The strategies I will discuss in this chapter circumvented the logic of this basic mechanism. Their users did not have to offer their generation at least cost to consumers, which in turn led to inaccurate schedules, misuse of generation equipment, and inflated costs. Confronted with faulty schedules, the system operator had to find technical solutions in the brief period of time between the closing of the markets and real-time operation. This exacerbated opportunities for problematic behavior and led to an inefficient operation of the system and a higher probability for errors. Over longer time frames, the strategies undermined both the financial stability of the industry and eroded the conditions for the reliable operation of the system. In other words, the strategies circumventing the basic pricing mechanism effectively turned the search for profits in the market *against* the logic of reliable system operation. They inverted the original intent to create a system where the markets produced outcomes that informed efficient grid management. I will now discuss the three strategies in turn.

6.2.1. Market Power

The simplest and most serious way to derail the market mechanism was the exercise of *market power*. A company has market power if it is able to profitably alter the market price away from the competitive level.[4] Companies gain market power when they do not face competition and consumers are willing to buy at inflated prices.[5] In electricity systems, market power emerges from the interplay between existing generation and load. Several technical features of electricity systems

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[4] CAISO used the definition provided by the FTC: "Market power to a seller is the ability profitably to maintain prices above competitive levels for a significant period of time." In economics, the qualification "significant periods" of time is not used because it is vague and introduces qualitative considerations into the calculation. CAISO, Market Surveillance Committee, "The Competitiveness of the California Energy and Ancillary Service Markets, March 9, 2000," *FERC* ER98-2843, 1.

[5] Severin Borenstein, "Understanding Competitive Pricing and Market Power in Wholesale Electricity Markets," *The Electricity Journal* 13, no. 6 (2000); Borenstein, Bushnell, and Knittel, "Market Power in Electricity Markets: Beyond Concentration Measures."

interact to produce market power. First, since it takes at least a year to connect new resources to the grid, the mix of generators in the electricity industry is *static* in the short run. The existing generators are also unable to increase their output arbitrarily. Outside a narrow band of efficient operating conditions, the cost of production increases exponentially. The risk of engine failure puts definitive limits on the output. Whenever there is a shortage of generation capacity, there is thus no way to quickly bring in new sources of energy. The second decisive feature is the need to constantly match demand and supply to sustain frequency across the grid. Since energy cannot be stored efficiently, production must meet all demand the moment it arises. As demand increases, more and more of the available generators will run to meet this demand. This means that the system becomes less and less competitive the closer the demand approaches the capacity limit of the industry. As soon as there are no (or very few) substitutes to meet the residual demand in the system, generators do not have to compete anymore and gain market power. Since the system as a whole can collapse if these "pivotal" suppliers do not contribute their generation assets, the resulting market power is substantial.[6]

For two reasons, this type of market power is extremely fluid. First, market power does not depend on the size of the generator. On a hot summer afternoon when the system operator needs 97 percent of all generators running to meet demand, even a firm that owns less than 6 percent of capacity can exercise almost unlimited market power.[7] This means that the ability to exercise

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[6] A market participant is "pivotal" if they are necessary to meet aggregate demand at a given moment. CAISO developed a pivotal supplier test (PSI) in 1998 to detect market power. If the supply margin is greater than the amount of capacity offered by a supplier being evaluated, the PSI is less than one, and buyers have supply alternatives. If the PSI is greater than one, the supplier is pivotal, c.f. A. F. Rahimi and Anjali Y. Sheffrin, "Effective Market Monitoring in Deregulated Electricity Markets," *IEEE Transactions on Power Systems* 18, no. 2 (2003); Sheffrin, "Empirical Evidence of Strategic Bidding in the California Iso Real-Time Market.". Also, c.f. discussions about the reform of the ancillary services in 1998: "Market Surveillance Committee Meeting September 18, 1998," R.4000.006, Box 12, Folder 1, ISO Market Surveillance Committee Meeting Files *CSA*.

[7] Borenstein, "The Trouble with Electricity Markets: Understanding California's Restructuring Disaster."

market power can be very widely diffused through the industry—it does not fall upon just a few large corporations.

Second, the ability to exercise market power depends on conditions that can change quickly; the ratio of supply to demand is in constant flux. The presence of limited transmission capacity complicates things further. In a system where certain geographic areas are connected via limited transmission lines, congestion can fragment the market and cut geographic areas off from competitors. Once a "load pocket" emerges, the number of possible competitors can shrink and endow the remaining companies with market power. Congestion patterns can change within minutes. Accordingly, a company can move from having absolute market power to having none within the span of just a few minutes.

The presence of transmission constraints has a second consequence. Since the ideal dispatch schedule is organized to maximize the available transmission capacity while minimizing the cost of generation, the exercise of market power can have complicated ripple effects on the dispatch structure of the system as a whole. If an inefficient generator replaces a more efficient one, the power flows in the entire system can change, which alter the dispatch schedule for the system. This requires additional adjustments that further move the system away from the optimal allocation. Similarly, the attempt to *create congestion* through strategic changes in the bidding structure can lead to such cascades of suboptimal adjustments. Since all elements of the electricity system hang together, even small shifts away from the optimal dispatch order can feed on each other and move the system away from equilibrium outcomes.[8]

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[8] I will discuss these issues further below in connection with the two games. Early insights about the interaction between congestion and market power in California's markets can be found in a research report commissioned by CAISO in 1999, c.f. London Economics, Inc., "Assessing Market Power in Newly Deregulated Electricity Markets, July 1999," R400.010, Box 19, Folder 18, Electricity Oversight Board Subject Files (I-T), *CSA*.

None of these problems would have been particularly severe if it had been difficult for market players to know when their generation assets were going to be pivotal. But even though market power was a highly fluid phenomenon, it was easy to predict for those who had it. Since the market mechanism required perfect information to operate as advertised, the markets produced all the information that was necessary to determine at what time one's resources would become "pivotal."

The first important information was the level of aggregate load in the system. Though the system load fluctuated strongly, the long-term fluctuations were predictable because they largely followed historical patterns. Daily fluctuations in demand were predictable from weather patterns. The ISO published this and a variety of other information about the system as a whole on its WeNET (later OASIS) website. Apart from publishing market results, they released information on line outages, forecasts for the next few days, the real load on the system, and a variety of other technical parameters.[9] The next crucial piece of information was the combination of generators needed to meet this demand. The Electric Information Agency (EIA) documented the available capacity in the industry in some detail. It published information on ownership of existing plants, their nameplate and real capacity, age, outages, and planned expansions.[10]

The operating characteristics of generators (e.g., heat rate) and the most important factors that determined their costs were public knowledge. From this information, as well as the market information from CAISO and PX, the sellers could determine easily where exactly their generator

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[9] The publicly available information can be reconstructed from CAISO's old websites from 1998 to 2000. They can be accessed through ArchiveX. "California ISO Homepage," https://web.archive.org/web/19981212023502/http://www.caiso.com/, last accessed 03/28/2020.
[10] EIA, Form 860a "Annual Generation Report," can be accessed via: https://www.eia.gov/electricity/data/eia860/, last accessed 03/28/2020.

would be located in the supply stack. This was enough to predict where the pivotal suppliers would be under conditions of tight supply.

Companies that obtain market power can make almost unlimited use of it. Unlike most other commodities, electricity is required for nearly all aspects of everyday life. The demand is not responsive to price. Price increases will not lead to a decline in use.[11] In California, most end users did not even have any way of knowing the cost of their present energy use. They had flat, monthly contracts with the utilities and only learned about the cost of their consumption a month after it was done. But even if end users had been able to access real-time meters and had been paying rates that were pegged to wholesale prices, the demand elasticity would not have exceeded ten or fifteen percent —the service is too essential to modern life to be curbed easily.[12]

Accordingly, companies that obtain and exercise market power were in a powerful position: they could charge almost arbitrary sums without losing profits. In that sense, they are essentially in the same position as a hospital that receives a patient who suffers from a bullet wound but does not have insurance. Since the patient cannot go elsewhere and absolutely needs treatment, the hospital could ask an arbitrary price if there are no legal or ethical barriers that prevent the hospital from doing so.[13] In sum, opportunities for market power emerge when a generator is of pivotal

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[11] The introduction of smart meters and the "internet of things" is beginning to change this crucial demand-side market flow. Once electric appliances can communicate with the grid operator and respond to price fluctuations, it will be possible to coordinate the demand relative to available supply and use the existing capacity much more efficiently. This also improves on various problems that the intermittency of renewable energy poses. While some states (including Illinois) are starting to implement smart grids, the technology was not widely available in California during the 1990s. Sivaram, *Taming the Sun: Innovations to Harness Solar Energy and Power the Planet*.

[12] Since market power takes place at the capacity limit of the system, one could argue that even 10 to 15 per cent of demand elasticity resolve market power decisively. Smith, Rassenti, and Wilson, "California: Energy Crisis or Market Design Crisis?" I disagree with this argument, however. Why it only holds in the short run as I explain below.

[13] In that sense, an insurance is a "hedge."

importance to meet demand in the market. The exercise of market power derails the way the market process finds the optimal dispatch order for the short-run operation of the system.

But market power also undermined the sequential logic of California's forward markets. As outlined before, these markets were designed to feed into each other and generate increasingly accurate dispatch schedules. In each market, buyers and sellers had to act on their best guesses about future production and consumption. Subsequent markets would then be used to refine the schedules according to new information.

The specter of market power disrupted this logic of sequential improvements because it drove all trading activities into the real-time markets of the ISO. These markets were not designed to handle a lot of traffic—they were meant to procure less than 5 percent adjustment capacity. In addition, they operated very close to dispatch, which left very little room to correct errors.[14] This concatenation of market activities occurred because the presence of market power reconfigured the incentives for all actors in the forward markets.

Due to the division into a wholesale and a retail side, the forward markets operated by the SCs featured *elastic* demand. The buyers were looking for cheap offers to serve anticipated *future* energy needs. Increases in price would lead them to buy less.[15] Of course, the must-buy requirement forced the utilities to buy their energy through the forward markets of the PX. But they could correct their anticipated needs downward. This would lower the aggregate demand step-functions in the day- and hour-ahead markets and thus depress the market clearing price that was calculated

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[14] CAISO, Market Surveillance Committee, "Annual Report on Market Issues and Performance, June 1999", Chapter 2, http://www.caiso.com/Documents/Chapter2_1998AnnualReport_MarketIssuesandPerformance.pdf, last accessed 03/28/2020. (Henceforth, Market Surveillance Report 1998).

[15] This can be observed in the diminishing quantity of PX load in comparison to system load. Though the large amount of fluctuation renders the mean a bad measure of this difference, it can still give a rough indication of the magnitudes. In 1999, the mean difference between the two loads was 3932 MW/h, and in 2000, the mean was with 5740 MW/h. This is based on the data from the California Energy Institute.

at the intersection of supply and demand.[16] But since the utilities and ESPs could not control how much energy the end users consumed, they had to buy the remaining energy in CAISO's imbalance markets. The ISO basically settled all differences between real consumption and forward contracts through its internal markets. The desperate attempt to avoid being the victim of market power effectively pushed the buyers into the real-time markets.[17]

As outlined in the last chapter, the CAISO markets worked differently than the other forward markets. The BEEP stack simply ordered the supply bids from low to high and then cleared the market in 10-minute intervals relative to the needs at that moment. CAISO was the only entity making decisions to buy energy, and it would buy whatever was necessary to keep the system running. These markets were therefore characterized by near complete demand inelasticity. The operators had only had two ways to defend themselves against high prices: they could make use of pre-arranged contracts to curtail load in emergency situations, and they could reduce reserve margins and use "replacement reserves" to supplement imbalance energy.[18] Neither of these measures would reduce the aggregate demand significantly. Accordingly, generators that were necessary to serve demand always showed up in the supply stack of BEEP and could exercise market power. This had effects on all other markets as well.

As soon as the imbalance markets were affected by market power, the incentives in CAISO's markets for ancillary services shifted too.[19] As we have seen, a generator that had been

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[16] See chapter 5 for details.
[17] During the litigation of the crisis, the power marketeers argued that the utilities had defrauded the PX by understating their demand and that they were to blame for the shift of business into the imbalance markets. For example, c.f. "Statement of John Stout before the House Committee on Energy and Commerce, Exhibit No. CA-228, September 11, 2000," *FERC* EL00-98-000, p. 2. California's Parties contested this heavily in "Prepared Testimony of Dr. Gary A. Stern, Exhibit No. CA-3," *FERC* EL00-98-000, p. 31-45.
[18] They could also try to use out-of-market purchases, i.e., buy from other balancing authorities, c.f. CAISO Report 1998, 2-14. But due to the games outlined in section 1-B and C, this recourse was not likely to lower the prices.
[19] CAISO's ancillary service markets were the first of its kind and produced significant problems right from the start. They were reformed multiple times. I focus here on the kind of market power that could be exercised

selected to provide ancillary services might *not* be called to serve load in the real-time energy markets. It was only called to provide imbalance energy if the ancillary services were not needed. Since generators could choose to either sell in the ancillary service markets or in the imbalance markets, the imbalance markets established a clear measure of opportunity cost for those who were selling into the ancillary markets. Accordingly, these opportunity costs would be reflected in the bids for ancillary services.

Whenever the imbalance markets experienced price increases, the ancillary markets would too. This means that the effects of market power spread to other markets that were linked to the imbalance markets.[20] Since not all generators in a system qualify to offer ancillary services, the number of potential suppliers in these markets was smaller to begin with, and they were even more vulnerable to market power than the imbalance markets.[21]

In sum, the conditions under which the exercise of market power became possible derailed the market mechanism in a variety of ways. When we shift our perspective from the larger system to individual players, we see how the presence of incentives for the use of market power led to a variety of undesirable behavior even on the part of companies that could not exercise market power themselves. When the operating conditions approached a point where market power became

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throughout all of these iterations and will later consider specific design problems that emerged when the CAISO tried to apply short-term fixes to different aspects. A history of ancillary service market re-design can be pieced together from the CAISO, “Market Surveillance Report 1998;” the submissions of CAISO under FERC docket ER98-2843, in which the redesign was negotiated after CAISO had tried to limit access to these markets for sellers with market power; and finally, the business documents of the market monitoring committee between 1998 and 1999, to be found in R.400.006-R.400-007, Box 12, Market Surveillance Committee Meeting Files, *CSA*.

[20] “The Competitiveness of the California Energy and Ancillary Service Markets, March 9, 2000,” Market Surveillance Committee, CAISO, FERC ER98-2843, p. 4.

[21] There were other problems with the CAISO markets. Most important were incentives to withhold power to activate RMR contracts, software problems that prevented suppliers outside California from offering their supplies, and clearing rules for the auctions that created perverse incentives in the beginning. These problems are discussed in the Market Surveillance Committee meetings between 1998 and 2000, c.f. “Presentation: Top Three Issues, discussed at August 12th 1998 Meeting,” R400.006-R400.007, Box 12, Folder 1, ISO Market Surveillance Committee Meeting Files, *CSA*.

available, companies could use two strategies to exercise it. If they were uncertain whether some of their assets were going to be necessary to meet aggregate demand, they had a strong incentive to shut down plants to increase the likelihood that other plants would become pivotal. Since the in-state fossil fuel plants were old, there was always some reason that could be invoked to shut these plants down.[22] As one interviewee summarized the logic: "There were companies who said: 'I have three generators, if I take two down and I just let one on I will make it ten times more money than if I keep them all three.'"[23] These incentives are directly opposed to the logic of system operation because they exaggerate an already existing shortage and thus increase the risk of system failure. The system would have required reserves to come online during shortages, not the opposite.

The alternative strategy was called economic withholding. If the sellers were sure that their capacity was necessary to meet load, they simply submitted an inflated bid curve to the PX and ISO markets. If their plant was selected, it drove up the market clearing price and created windfall profits. Even if it was not selected, the substitution of a different generator still increased the market clearing price. As a member of the market monitoring unit put it in an interview: "A part of your portfolio drives up prices and the rest of your portfolio enjoys these wonderful high prices."[24] The resulting price inflations created problematic incentives for other companies as well. At certain levels, it became rational to run the engines of generators far above their efficient output levels. Of course, this would lead to engine breakdowns later on. But since such breakdowns were more than recompensed by inflated prices and since they were the source of *more* market power for

[22] Interview with Lennie W., 02/02/2018.
[23] Interview with Carmella G., 11/28/2017.
[24] Interview with Anelise S., 13/12/2017.

companies with several units, the practice became rational. Market power thus created incentives to destroy the system's material infrastructure.[25]

Conversely, periods of low demand constituted the only time it was reasonable to schedule legitimate maintenance shutdowns. This was a common practice even before restructuring. Utilities usually scheduled maintenance during the spring and winter months. But they used to coordinate these shutdowns so that the maintenance work was spread over many days and weeks. This way, the operators made sure that there would be sufficient backup generation in case of unexpected events. Now, the utilities did not directly coordinate shutdowns and the market signals were the same for everyone; accordingly, multiple shutdowns occurred at the same time. This led, once again, to incentives for the exercise of market power at the expense of system reliability.[26]

I will now turn to two other types of "games" that violated California's market mechanism. Though sellers devised a vast variety of games, they were usually variations on two basic themes. The first class constituted illegal arbitrage trades, while the other class exploited profitable differences between the physical reality of the grid and its representation in the market model. Though the individual games were often quite complex, the underlying principle is simple to grasp. Just as in the case with market power, the market occasionally generated incentives for trades that contradicted the reliable operation of the system. But in the case of the games, the tariffs that governed the markets put laws into place that were designed to rule these trades out. The games were designed to circumvent these rules and take advantage of the profitable trades. To understand the

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[25] Interview with Brian S., 13/03/2018.
[26] San Diego Gas & Electric Company, "California Parties' Supplemental Evidence of Market Manipulation by Sellers, Proposed Findings of Fact, and Request for Refunds and Other Relief," FERC Dockets EL00-95-000 / EL00-98-000, p. 34-35.

games, it is necessary to understand why the trades were prohibited in the first place. I will begin with a discussion of the arbitrage games and then discuss the congestion strategies.

6.2.2. Arbitrage Games

The first set of games was designed to exploit illegal arbitrage opportunities.[27] Whenever there was a price difference between market locations or time points, power marketers had an incentive to trade on it. They bought cheap energy at one location or time point and then sold it for a profit at another. In economic theory, the purpose of these trades is price discovery and market liquidity. If traders compete to execute arbitrage trades, the trades will tend to equalize price differences between locations because the competition will minimize the profits that a trader can make from an arbitrage business. By giving "thickness" to markets, these participants make sure that all conceivable obligations can be traded at a competitive price—even in cases where such trades are "speculative," i.e., based on uncertainty about future prices.[28] In a setting with many different marketplaces, the activities of arbitrage traders were crucial to enable the convergence of prices and thus the convergence of the dispatch solutions that the different marketplaces produced.

One potential arbitrage opportunity existed between the real-time markets in the ISO and the forward markets of the PX. When there were price differences between these markets, it would have been profitable to trade on them. However, these kinds of arbitrage trades were almost always prohibited. Since the PX was a trading house for financial obligations, sellers neither had physical

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[27] The next two sections draw from the detailed descriptions in Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*; Lambert, *Energy Companies and Market Reform: How Deregulation Went Wrong*.

[28] In theoretical economics, arbitrage is considered "riskless," i.e., it is an instantaneous realization of profits from price differences between locations. In reality, arbitrage also includes speculative trades, where traders "bet" that they can make profits at a later point in time without insurance that they will be able to do so. Koichiro Ito and Mar Reguant, "Blowin'in the Wind: Sequential Markets, Market Power and Arbitrage," *The American Economic Review* 106, no. 7 (2014).

control of the assets whose output they sold, nor did they have to know technical details about the asset's dispatch capabilities. In fact, the PX auctions, as well as most bilateral contracts, did not even require that bids were resource-specific, i.e., tied to particular generators. During the auctions of the day- and hour-ahead markets, traders only needed to specify if they sold firm or non-firm energy.[29]

The lack of product specificity eased trading and improved liquidity. Generators could compete, even if they were not exact substitutes. Power marketers could more easily take positions of energy without owning generators. Since the resulting commitments were set in advance of dispatch, there was plenty of time to perform the technical tasks necessary to produce the energy that was sold. One generator might take a longer time to come online than another, or it may have higher operating costs at different times of dispatch and therefore need to be started at a specific time to produce cheaply later on. Either way, in the forward markets, these technical differences do not matter. They are priced into the energy that is being sold. However, things change in the minutes before dispatch. At that time, the technical characteristics of specific generators matter because they might prevent a generator from delivering right away.

Since CAISO's imbalance markets were designed to buy adjustments for the real time management of the electricity system shortly before dispatch, these markets had different bidding rules. All generation resources that wanted to enter these markets needed to be able to follow technical dispatch instructions along tightly specified technical criteria. The operators in the control room had to know where the resource was located, what its technical characteristics were, and

[29] After the day- and hour-ahead auctions and after trades had been accepted, the sellers needed to specify the technical details for the generators that would execute these trades. The SC would then submit this information to the CAISO, c.f. "California Electricity Market Primer, prepared for the CalPX Board of Governors (February 2000)," R400.010, Box 18, Folder 12, Electricity Oversight Board Subject Files, *CSA*.

they had to be able to send binding instructions to these generators. Resources that provided ancillary services had to meet even higher control requirements. Accordingly, CAISO imposed restrictions on the participants in these markets—companies that wanted to enter the energy markets had to fill out forms that specified a variety of technical characteristics.[30]

The restrictions largely kept power marketers out of the markets because they did not usually control the assets that produced the energy they wanted to sell. This was a deliberate move: the markets were supposed to rule out speculative trades and sustain only "genuine" offers of physical resources. However, in order to link the SCs' markets with the real-time markets—to enable the progressive move from one market into the next—the products had to be standardized. This meant that the technical differences between the products sold in the imbalance and forward markets were not reflected in either market; from the perspective of the markets, the products were equivalent though they were technically distinct. Given that they made money with arbitrage businesses, the power marketers therefore had an incentive to find a way around the restrictions as soon as there was a price difference between the forward and the real-time markets. These kinds of trades impacted the work of the system operator because they prevented an effective real-time balancing of the system.

The next section will address the question of whether structural features created the persistent price differences between the markets. However, we can already observe that the presence of market power exacerbated the problem, and arbitrage was itself a way to exercise market power. As outlined in the previous section, the exercise of market power concentrated all trading activities into the real-time market. To the extent that demand drained out of the forward markets, the market

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[30] "ISO System Functionality Staged for Implementation after January 1st 1998," R.400.010, Box 18, Folder 8, Electricity Oversight Board Subject Files, *CSA*, pp.5-6.

clearing price could lie substantially below the real time price. This created price differences that heightened incentives for arbitrage.[31] In turn, by entering the real time markets with energy that could be sold at inflated prices, the power marketers found an avenue to exercise market power in the real-time markets.

In sum, the problem was that there was a discrepancy between the logic of the market and the logic of system management whenever price differences between forward and real-time markets emerged. From the perspective of the markets, there was profitable trade to be made between these two markets—the same product was priced differently at two temporal locations. But from the perspective of the system, this trade was not desirable because it might violate the requirements for real-time balancing of the grid. Accordingly, a restriction was imposed that now appeared as an obstacle to profit from the perspective of the markets. The games were developed to circumvent these restrictions.

The first strategy involved fraudulent export schedules.[32] The ISO allowed importers of energy to participate in the real-time markets as long as they could specify where the resources were sourced and what transmission interface they would use to deliver the output. Since energy from outside California was managed by other balancing authorities, CAISO did not require the immediate sellers to have physical control over the resources. The other balancing authorities, which were mostly composed of vertically integrated monopolies, would ensure that the schedules were met exactly as specified.

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[31] Price caps that regulators imposed on both the PX and the ISO markets exacerbated the price differences and thus the arbitrage opportunities. Since the ISO eventually capped prices at $250, they effectively encouraged the utilities to move most of their demand into the real-time market and created significant arbitrage opportunities between the two markets. But even prior to these escalating factors, the power marketers faced strong incentives to get around CAISO's tariff restrictions and devised strategies to this effect. Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*.

[32] FERC, "Final Report on Price Manipulation in Energy Markets" (short: FERC Final Report), FERC Docket PA02-2-000, VI.11-26.

Power marketers used this rule to circumvent their restricted access to the imbalance markets. They found ways to "launder" energy from California to make it look like it came from outside California. The trick was simple: they would first buy energy in California (either bilateral or in the PX) and then schedule this energy for export to another party outside California. This party sold the power right back to the power marketer for a small "parking fee." Since it now seemed like the energy was coming from "outside" California, the power marketer could sell the energy as "import" to CAISO and circumvent the control requirements of the tariff.

To obfuscate the movement of energy further, additional transaction partners could be added to the chain before the marketer would be "importing" the energy into California. A presentation slide entitled "Real Time's Best Month EVER" that had been submitted as evidence in a FERC proceeding gave an example that summarized the strategy concisely: "Prices are sky high in Mid C, power is tight; we are buying from all over California through the PX market. Snohomish acts as Mid C sink and resells us energy for $10 more. We wheel it back to the ISO and collect our big fat check."[33] In the Enron memos, this strategy was referred to as "Ricochet" because the energy would bump around the (fictional) network model before "returning" to California.

Of course, the strategy moved no real energy. It was purely a financial fiction created to sell energy into the CAISO markets without controlling the actual generation assets. During the "100 days of evidence," the California parties produced internal communications from the power marketers that aptly described the scheme like this: "They are stealing the ISO's lunch and selling

[33] Cited in: "Prepared Direct Testimony of Gerald A. Taylor on Behalf of the California Parties, Part 2, Exhibit No. CAL-324, May 15th 2015," *FERC* EL02-60-007, p. 91.

it back to them."[34] See figure 6-1 for an illustration. The green lines indicate the import/export trades.

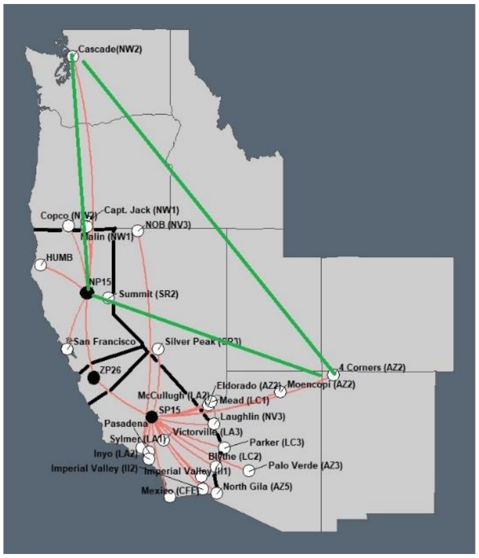

Figure 6-1 – Import/Export Strategy

A variation of this game allowed power marketers to sell ancillary services that they did not possess—effectively a form of "short sale." The trader would simply bid to sell fictional ancillary service capacity from resources outside CAISO's control area. Again, they would declare them as imports from other balancing areas, which resolved the need to specify the technical characteristics of the asset. If the power marketer was called on to provide these resources, the company would quickly procure the necessary resources in a bilateral transaction.[35] Since ancillary services were usually requested to run in emergency situations with little time to spare, and since the power marketers did not actually own the necessary capacity, these sales could create real problems for grid management. If the seller was unable to find the missing capacity, it could simply disappear

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[34] "Prepared Testimony of Gerald A. Taylor on Behalf of California Parties, Exhibit No. CAL-055, September 21, 2012," *FERC* EL01-10-085, p. 1
[35] Ancillary services were sold in day-ahead markets; see chapter 5.

from the markets. The power marketers had only to fear a fine, but the system as a whole could collapse.

Another strategy along the same lines was referred to as “Fat Boy.”[36] This scheme allowed power marketers to enter the real time markets via a fraudulent load schedules, i.e., fraudulent statements about anticipated demand. The strategy took advantage of the fact that anyone could register as an SC. Recall that the SCs were brokers who facilitated trades between buyers and sellers, thus running the forward markets. Upon concluding a trade, the SCs had to submit the information to the CAISO. Any time they submitted schedules, these had to be balanced—the aggregate load of buyers had to match the aggregate production of sellers. The original reason for this requirement had to do with plans to create a competitive market for SCs.[37] But the requirement was also important to ensure that only *unplanned* deviations in the schedules would have to be accommodated through the imbalance markets. If all schedules were balanced, the ISO did not have to perform complicated cross-balancing services before starting the imbalance markets. The provision was thus in place to increase slack in the management of the grid.

Some of the power marketers had registered as SCs, most notably Enron. As such, they could act in three capacities: as broker, buyer, and seller of energy. If they also had a retail branch, they could easily overstate the anticipated consumption in the schedules that they submitted to the CAISO. They would simply create fictional load on their schedules, which would be met by real generation from power marketers. In the real-time market, the ISO would recognize that the load was much smaller than the schedule had stated, and the generation would count as “positive uninstructed imbalance.” In other words, there would be unused extra generation on the balance sheet

[36] “FERC Final Report,” VI.12-14.
[37] I will discuss this further in chapter 9 and below.

of the SC. If there was insufficient generation to meet load, the system operator would use this energy to meet the load, thus allowing the power marketer to passively sell in the imbalance market. Due to the two-settlement system, the unused generation would be sold at the level of the real-time energy. This way, the power marketer running the scheduling coordinator could smuggle their production resources into the imbalance market and arbitrage the market.[38]

In sum, the first set of games constituted a form of illegal arbitrage trading. In each case, the power marketers found ways to circumvent restrictions on access to CAISOs real-time markets. These strategies usually involved steps that obscured the origin of the resources they sold and the falsification of bidding portfolios. They fed on incentives to arbitrage price differences, which were heightened by the presence of market power and, in turn, enabled additional avenues for the exercise of market power. Arbitraging markets that suffer from market power itself constituted a form of market power if the energy was pivotal.

I will now turn to the last set of games.

6.2.3. Congestion Games

The other set of games aimed to profit from incentives to relieve congestion in the transmission system. As outlined before, the California markets included implicit markets for transmission capacity. They were designed to include the presence of scarce transmission capacity into the pricing mechanism. Recall that "congestion" is a fiction that is used to point out problems in a planned dispatch schedule. All real flows of energy are instantaneous. If a given dispatch schedule

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[38] The utilities used the same strategy to *under*state their load in the PX. Once CAISO imposed price caps on its markets, the strategy presented a means to protect themselves from the escalating prices in the PX because they lowered the intersection between supply and demand curve in the day- and hour-ahead markets and would never pay more than the price caps, c.f. fn. 17.

is flawed because it would lead to overheated lines, it needs to be changed. Some generators need to reduce their planned production and other generators have to step theirs up. The market for transmission capacity was supposed to find the most important adjustments ahead of time by pricing transmission on paths that were often congested. The PX used a simplified network model with three zones and 26 scheduling points to represent the transmission network. If schedules produced in the forward markets created congestion in the network model, the system operator would use adjustment bids to determine who would get the greatest benefit from using the congested interfaces. This would help find the most cost-effective way to organize the necessary redispatch. The system thus generated incentives to back off generators that would make less money selling outputs to one location than another.

Now, the situation changed when there was congestion in the system that was not represented in the market's network model. In real time, the system operator used a full network model to see if the schedules could be implemented. If there was residual intrazonal congestion that had not been resolved by the market process, the ISO would use the adjustment bids to pay for necessary last-minute adjustments. The costs of these adjustments were socialized because they responded to congestion that had not been represented in the market. If generators were unable to fulfill their obligations because of such "unpredictable" congestion, they might then be paid to back off. Now, whenever it was possible to predict intrazonal congestion ahead of time, sellers had an incentive to make trades that profited from it. This meant that they would either *create* intrazonal congestion or *exacerbate* it by selling energy on lines that were already congested. These incentives were detrimental to the market mechanism because they led sellers to make trades that made the aggregate dispatch less efficient, increasing the work for the system operator and generating payments to relieve congestion that would have been avoidable. Since such trades constituted violations to the market mechanism, the tariff generally prohibited them.

A first iteration of a game to profit from artificial congestion was the infamous “DEC game.”[39] In the forward market, traders in two separate companies would schedule a trade between two locations in the same zone. This trade would far exceed the capacity limits of the line that connected the two locations. But since the transaction took place within the same zone, the market for transmission capacity would not reflect this congestion. From the perspective of the simplified network model, it looked like the trade took place at the same location. Accordingly, the trade was accepted, scheduled, and submitted to the system operator. In real time, the system operator would now try to implement the schedules. Since it used the full network model, it recognized that the trade could not be executed. To deal with such real-time fluctuations, the system operator would buy “decrements” from the trader, i.e., pay the generator to decrease its output and relieve the congestion. The price for the decrement was established via adjustment bids that specified how much the lost opportunity was worth to the trader. Conveniently, the DEC player had submitted very high adjustment bids and now reaped a massive windfall for *not* delivering energy—energy they could not have delivered in the first place. Since the system operator only had a couple of minutes to resolve the problem before dispatch, this game put strain on the reliability of the grid. The profits from this game depended on the fact that the forward markets were supposed to be the best approximation of the real-time market. As soon as traders figured out how they could get paid for their ability to predict or create congestion, they derailed the market mechanism (and system

[39] Outlined in Ziad Alaywan, Tong Wu, and Alex D. Papalexopoulos, "Transitioning the California Market from a Zonal to a Nodal Framework: An Operational Perspective" (paper presented at the Power Systems Conference and Exposition, 2004. IEEE PES, 2004), pp.2-3.

reliability), broke the precarious connection of mutual improvement between the two markets, and made a massive profit.[40]

The second game was called “Death Star” and revolved around a similar flaw. “Death Star” was the generic name for a variety of games with names such as “Forney’s Perpetual Loop,” “Red Congo,” and “NCPA Cong Catcher.” Each relied on specific agreements with other market participants, and the names indicated with thinly veiled codenames which company served as counterparty.[41] The Enron memos described the point of these games succinctly: “The net effect of these transactions is that Enron gets paid for moving energy to relieve congestion without actually moving energy or relieving any congestion.”[42] The game took advantage of the fact that power flows into opposite directions cancel each other out. Accordingly, certain decisions to produce energy can free up transmission capacity and render the overall usage of the grid more efficient. The transmission markets were designed to incent such trades and rewarded traders who offered counterflows on congested pathways. The game was designed to take advantage of this incentive without actually moving energy.

The ISO only controlled parts of California’s grid and was tied into the Western Interconnection. It could therefore only “see” power flows on its network and optimized the use of the grid (as much as it was allowed to) within the boundaries of its jurisdiction. Of course, real power flows move on all available paths. How exactly power flows interact therefore depends on the system as a whole, not just the part that the ISO managed. This made it possible to create

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[40] “FERC Final Report,” VI.26.
[41] McCullough Research, “Memorandum to Research Clients: Congestion Manipulation in ISO California, June 5, 2002,” p.4/5. He elaborated further on this analysis in “Examining Enron: Electricity Market Manipulation and the Effects on the Western States,” Hearing Before The Subcommittee on Consumer Affairs, Foreign Commerce and Tourism of the Committee on Commerce, Science, and Transportation United States Senate, 107th Congress, 2nd Session, April 11, 2002, p. 69-83.
[42] “Enron Trading Memo, December 8, 2000” (short: second Enron Memo), https://www.ferc.gov/industries/electric/indus-act/wec/enron/12-08-00.pdf, last accessed 03/28/2020, p. 5.

schedules for energy flows that appeared to provide counterflows, but did in fact cancel each other out entirely. No energy would flow, but it looked as if the company provided a counter-flow.

The game would begin when traders could confidently predict congestion somewhere in the California network. For example, they were often able to tell when Path 15, the main line that connected northern and southern California, was congested. They would then schedule a counter-flow into the opposite direction, which would generate capacity payments for relieving conges-tion. From CAISO's perspective, they had provided an important service and increased the avail-able transmission capacity. At the northern delivery point, the company would then move the power outside of California, e.g., to Oregon or Washington. From there, they would send the power back south, and then to the initial scheduling point in California. The complete schedule was therefore circular.[43]

Such circular schedules do not actually lead to power flows; they simply cancel each other out. But the incomplete market for transmission rights did not reflect this fact. It only re-flected half of the complete schedule, so the company could reap payments for providing trans-mission capacity when they produced no energy at all. See figure 6-2 for an illustration. The red arrow indicates the congestion on Path 15, while the green arrow indicates the direction of the circular energy flows. From the perspective of California's grid, they look like south - north counterflow trades. From the perspective of the system as a whole, they are circular trades that cancel each other out.

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[43] See, for example, the famous description of "Forney's Perpetual Loop" in Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 166.

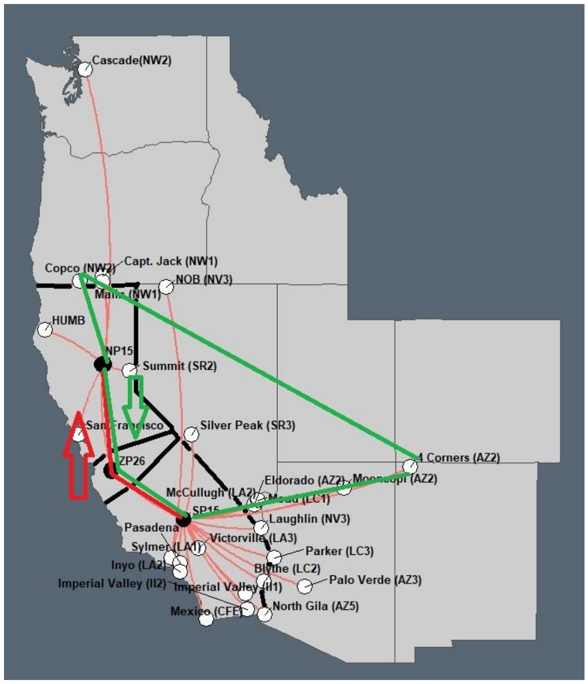

Figure 6-2 – Congestion Game

The game used the physical reality of counterflows in the whole network to provide fictional counterflows to the ISO. It turned the physical reality against its representation in the software. There were other versions of these games, such as load shift, which was a corresponding strategy to create fake congestion in the day-ahead and hour-ahead markets. A trader needed to have two trades, one to serve load in the northern zone, one to serve load in the southern zone. These loads would be overscheduled, i.e., the amount of energy served at each location would be far in excess of the real demand. The trader could now increase the fictional load at one location to increase congestion and also increase the load at the other location to provide a fictional counterflow. Or it could reduce the fictional load, shifting it from north to south or vice versa to reduce congestion this way. Since the load at both locations was fictitious, they could move it around arbitrarily, depending on the best way to increase congestion and then reap rewards for relieving it.[44]

Further variations on this strategy existed, but the basic point should be clear: power marketers could use their knowledge about real-power flows in the overall system to profit from their insufficient representation in the market model. These games were exacerbated by the exercise of market power. Changes in the dispatch structure led to new congestion patterns, and new congestion patterns led to further opportunities for congestion games. Conversely, congestion games could be played to create load pockets where generators would be able to exercise market power.

At the core of the different strategies, we encounter the same basic problem again and again: the existence of incentives to act in ways that were not aligned with the reliable operation of the system. When capacity was tight, the markets incented behavior that derailed the search for efficient schedules and destroyed generation assets. When price differences existed between the real-time and the forward markets, there were incentives to smuggle energy from unidentified resources into the markets. When there were ways to predict power flows not represented in the market, there were incentives to use the information to produce artificial congestion. Now, rather than explore to what extent a combination of these behaviors caused the crisis, we are going to approach the examination of these strategies differently. We have established how three types of behavior violated the market mechanism that aligned with the operation of the electricity system. Viewed from a systemic perspective, the availability of problematic incentives points to flaws in the underlying market design. They mark ways in which the design failed to deliver on the

[44] "Second Enron Memo," p. 2-3.

promise of the intellectual project of market design. Accordingly, it is now time to ask: What features of the design created these incentives? This will reveal how we can understand the California system as an instance of market design failure.

6.3. Structural Preconditions for Destructive Strategies

I have described three basic types of behavior that were detrimental to the market process: the exercise of market power, illegal arbitrage businesses, and congestion games. Under certain conditions, incentives emerged for players to engage in these activities. I will now trace these activities back to structural design features. Since the cybernetic project of market design requires institutions that configure the incentives for the market process as well as an oversight structure that can observe and control the market mechanism, we have to look at both of these components. While the basic organizational framework created the incentives for problematic behavior, the control structure created the opportunities to act on them. I will begin by considering the design flaws that are associated with the exercise of market power.

6.3.1. Problems with The Temporal Logic of California's Markets

Many empirical studies of the California crisis cite the absence of forward contracts, the must-buy requirement, and the retail price freeze as the major design flaws permitting the exercise of market power.[45] The argument is based on simple counterfactuals. Consider forward contracts first. If utilities had contracted much of their demand months and years in advance, they would

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[45] The discussion in chapter 3 covers the most relevant authors who take this view. See Borenstein, "The Trouble with Electricity Markets: Understanding California's Restructuring Disaster" for the argument about the importance of forward contracts; Smith, Rassenti, and Wilson, "California: Energy Crisis or Market Design Crisis?" for the importance of the retail price freeze; and Joskow, "California's Electricity Crisis" for all three arguments.

have been less vulnerable to the price fluctuations in the spot markets. Forward contracts also tend to reduce generators' incentives to raise spot prices. Since forward contracts are hedges for the buyers, any increase in spot prices will cause the generators' payments to the buyer to increase (or its receipts from the buyer to decrease). Thus, to the extent that the majority of its supply portfolio is committed under contracts-for-differences, a generator's incentive to exercise market power will disappear.[46] So, if the utilities had bought forward contracts for most of their demand, the incentives to exercise market power would have disappeared in the spot market.

A similar argument can be made about the must-buy requirements that forced utilities to buy their power in the PX.[47] Since the utilities were forced to buy their energy in the PX markets, they could not choose alternative suppliers. Under conditions of market power, an auction with a single clearing price exacerbated the problem: everyone would be beholden to the price that one company with market power imposed on the market. Accordingly, if the utilities had been able to buy their energy elsewhere, the utilities would have left the PX and bought their energy in bilateral markets, where market power might be less severe. A last counterfactual explains the relevance of the retail freeze. If there had been true retail competition, so the argument goes, end users would have switched to a variety of ESPs. In that case, the utilities would have had to purchase less energy in the PX. This would have rendered the financial infrastructure of the industry less vulnerable to utilities' misfortunes. With workable retail competition, there would also have been a more robust demand response to higher prices, which would have curbed attempts to exercise market power.[48]

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[46] E.g., Sweeney, "The California Electricity Crisis: Lessons for the Future," 31.
[47] E.g., Ahmad Faruqui et al., "Analyzing California's Power Crisis," *The Energy Journal* (2001): 41.
[48] E.g., Smith, Rassenti, and Wilson, "California: Energy Crisis or Market Design Crisis?"

I do not want to dispute that the three design features were proximate causes of the price spikes that began in 2000. But these arguments do not take a systemic point of view and suffer from hindsight bias. First, even if long-term forward contracts *had* been available, the utilities would also have needed to *know* that energy prices were going to go through the roof prior to the crisis. Just because forward contracts are available does not mean that people are going to use them. As hedges, these contracts are effectively bets on the future, and during the time of restructuring, there was strong evidence to suggest that wholesale prices would go down rather than up. One of the reasons California embarked on restructuring was because utilities had signed long-term contracts under very unfavorable conditions throughout the 1970s.[49] These contracts drove up the rates in the 1990s, triggered calls for restructuring, and taught California's utilities to avoid long-term contracts at all costs. Accordingly, the utilities had good reasons to stay away from forward contracts. From a *structural* perspective, the mere *availability* of forward contracts does not solve the market power problem.

A second, rarely recognized fact highlights the importance of this insight. The literature often cites the CPUC's restriction on forward contracting to explain why the utilities were exposed to the price risks in the spot markets. This restriction applied to bilateral contracts outside the main auction markets and was meant to increase business in the PX to reduce the potential for the exercise of market power by the utilities. But in July of 1999, the PX introduced so-called Block Forward Contracts. This gave utilities an opportunity to hedge some of their price risks inside the PX. They could buy contracts for the delivery of energy for entire months, up to twelve months in

[49] Duane, "Regulation's Rationale: Learning from the California Energy Crisis."

advance.[50] It is true that the CPUC restricted the number of contracts the utilities could buy. Each utility was limited to one-third of its historical minimum hourly load by month, or a combined capacity of 1,600 MW per month. After protests by PG&E and SCE, these limits were scaled up to 5,600 MW. Even though 5,600 MW constituted a minor share of the utilities' combined average demand on any given day, they did not utilize the forward contracts to this level. In 1999, the highest trading volume occurred in September of 1999 and amounted to a total of 3175 MW. In 2000, July was the month with the highest trading activity: only 4850 MW were sold. In other words, at no point did the utilities utilize even the limited amount of forward contracting they had access to.[51]

During the crisis, prices for these contracts went up significantly, and the CPUC made bilateral contracts available to the utilities, which might explain their lack of forward contracting in the PX. Nonetheless, before the crisis when cheap contracts were available, the utilities did not use them. The historical experience had primed them to be wary of forward contracts, so they did not use them. And why should they have?

When the markets started, wholesale energy prices were very low, and the expectation of excess capacity suggested that they would stay that way. As the CEO of the PX put it to me: "We finished the first year at an average price, I think of 2.4 cents a kilowatt hour, $24 a megawatt hour. Unbelievably low prices. When I looked at my electricity bill at how much the energy was and a distribution, and then the gap between those costs and what we were actually billed was a stranded

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[50] A single contract is equal to 1 MW for sixteen hours per day for one month, excluding Sundays. Companies could buy "blocks" of contracts to reflect the capacity they required, e.g. 1,600 contracts equal 1,600 MW for sixteen hours each day for one month, excluding Sundays.

[51] These numbers stem from Table 17 of Power Exchange "Second Annual Report to the Federal Energy Regulatory Commission, prepared by the Market Monitoring Committee of the Power Exchange, July 31, 2000," *FERC* ER98-2843, p. 48 (short: Second Surveillance Report 1999).

cost recovery for the utility. It was big, it was big. They were recovering their stranded costs."[52] Conversely, the utilities did not even consider how high the prices in the spot markets might become. As an engineer at PG&E told me, risk analysis never went beyond minimal thresholds. "They tried the regular stuff like 50 percent, 100 percent higher or 50 percent lower [than cost]. I don't know, whatever they tried, nobody ever thought to see what would happen if the prices would just jump like this, like you know—of course they couldn't guess $900—but maybe they should have tried 200."[53] Accordingly, there was no sense that forward contracts might be the crucial insurance against financial ruin.

It is also true that the retail price freeze combined with the mandatory 10 percent rate reductions effectively prevented the formation of an efficient retail market. Most consumers had no reason to switch away from the utilities because the rates they offered were just as good as the best offers other retail providers could make. Since the utilities did have to procure about 80 percent of the energy in California and since they did have to buy this energy in California's spot markets, they were very vulnerable to the exercise of market power. Thus they created one of the components that is relevant to market power: demand inelasticity.

The absence of substantial forward hedges together with the retail price freeze are the proximate causes of the crisis. They explain how specific opportunities for the exercise of market power emerged. But these explanations ignore the fact that the conditions for the possibility of market power would have existed in any case—the hazard would just have been diminished. Evidence from other markets supports this argument: the PJM markets, for example, had vesting contracts

[52] Interview with George Sladoje, 30/03/2018.
[53] Interview with Carmella G., 11/28/2017.

that established long-term hedges for most of the utilities. Accordingly, the exercise of market power was limited. Yet it occurred regularly during the first year of operation.[54]

When Texas restructured its electricity markets in 1999, it made “demand response” a prime policy objective and introduced competitive retail markets to that end. Despite the absence of a retail price freeze and incentives for distributers to improve metering, consumers did not take the opportunity to respond to wholesale prices.[55] The economic argument is that market power diminishes in the face of elastic demand.

On the surface, there can be no doubt about this: when prices go up, people will eventually jump ship, and at some point, the markup from the exercise of market power will be eclipsed by the opportunity cost of lost customers. But the argument is generic. It does not consider that decision-making itself has a cost. In order to have truly elastic retail markets, individual consumers would have to monitor the prices in the wholesale markets and adjust their consumption to periods of lower pricing. Not only do people not want to do this because it is a time-consuming bother—as the lukewarm customer reaction to the introduction of retail markets for electricity shows— but it is also the case that the consumption of electricity is tied to the rhythm of the workday. Most people do not have the choice to wait with their laundry until the early afternoon because they are at work at that time.

Further, the technological infrastructure for this kind of demand response was not in place. True retail competition could have brought the necessary updates, but only if the customer had wanted it, which would have first required price spikes. All this might change with the introduction

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[54] Erin Mansur, *Pricing Behavior in the Initial Summer of the Restructured P.J.M. Wholesale Electricity Market* (Berkeley, CA: University of California Energy Institute 2001).
[55] Jay Zarnikau and Ian Hallett, "Aggregate Industrial Energy Consumer Response to Wholesale Prices in the Restructured Texas Electricity Market," *Energy Economics* 30, no. 4 (2008).

of the Smart Grid and the internet of things, where the decision-making process can be taken over by the machines themselves. But while end users had to provide the necessary demand elasticity, it would never have amounted to more than a slight tilt to the vertical demand curve.

While the retail price freeze, the must-buy requirements, and the absence of forward hedges explain where market power emerged at specific instances, they do not capture the structural reasons for the emergence of market power. These empirical arguments merely highlight that the three design features the literature has focused on beg the question.

What, then, are the decisive design flaws from the perspective of the system's architecture? To answer this question, we have to ask where the ability to exercise market power came from. A small piece of the puzzle is the fact that there were structural reasons: utilities had little incentive to set up long-term forward contracts. So even if the situation in California had indicated that prices were going to go up in the next few years, utilities would not have had strong incentive to hedge their bets. The reason was that the corporate structure was set up in such a way that they could move profits out of the market system while shifting losses to consumers.

All three utilities had so-called "unregulated" affiliates that could play the markets as wholesale sellers. These companies were separated from the utilities via a firewall—they were not allowed to share information, offices, or employees. But they were still tied to the larger corporation via a holding company that acted as parent to both the affiliate and the utility. The utility could funnel profits into the affiliate and vice versa. This means that the affiliate could enjoy the benefits from the exercise of market power, while the utility could enjoy the profits from retail sales when the wholesale prices were low.

As long as there was not a real crisis, the utilities position was already hedged—they profited from low prices just as much as from high prices. Since forward contracts are on average more expensive than short-term contracts because they average the risks, it was thus more efficient to stay in the short-term markets. Besides, since long-term contracts undermine the profit margins in the spot markets for sellers, such long-term hedges would have cut into their own profits on the other side of the markets. In other words, the ability to play both sides of the market acted as a more profitable hedge for the utilities than the genuine article would have—only as long as there was no crisis that seriously undermined the utility and endangered their ability to recover the cost from their consumers, of course.[56] Here, we see for the first time that the ability of players to act on different sides of the market constituted a problematic structural feature in the markets. But this is just a small part of the puzzle.

The deeper reason for the emergence of market power lies in the temporal logic of the market. As we have seen, market power emerged whenever the system was pushed close to the capacity limit.[57] The only way to prevent the emergence of market power is to ensure that the system does not reach its capacity limits. The reserve margins had to be high enough to establish a competitive fringe regardless how much demand existed in the system. To ensure this excess capacity, the system must be designed to sustain investments that exceed the reserves necessary at peak demand. But even though the creation of California's markets led to an uptick in applications

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[56] However, even in that case, they had a reasonable expectation that the CPUC would eventually allow them to recover the losses or that they would be bailed out by the government if something went really wrong; after all, they were systemically important. Of course, this is what happened and would have been prevented by more competitive retail markets, which would have reduced the systemic importance of the utilities. Nonetheless, the ability to play on both sides of the market made long-term forward contracts less attractive under conditions of moderately increasing prices.

[57] It is interesting to note that restructuring was premised on an excess of supply in California. In 1995, the CEC had issued a biennial planning document that projected growth of demand and available supply until 2001. It estimated a vast excess of supply with reserve margins of 21-23 percent (16 percent was the NERC standard). But the two utilities had vastly inflated their descriptions of available supply. For example, they treated interruptible contracts as surplus energy, made projections about purchases that they never intended to make, etc. Marcus and Hamrin, "How We Got into the California Energy Crisis." So, the planning horizon for new generation was flawed prior to restructuring. This had to do with the fact that the utilities wanted to increase the amount of stranded costs they would be able to recover during restructuring. Contrary to their statements, they were trying to minimize their generation assets to not be exposed to market risk. This problematic starting point was then exacerbated by the dynamic described here.

for new capacity, the system was not designed to provide incentives for these investments *in time* to prevent the exercise of market power.[58]

To understand this problem, assume for a second California's system had not been at the capacity limit. The structure of the PX auctions (where most of the transactions took place and sent price signals to all other markets) incentivized generators to bid as low as they possibly could to sell as much of their output as possible at the market clearing price. The least expensive generator required to meet the last MW/h of demand would set the price for the market as a whole. What would such a generator bid? In California, this would be a generator that had been built before deregulation. Assuming the generator does not already have market power, it would usually prefer to sell something rather than nothing. Worried that it might not be selected because it is right on the market's fringe where capacity might or might not get selected, the generator would bid its marginal operating costs—just enough to survive. This means its *fixed* costs would not be reflected in the bid.[59] It would effectively operate at a loss relative to the initial investment costs to set up the plant. As a result, *excess* capacity in a competitive market for energy-only will cause prices to fall to a level well *below* the *average* cost of producing electricity. This would lead to losses for suppliers who had not recovered their fixed costs before restructuring. More importantly, the prices would also be insufficient to incent the entry of new generators.

But why does excess capacity depress the market clearing price below the average cost of production? The answer is that the efficiency of perfectly competitive markets is pegged to a particular moment in time. California's spot markets were designed to generate optimal schedules for the dispatch of energy during a specific hour of real-time operation in the future. All forward

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[58] Between 1997 and 2000, applications averaged about 3,300 MW Sweeney, *The California Electricity Crisis*, 103.
[59] Particularly for assets whose costs had been recovered before deregulation.

markets were ultimately oriented towards a particular moment of real-time operation. But from the perspective of any given hour of real time operation, generation that would not be needed represented nothing but *waste*. Accordingly, an efficient market would not pay the owners of this superfluous generation for it. The reason why this additional generation capacity was necessary was that it created redundancies: one supplier could be replaced with another. Such redundancies, a standard tool of engineers, do not factor into the logic of perfectly competitive markets that generate *efficient* results for the particular allocation problem they are solving (dispatch schedule for a given hour). This excess capacity was a crucial precondition for the market mechanism to work as required, yet, it was not reflected in the market.

The presence of forward markets would not change this problem.[60] Even if companies start to buy energy to meet *future* increases in demand and thus create incentives to build new generation, these transactions do not cover the excess capacity that will never be used to serve anyone but is only necessary to sustain a competitive fringe. Ancillary markets, designed to provide emergency capacity of various types, suffer from the same problem. These markets price the risk of shortfalls in the short-run, not the excess capacity needed to keep up with—and stay ahead of—growing demand.

The only time when the required excess capacity would be priced were moments when it had already disappeared. Investors could recover the cost for an investment into plants that operate at the capacity limit of the system if these generators can benefit from large *price spikes*.[61] Such price spikes are not the same as the exercise of market power because they reflect marginal cost.[62]

[60] As classic arguments from game theoretical analyses might suggest; see Blaise Allaz and Jean-Luc Vila, "Cournot Competition, Forward Markets and Efficiency," *Journal of Economic Theory* 59, no. 1 (1993).
[61] Or if the plant is frequently selected to sell ancillary services instead of energy.
[62] This effectively blurs the line between the exercise of market power and legitimate price spikes—another reason why it was difficult to settle allegations about the exercise of market during the energy crisis.

Once a peaker is built that only operates a few hours each year, the only way to make up the investment cost is to reap astronomical sums during the few hours that it runs—unless there is some other mechanism to recover the capacity investments, of course.[63] If such price spikes become possible, incentives to create new generation capacity immediately begin to pull investors into the markets. But from the perspective of the system, this would be too late. Since the price spikes only become available when the system is already close to the capacity limits, the specter of market power would immediately rise.

But once companies can begin to exercise market power and can do so for long periods of time, the market mechanism begins to undermine the logic of system operation because it takes many months to bring new energy online. The competitive fringe has disappeared and pivotal generators are beginning to exercise market power. The looming dangers for system reliably create regulatory uncertainty as well as the danger of market collapse. This eradicates the incentives for investments once again; since no one knows if the price spikes will be allowed to continue and no one knows whether the markets will survive, it becomes very risky to invest. Particularly, if you consider that the price spikes will disappear when the system returns to normal operating conditions and the real-time markets depress the market price below the fixed costs for investments. In other words, the markets did not price the excess capacity until the point when it was missing. But since it was a condition for successful operation of the market process, the market stopped working as soon as it could create incentives for the creation of excess capacity.

Thus the deeper reason for the existence for market power was that the slow expansion of the system that is necessary to avoid the emergence of market power could not be sustained by

[63] This is the reason some markets, such as the wholesale markets in Australia, explicitly allow prices at around $10.000 per MWh.

markets that only price the resources needed in specific moments of real-time operations. Since they did not price the necessary capacity, the markets thus eroded the conditions under which the mechanism worked as desired. Incidentally, this is also the reason why a moderately elastic demand elasticity in the short-run would not solve the problem of market power. In the long run, demand would grow and the supply would dwindle to the point where demand becomes inelastic again.

In sum, the fact that the markets all ultimately sold energy for delivery in real time imposed a short-term logic on the market. While the system operated below the capacity limits, it set prices that were too low to allow generators to recover their fixed costs, making new investments supremely unprofitable. Once it set prices that allowed recovery of investment costs, the system was already close to the point where the exercise of market power eclipsed scarcity pricing.

Only an investor that could have been sure that the prices were going to go up would have invested at a moment when the prices were low. Since this depended on a monopoly at the edge of the system, it was dangerous to act on such an opportunity. If others took it, the investor would end up with capacity that was not going to be recompensed by the market.[64] Since investors tend to recognize the flawed temporal logic of the markets, the “missing money” problem of electricity markets is well-known today.[65] In an uncertain regulatory environment, the California system was on a perpetual course for self-destruction, and the risk of system collapse drowned out the potential price incentives that might help to ameliorate the situation.

The central design flaw was thus the way different temporal horizons of decision-making were folded into a market that only reflected individual hours of real-time operation. The design

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[64] Jens Beckert, "Imagined Futures: Fictional Expectations in the Economy," *Theory and Society* 42, no. 3 (2013).
[65] William W. Hogan, "On an “Energy Only” Electricity Market Design for Resource Adequacy," (Cambridge, CA: John F. Kennedy School of Government, Harvard University, 2005).

did not account for the temporal structure of new investments required to avoid the existence of market power.[66] It only priced what was necessary to serve demand at specific instances in time—either in the short-term or at particular instances in the long-term. The logic of the market thus progressively pushed the system into a direction where market power became available.

6.3.2. Separation and Equality Provision

Now I will consider the design flaws underlying the other two problematic types of behavior. As outlined before, the first class of behavior consisted of illegal arbitrage businesses. Power marketers had strong incentives to arbitrage price differences between the spot market in the PX and the ISO. But the CAISO markets required sellers of energy to have direct physical control over their assets in order to be able to use these resources for grid management. The decisive question is why these profitable price differences existed. In an efficient commodity market, all contracts—forward and spot—for delivery of goods at the same time and location will, on average, transact at the same price.

In theory, price changes will simply reflect *random* changes in the information that becomes available between forward and spot markets. The deviation will have a distribution with the mean zero.[67] But in California, the markets displayed large and consistent differences over time. These differences started to widen in the summer of 2000, when the crisis began. Average day-ahead prices in the Power Exchange were more than 15 percent below prices for the same product

[66] Other electricity markets, most notably the PJM markets, ultimately avoided this problem by introducing separate capacity markets that would deal with the addition of new generation assets over longer periods of time. However, these capacity markets have no real demand—the demand curve will be constructed on the basis of political negotiations between stakeholders. There is no solution to this problem that would find the adequate balance on the basis of purely decentralized decisions. Hence, these structures are also referred to as "market-like" entities. Breslau, "Designing a Market-Like Entity: Economics in the Politics of Market Formation."
[67] See the discussion of the two-settlement system in chapter 5.

in the real-time market of the ISO, and by September 2000, prices in the ISO were higher than prices in the Power Exchange for over 70 percent of the hours.[68]

Part of the reason for this divergence was the price caps that the ISO imposed in response to the Western energy crisis. This meant that the utilities increasingly tried to shift their load into the real-time markets, reducing the load in the PX and generating inadequate forward schedules at different prices. It is plain, in other words, that the exercise of market power in combination with price caps helped to throw the markets off balance. Much capacity bid into the PX was also "must-run" capacity that was priced on the basis of preestablished contracts. Since this capacity was priced separately, it was bid into the market at zero cost, which depressed the market price.[69]

However, even in the absence of market power and must-run contracts, the price differences would have persisted because there were a variety of differences in the way the ISO markets operated. This means the decisive underlying design flaw was the separation of the Scheduling Coordinators, in particular the PX, from the CAISO. The requirement that CAISO treat all schedules received by SCs equally made it difficult to counterbalance these problems.

Consider first the impact of market separation. When the markets first opened in 1998, the ISO used imbalance energy to construct the BEEP stack; it combined ancillary services and imbalance energy into a single supply stack. As we have seen, the clearing price was computed every ten minutes, relative to the demand the CAISO had to meet. But operators sometimes skipped over low-cost energy bids from some of the ancillary services in order to retain these sources as

[68] Established in the CAISO/PX market dataset from the California Energy Institute.

[69] Problems with the RMR contracts persistently confounded the redesign efforts. How to inoculate the market process from these contracts and reduce their importance represented a recurrent theme in the meetings of the board of governors for the ISO, c.f. for example the minutes for the meetings in the second half of 1998 and the first half of 1999, in "Independent System Operator Board of Governors and Committee Meeting Files," R400.006-R400.007, Box 6-7, *CSA*.

reserves.[70] This means that the imbalance energy price might suddenly rise because lower cost generation was not selected. A second source of price differences was the way the ISO used the imbalance market. Generators could submit decremental and incremental bids for the real time markets. The inc bid was a bid to supply an additional MW output should the clearing price be equal to or above its bid. The dec bid was a bid to reduce the output should the price be equal or above the clearing price. Now, depending on the situation of supply, the use of generators may be more cost-effective if some generators increase their outputs while others decrease them. A price difference between the clearing price for increments and decrements would indicate as much. But the ISO never performed such balancing operations. Instead, it used the inc bids when there was an undersupply, and it used the dec bids when there was an oversupply. This meant that the way prices were set allowed a certain level of inefficiency to persist that pushed up the price in comparison to the PX.

Another reason arbitrage opportunities emerged had to do with the different treatment of ancillary services. In the day- and hour-ahead auctions at the PX, ancillary services were sold after the main energy auctions were done. In other words, only if your energy was not selected in the auctions for firm and non-firm energy could you sell it as capacity in the ancillary service markets. In CAISO's markets, this logic reversed. If capacity committed as ancillary services were called upon in the real-time market, it would be paid twice: once for the capacity and once for the energy delivered.[71] This meant that participants of CAISO's markets had a chance to sell their output

[70] Borenstein et al., "Inefficiencies and Market Power in Financial Arbitrage: A Study of California's Electricity Markets," 9.
[71] Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 146.

twice—once as ancillary service and once as imbalance energy. You could make twice the profit by moving ancillary services from the forward into the real-time markets.

Another example of the same problem was the "balanced schedules" or "equality" requirement that forced the ISO to make adjustments within the portfolios of SCs rather than the system as a whole. When the ISO encountered problems in implementing the schedules of a given SC, they faced certain limitations on their ability to optimize the dispatch. The ISO was only allowed to consider the resources within the portfolio of one SC to decrement or increment generation resources. This meant that it might be impossible to implement a more efficient solution at a lower cost. Lastly, using the ISO rather than the PX was associated with lower transaction costs because the ISO had a fixed charge for all energy produced or consumed in California, while the PX transaction charge only applied to energy sold or bought in the PX market.[72]

In other words, there were certain operational differences between the PX and the ISO that sustained a level of price difference between the organizations. This price difference can be traced to prohibitions on the ISO to optimize the schedules it received, which increased the price. Since the operators simply used the generation assets that were available to them without optimizing their use relative to market price, the resulting prices could differ from those that would have been found by a perfectly competitive market. Since these differences were not themselves part of the market process in the PX, they persisted. While the ISO markets were designed to supply additional resources for grid management, the PX was designed to produce efficient schedules. The

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[72] Prior to August 1999, there was yet another source of price differences. Ancillary services need to be procured to back up promises to generate—that is, if you promise to sell or buy a certain quantity of energy, you also need to procure ancillary services. In the PX markets, these ancillary services were originally sold relative to the scheduled energy rather than consumed energy. If you did not schedule any demand or supply in the forward markets, you therefore did not have to pay for the ancillary services that responded to whatever you produced or used in the real-time markets.

assumption that those two functions could somehow be separated—that grid management was somehow independent from the production of efficient generation schedules—was the core design flaw in California's markets. It created opportunities for arbitrage that sellers then tried to capitalize on. These arbitrage opportunities were problematic from a safety point of view because they did not represent trades that could be translated into physical reality.

The market separation and equality to provisions introduced a deeper problem into the market. Since the PX and the CAISO markets had to harmonize with each other, it was necessary to standardize the products that would be traded between these institutions. Obligations from the forward markets were supposed to progressively move into the next closest market until they were matched against the real-time dispatch of energy. To allow this successive movement, the products had to *appear* as equivalent from a financial point of view.

But from a *technical* point of view, the products were different. The products in the PX were financial obligations that were traded according to principles of financial markets. Since the realization of these obligations were in the future, several technical characteristics of the underlying physical reality could be neglected. The technical characteristics and the precise location of generators were not important because the slack time until dispatch could be used to align the generators with whatever the rest of the system required. However, by the time real-time dispatch came around, resources had to respond to the operator's instructions seamlessly—this was the point where actual adjustments had to be implemented to maintain system balance. What was traded in the ISO were thus in some ways different products than the financial products. They were resources to solve technical adjustment tasks. However, the *information* required to perform these adjustment tasks was located only with the ISO. Only the ISO had live information on the physical electricity infrastructure, the actual power flows, and the interactions between the different generators. The market separation therefore made it impossible to represent the full technical complexity of the electricity system in the financial markets. The equality provision prohibited the ISO from taking control over all schedules and optimizing them from a central position. It forced the ISO to make adjustments on the basis of an ad-hoc logic imposed by the schedules rather than optimize on the basis of a view of the system as a whole. This meant that even a market process that delivered optimal approximations to real-time dispatch would never lead to an optimal dispatch schedule in real time because the system operator was unable to complete the optimization algorithm. They had to work with incomplete market schedules rather than the view of the system as a whole. This cemented substantial differences between the markets in the core of the system and created persistent price differences between the different markets. In order to align the two markets, a single entity would have had to operate them according to consistent principles, i.e., by organizing the entire process consistently with the technical requirements of grid management. Only if the market mechanisms were equivalent would the products become genuine substitutes. Then the price differences would indeed disappear, and with them, the need to prohibit arbitrage trades.

In sum, the fundamental design flaw was the separation of the PX from the ISO and the equality provision. This led to the different operational procedures in the two markets, and the limits on the ISO's ability to optimize dispatch schedules globally. The deeper problem was that the separation and equality provisions made it impossible to represent the full complexity of the electricity system in the market while preventing the system operator from optimizing the market results relative to the full picture of the system. This created persistent price differences, which incentivized arbitrage opportunities that would undermine the work of the system operator.

These flaws interacted with the exercise of market power because the differential reaction to market power created vast price differences between the marketplaces. Another byproduct of the separation of the forward markets was that the complexity of market interactions was exacerbated substantially. Since market players could not just decide between different time points, but between dozens of SCs, the arbitrage opportunities increased by virtue of having many different marketplaces with different characteristics to choose from. This is a point of some significance: each time, a market fragments organizationally, slight differences in the rules that guide these markets create arbitrage opportunities. To the extent that these differences do not reflect the ultimate requirements for technical dispatch—to the extent that the market logic excludes elements of the technical balancing process—incentives will emerge to arbitrage the ISO. This, in turn, will impact the dispatch disadvantageously.

6.3.3. Physical Representation of the Grid

The last type of problematic behavior rests on another fundamental design flaw. Congestion games derived from the fact that the representation of the grid did not correspond to its physical reality. Since energy flows on all available paths might create congestion anywhere in the system, a schedule that looked feasible in the three-zone model of the market could turn out to be infeasible when compared to the real network. To change the schedule, the ISO would pay generators to change their output. This created strong incentives to find or create congestion not represented in the market and then trade on it. Accordingly, there were incentives to fabricate infeasible schedules and get paid to correct them. The design flaw underlying this logic was quite simple: since electricity will always flow according to the law of physics, the only way to truly align the incentives of the market with efficient dispatch is to represent the physical system as a whole in these markets. The simplified representation established a strong requirement that market participants could not know anything about the system not represented in the market. It assumed that the only predictable congestion would occur between the zones. Since market players could influence where congestion occurred, they violated the requirement as soon as the markets started to operate. Congestion patterns began to diverge from the expectations embedded in the market, and market players had an incentive to detect them. Other markets, such as the PJM Interconnect, address this problem by computing different market clearing prices for all nodes in the system from a central location. While the California markets were supposed to resolve the major sources of congestion through a trading process, the PJM markets take in information about cost and then compute the correct solution centrally. In other words, they move most of the computational complexity from the user onto software. This makes it possible to use a more complex representation of the network as the basis for the calculation of market prices.[73]

In sum, California's market system had several design features that created incentives for the destructive behavior outlined in the first section. These features were the temporal logic of the markets, the separation of the SCs and the ISOs, the equality provision, the ability of companies to sit on two sides of the transactions, and the lack of an adequate representation of the grid in the transmission markets. Note that each of these design flaws can be understood as insufficient market representations of features that were relevant for grid management. These were combined with limitations on the ISO's ability to use the full set of information about the system to complete the

[73] For a comparison of the basic market designs in 1998, see Lisa Cameron and Peter Cramton, "The Role of the I.S.O. In U.S. Electricity Markets: A Review of Restructuring in California and P.J.M.," *The Electricity Journal* 12, no. 3 (1999). For the logic of the zonal vs. nodal pricing, c.f. Alaywan, Wu, and Papalexopoulos, "Transitioning the California Market from a Zonal to a Nodal Framework: An Operational Perspective.". For the development of PJM more generally, Jeremiah D. Lambert, *Creating Competitive Power Markets: The P.J.M. Model* (Tulsa, Oklahoma: PennWell Books, 2001).

optimization algorithm and find the optimal dispatch structure in the short and long run. With respect to market power, the problem here was that the ISO did not have means to centrally impose costs for the excess capacity that had to be constructed to keep the system competitive at all times.[74] Together, these design flaws created incentives to act in ways that derailed the market mechanism and turned it against the reliable operation of the grid. However, none of these flaws produced problematic incentives all the time. It was only under certain operating conditions that problems emerged. Market power emerged when the system was operating close to capacity; congestion games emerged when the power flows deviated from the simple representation in the market model, and illegal arbitrage opportunities emerged when there were price differences between the forward and real-time markets.

While the market process might thus be perfectly aligned with the requirements of reliable system operations for some hours, it might diverge at other hours. This situation is comparable to supply chains, where processes that feed into each other must be kept within certain tolerance levels. As soon as a process exceeds the tolerance level, it needs to be constrained back into shape. All three types of behavior therefore required intervention by a control structure. This structure would have monitored the market process, identified moments when the incentives became misaligned with the goal of least-cost dispatch, and then taken measures to constrain the process back into alignment with the rest of the system. I will now analyze the control structure to determine why it was unable to constrain the problematic behavior.

[74] I will come back to this in chapter 10. There is no fully functional market mechanism to resolve the temporality problem, which means that the oversight structure must impose substantial requirements on the creation of additional capacity. The so-called "capacity markets" are themselves administrative structures because the "demand" is determined by committee. However, California did have no such structure in place.

6.4. Flaws in the Control Structure

In cybernetic systems, control structures are higher levels that impose constraints on lower levels, which is usually implemented via a control loop. The higher level observes the lower level, constraining its operation back into line with a set of preestablished parameters. Complex systems can also have homeostatic control structures of automatic adjustments—for example, when opening a door to a transformer room physically switches a circuit breaker. The basic idea of a self-regulating market is a homeostatic mechanism. The tendency of buyers to adjust their consumption to increases in price is a form of self-regulation, where parts of a larger system respond to changes in the environment (e.g., difficulties in producing a commodity). The problems I just discussed required active intervention because they derailed the required market mechanism. I will first discuss the general requirements that resulted from the design flaws, and then juxtapose them with the existing control structure.

6.4.1. Requirements for California's Control Structure

An effective control structure has several different components. First, the controller must have a specific *goal*—they must try to impose conditions onto the underlying process. Second, they must be able to intervene in the process they seek to control. Engineers refer to such means of intervention as "actuators." And, third, they must be able to observe the system on the basis of a theoretical model, i.e., they must be able to collect the data that is necessary to determine how the goal can be met. In more complex systems, computers are typically interlaced with this process. Sensors collect data that is then processed by software and displayed in a summary fashion to the controller, creating a synthesized perception. Similarly, the actuators are controlled via software interfaces. With these additional steps of mediation, additional avenues toward error can enter the system. If the software does not process the data correctly or if the controls fail to manipulate the actuators as anticipated, controllers may have an inaccurate understanding of the process they are trying to control. Each of the steps in this control loop takes time. Accordingly, there is always some lag between the emergence of a problem, the activity of the sensors, recognition by the controller, and the correcting response. These lag times can become extremely relevant in tightly coupled systems, such as where there is little slack between different processes that are linked via inputs and outputs.[75]

In California, these goals would have required a highly centralized control structure with substantial ability to observe and intervene in the market with minimal delay. This follows from the problems discussed in the previous section. The temporal logic of the market eroded the conditions under which the system operated as intended. Since there was no way to price the excess capacity necessary to sustain a competitive fringe before that capacity had been eroded, an administrative structure would have had to evaluate the necessary level of supply and imposed the costs to provide this "externality." In the absence of an administrative mechanism to create the required excess capacity, it would have had to evaluate *each transaction* to determine whether or not the market clearing prices reflected legitimate marginal costs or the exercise of market power because market power was fluid and distributed among all participants. In the presence of price spikes, it would have been necessary to determine if they were legitimate marginal cost bids or illegitimate attempts to drive up the market clearing price. This would have required decisions about the specific technical characteristics of the generator and their location in the dispatch structure. Similarly, this oversight structure would have had to discern if trades represented genuine attempts to serve

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[75] This description closely follows conventions of safety-system engineering, which shares the cybernetic heritages of market design. Leveson, *Engineering a Safer World: Systems Thinking Applied to Safety*, 80-87.

demand in the system or if they constituted attempts to take advantage of illegal arbitrage opportunities or predictable deviations of power flows from the network model of the markets. To this end, the oversight structure would have to see all transactions in the system as a whole and see how they related to the physical flows of energy in the system. Only if they represented "rational" trades in terms of the search algorithm designed to produce a least-cost dispatch of all available generation assets would the trade be accepted. In each case, the oversight structure would have needed the power to prohibit illicit trades and constrain the system back onto the path of equilibrium.

The level of control that the design flaws imposed was thus far higher than we would expect from the discussion in chapter three. The discussion of the intellectual project of market design suggested that market designers may be able to overcome the problems of centralized planning if most substantial decisions remain with individuals. If the oversight structure merely needs to enforce the form but not the substance of economic decision-making, a flat bureaucracy with minimal staff and software may be able to observe the market effectively. However, in the California system, this was patently not the case. Due to the highly fluid nature of market power and the various strategies to take advantage of congestion and arbitrage, the oversight regime would have needed to evaluate the individual trades to determine if they fit the requirements of blueprint. In other words, do they represent trades that would have occurred in a market that worked according to the required mechanism? The various ways external considerations could enter the markets thus made it necessary to check whether individual trades reflected the calculative rationality required to arrive at equilibrium outcomes.

The design flaws formed these higher requirements because they created a variety of incentives for problematic behavior. But they also made it more difficult to meet the requirements because they increased the dynamic complexity of the markets dramatically. The fragmentation of the system into many different SCs and separate marketplaces created interlinkages between markets with widely different operating characteristics. These differences could shift incentives in any individual market and derail the intended mechanism. Again, the basic idea was that the strategic interactions between market participants would discover the best approximation to the economic dispatch (in the short- and long-run), while taking the most important sources of congestion into consideration. For this process to work, the trades in all markets had to converge on a single aggregate schedule that progressively improved as the real time got closer. This meant that all markets were interlinked despite their different temporal, geographic, and operational differences. To ensure that each of these markets fed into the next, an oversight structure would have had to keep the different interactions between the markets in view, calculate acceptable permutations of behavior, and check if the individual trades conformed to them. The design flaws of the California market thus created very high boundaries for effective oversight. I will now show how the control structure in California fell short of these requirements.

6.4.2. First Flaw: Poorly Defined Goals

A functional control structure requires a clear goal that animates the oversight. In California's markets, these goals were not clearly specified. FERC derived its jurisdiction over the wholesale markets from the 1935 Federal Power Act (FPA). This act imposed on FERC the responsibility to ensure "just and reasonable" electricity prices. In the era of vertically integrated monopolies, the agency interpreted this to mean a price that would allow companies to recover the cost of producing electricity plus a fair fate of return on the capital invested by the firm. If prices turn out to be unjust and unreasonable, FERC has the power to take action that resulted in just and reasonable prices. Finally, any payments in excess of just and reasonable prices can be refunded by FERC.[76] Once FERC began to deregulate electricity markets, it interpreted the standard in the following way: just and reasonable prices are those prices that would obtain in a competitive marketplace. This tied the "just and reasonableness" standard to the question of whether a market was competitive. But the FPA had been passed to prevent the exercise of market power and discrimination in market transactions that were subject to *ex ante* price regulation. The new interpretation sustained this *ex ante* perspective. Aware of the problems posed by market power, FERC assumed that unless a firm could prove that it did *not* possess market power, it was not eligible to receive market-based prices. If it did possess market power, it could charge only regulated rates. This implied that companies had to apply to enter a given market and receive market-based rates. Part of this application was a demonstration that the company would not have market power. Thinking about market power from an *ex-ante* perspective, FERC assumed that the application solved the problem: any firm entering the market was now free of market power. Accordingly, there was no immediate need to specify how markets should be monitored for market power (or any other type of problematic behavior). Between 1996 and 2001, FERC did not translate the just and reasonableness requirement into specific goals for market monitoring.[77]

The market monitoring units at the PX and the ISO derived their jurisdiction from FERC, which meant that these organizations could not specify clear goals either. This was not just true for the exercise of market power, but anomalous market behavior in general. Fraudulent or manipulative behavior was not clearly defined by either FERC, CAISO/PX, or any of the regulations that governed transactions in the Western Interconnection. The CAISO tariff, for example, defined

[76] United States Code: Federal Power Act (FPA), Paragraph 205 and 206, (16 U.S.C. §§ 824d, 824e).
[77] GAO, *Concerted Action Needed*, 33.

anomalous behavior as “any behavior departing significantly from that observed in normal, competitive markets.”[78] But what “normal” meant was not clearly specified. At the time of the crisis, FERC’s oversight was implemented through the different tariffs that governed the local market exchanges. These were the PX, the CAISO tariffs, the WSPP agreement for transactions in the Pacific Northwest, and the rules for market-based rate authorization. None of these tariffs even contained the term “manipulation” or specified it any clearer than the CAISO/PX tariff.[79] The head of market monitoring described her experience at CAISO like this:

> A: [Developing] the market monitoring protocols was an afterthought. I was a new person joining the team and they said to me: “Oh, that [task] is undesignated. Go and write the protocols and then we will get ready to file them. […]” I basically wrote up the protocols based on just pure economic theory and my understanding of how market players can manipulate markets and how they can withhold through both price increases and shutting down power plants. So, that’s how I wrote the protocols.

Later in the interview, she described how she visited FERC and explained the indicators to them:

> A: The main thing I did was to come up with indicators to monitor [the markets]. I sort of did that by the fly of my pants, being just a good economist, and I remember being shocked when FERC requested that I should come in and show them how I put together my indicators—because they had nothing.
>
> G: They had nothing?
>
> A: They didn’t know how to … they had nothing. They didn’t know how to do it.[80]

In sum, FERC had not established clear *goals* for market monitoring. There was no preestablished standard for a level of acceptable prices or behavior. The different market monitoring units developed these standards by themselves based on trial-and-error experiments.

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[78] CAISO Tariff, April 1998, Vol. III, ISO Market Monitoring & Information Protocol, 2.1.1.
[79] Taylor et al., *Market Power and Market Manipulation in Energy Markets: From the California Crisis to the Present*, 183.
[80] Interview with Anjali Scheffrin, 12/13/2017.

6.4.3. Second Flaw: Insufficient Ability to Intervene

The second requirement was the ability to intervene decisively and quickly when trades did not conform to the mechanism. This ability was very limited as well. This problem had several different dimensions. Opportunities for the exercise of market power generally emerged on the level of the interactions between buyers and sellers. The different gaming strategies played out through the software interfaces of scheduling coordinators and CAISO. The different types of behavior would have had to be curtailed by the next higher level.

With respect to the exercise of market power, SCs should have been responsible because they monitored the trading behavior they facilitated. But as we have seen, it was very easy for any market participant to become a scheduling coordinator. To apply, any company merely had to prove that it could fulfill the hardware and software requirements to interface with the ISO, that it had a legal right to represent its clients, and that it had the necessary credit rating to act as an intermediary.[81] Since power marketers who had an interest in gaming the system could simply apply to become scheduling coordinators, they could effectively evade any direct control over their transactions. This was an important design flaw we already came across. The markets were not adjusted to the possibility that players might play different roles at the same time and thus defy the incentives designed for a specific role.[82] As a result, several scheduling coordinators were able to submit trades to the ISO that effectively met the "balanced schedule" requirements but falsified

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[81] *San Diego Gas & Electric*, "CAISO Scheduling Coordinator Application Protocol, FERC Electric Tariff First Replacement Vol. No. II, Exhibit No. MID-18, October 13, 2000," *FERC* EL00-95.
[82] This is what PG&E did when it moved profits from stranded cost recovery into an unregulated affiliate that gamed the markets. Beder, *Power Play: The Fight for Control of the World's Electricity*, 115.

the technical information the ISO requested from sellers who wanted to enter its spot markets. With respect to most SCs, the fox thus guarded the key to the hen house.

Of course, the most important scheduling coordinator was the PX. The PX was a nonprofit organization, which means that the problems of intervention were different here. The ability of the PX to correct schedules was limited. Buyers and sellers submitted their bids either via telephone or through the software interface to PX's transaction "TA" system. The TA system evaluated the bids in terms of the PX's Bidding and Bid Evaluation Protocol (PBEP).[83] This protocol was designed to ensure that the bids matched the market design. Effectively, it made sure that the bids added up to upward sloping supply curves and downward sloping demand curves and that there was no overgeneration in the resulting schedules. The protocol also evaluated the bids in relation to previous bids (in other hours, in the day-ahead market, etc.) to make sure that revisions only improved the market clearing price downward.[84] However, the PX did not check the technical feasibility of the resulting schedules. It merely created balanced schedules and then submitted them to the ISO. Apart from the passive controls imposed through the software, the PX had an internal market monitoring unit and a smaller market surveillance committee. The internal unit was physically separated from the other parts of the organization by special access doors, and they were relatively small. The PX's group had around seven members between 1998 and 2001.[85] The external market surveillance committees were headed by three academics, only one of them an economist. The external board had a limited, advisory function, and its relation to the internal unit was,

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[83] California Power Exchange, "Introducing California's New Electricity Markets, Presentation to Market Participants, 1997," George Sladoje, Personal Archive.
[84] Robert Wilson, "Activity Rules for A Power Exchange," Report to the California Trust for Power Industry Restructuring, Stanford Business School, 02/21/1997." This document describes the activity rules as well as the considerations that went into their construction.
[85] Ferdinand M., Interview, 02/19/18.

at times, acrimonious.[86] Effectively, the internal unit was responsible for market monitoring and corrective actions, but it had exceedingly limited enforcement abilities. The PX did not receive the authority from FERC to impose sanctions or penalties. The monitoring units were meant to merely note problematic behavior and then inform FERC, which held the sole sanctioning power. The market monitoring unit was a subdepartment of the compliance unit.[87] Initially, there were only two market monitors. In August of 1999, four additional positions were added, which made up the rest of the compliance department. If the monitors discovered anomalous behavior, they would first alert the vice president of the compliance unit. He decided whether the problem required further investigation, which was conducted by an economist and a mathematician in the "economic analysis" unit. This unit would analyze the bid data to establish whether a violation might have occurred (an inquiry).[88] Then, they asked the accused party to react to the charge, potentially interviewing them. This opened a formal investigation. After analyzing the results of the interview as well as evidence gathered through recorded telephone conversations and other sources, compliance recommended to the CEO whether the matter should be pursued further. After a hearing is held on the allegations of misconduct, the CEO determined whether a violation of the rules had been proven. At any point in the investigation process, the CalPX and the participant could negotiate a settlement. If the CEO decided to impose sanctions after determining that a violation had taken place, he needed to go to FERC, open a proceeding, and ask them to impose those sanctions. This would, again, lead to comments and reactions to comments, with FERC eventually either approving a settlement, revoking market-based authority, or disgorging profits. Not only did the

[86] Ferdinand M., Interview, 02/19/18.
[87] PX, "Second Surveillance Report 1999," pp. 62-66.
[88] D. Jermain, "Memo: Completion of Report on Enron's Actions for May 25, 1999," George Sladoje, Personal Archive.

PX not have effective tools to sanction offenders, but the process to impose any kind of penalty could take upwards of a year. This encouraged early settlements, which tended to be at a fraction of the profits the illegal activities generated.

On the next higher level, at CAISO, the situation was not much different. Just like the PX, it had an internal market monitoring unit and an external market surveillance committee. Their primary task was to watch out for market inefficiency, gaming, and the exercise of market power. In contrast to the PX, CAISO's committee closely cooperated with the internal unit and conducted original analyses on the basis of primary data. This had partly to do with the fact that CAISO's external board consisted of economists from California's universities who were closer to the markets than the members of PX's external board. However, just like the PX, they had no authority to sanction or penalize rule violations directly. If either of the two units detected anomalous behavior in violation of tariff rules in its own or any of the other markets, it would conduct an investigation, inform management, and recommend further action. However, any sanctions had to be approved by FERC.[89] The few tools that CAISO had available to react to problems were extremely ineffective. Principally, they used so-called "Reliability-Must-Run Contracts" to constrain market power. When the price spikes began to occur frequently in the real-time markets, the ISO instituted a series of price caps on their imbalance market—first at $250 until October 1, 1999, when it was set at $750. When the crisis hit, it was reduced to $500 and finally to $250. These caps proved highly contentious, but helped to limit the damages while the ISO tried to determine what was happening. FERC approved these caps relatively quickly in emergency proceedings since they did not require any investigation of specific supplier behavior. They merely needed to determine that

[89] "MMIP," 4.4.2.

the markets were not “workably competitive.”[90] However, the price caps only exacerbated the problems: since the utilities knew that the exercise of market power would be curbed in the imbalance markets, they began to under-schedule their demand in the forward markets. They falsely claimed that they would require less energy than anticipated. This moved the bulk of energy transactions into the imbalance markets, which rendered the forward schedules widely inaccurate. Suddenly, the CAISO had to develop the correct schedules in very short time frames before dispatch with market technology that was not designed to deal with large quantities of demand and supply. The danger of falling short increased, and the system experienced more and more Stage 2 emergencies. In addition, the price caps merely told suppliers where the limits to the exercise of market power was located. This enabled them to coordinate their efforts to reach this level more effectively (because they knew that everyone was going to bid close to that level). In other words, the price caps sent a strong signal that market power was present and incentivized suppliers to bid their energy into the markets close to this level. The market therefore effectively reached the price caps almost every day.

The RMR contracts were similarly problematic. The designers had been aware of the problem that load pockets posed. The RMR contracts had been agreed between generators that were located in known load pockets. Unfortunately, the congestion patterns changed once the system started to operate, which meant that several areas were missing RMR contracts that would have needed them. Secondly, RMR contracts paid at regulated rates that were higher than the market prices before the crisis. Before the crisis, these contracts established opportunity costs for using the markets that might incentivize sellers to withhold their energy from the markets so that they

[90] See the filings in ER00-95; for example “Order Directing Remedies for California Wholesale Electric Markets” 93 FERC 61,294, December 15, 2000.

would be paid on the RMR contracts. Since this reduced the number of competitors in the markets, the remaining supplies would gain market power. De facto, the RMR contracts therefore often created rather than restrained market power. In sum, the SCs and the ISO did not have the authority to effectively intervene in the markets, and the few tools that were available proved either useless or created more problems than they solved.

Even if the scheduling coordinators had all been neutral entities with direct authority to sanction, the control structure would have faced an additional problem of intervention. The different markets were interdependent. The exercise of market power in one market could have effects on other markets. For example, by withholding output from the day-ahead market to exercise market power in real time, the day-ahead market would also have less supply and might incur price spikes. The exercise of market power in any market therefore tends to reverberate through markets whose products are close substitutes. Similarly, the incentives for the illegal arbitrage businesses depended on the relationship between the prices in the PX and the ISO. Some of the games relied explicitly on the ability to move energy from California into the wider markets for the Western Interconnection and then back into California. Given these interdependencies, it would have been necessary to have centralized oversight and intervention or at least close cooperation between the different scheduling coordinators. Neither of these was the case. The only institution that was responsible for all market activities in the Western Interconnection was FERC. But before and during the crisis, its enforcement capacities were exceedingly limited. Its regulatory authority was designed for a world of regulated monopolies, not complex and highly volatile market processes with many participants. Effectively, FERC could revoke market-based authority for companies that violated market rules or exercised market power. It could reset prices that were '"unjust and unreasonable," and it had the ability to disgorge illicitly earned profits, but only within a fixed time period before the moment it received an official complaint.[91] This made violations prior to this "Effective Refund Date" immune from prosecution. However, to determine that a violation had taken place, a case needed to be filed with an administrative law judge, and evidence needed to be filed and commented upon by all interested parties. It could take months and years for the case to be resolved. Settlements, again, tended to be agreed upon at a fraction of the profits the sellers derived from their strategies. Given the unwieldy administrative apparatus and very limited enforcement authority, the regulators were unable to intervene effectively when the market process moved beyond acceptable tolerance levels.

6.4.4. Inability to Observe

The third requirement was the ability to observe all market transactions and determine if they violated the market mechanism. One can imagine that the limited ability to intervene was matched by a similarly inadequate ability to observe the markets. The control structure would have needed to collect and analyze data from the process that needed to be controlled. Specifically, they would have had to determine how trades corresponded to the physical reality of the electricity system and whether they followed the basic logic of competitive pricing. In California, there were a variety of obstacles to effective observation. The best way to approach these problems is to consider the flow of information in the California market structure. See figure 6-3 for a detailed depiction.

[91] FERC interpreted its own authority to intervene conservatively, which partly explains the hesitancy to prosecute sellers' behavior during the crisis. "Order on Remand, Puget Sound Energy Inc.," 137 FERC 61,001, October 3, 2011.

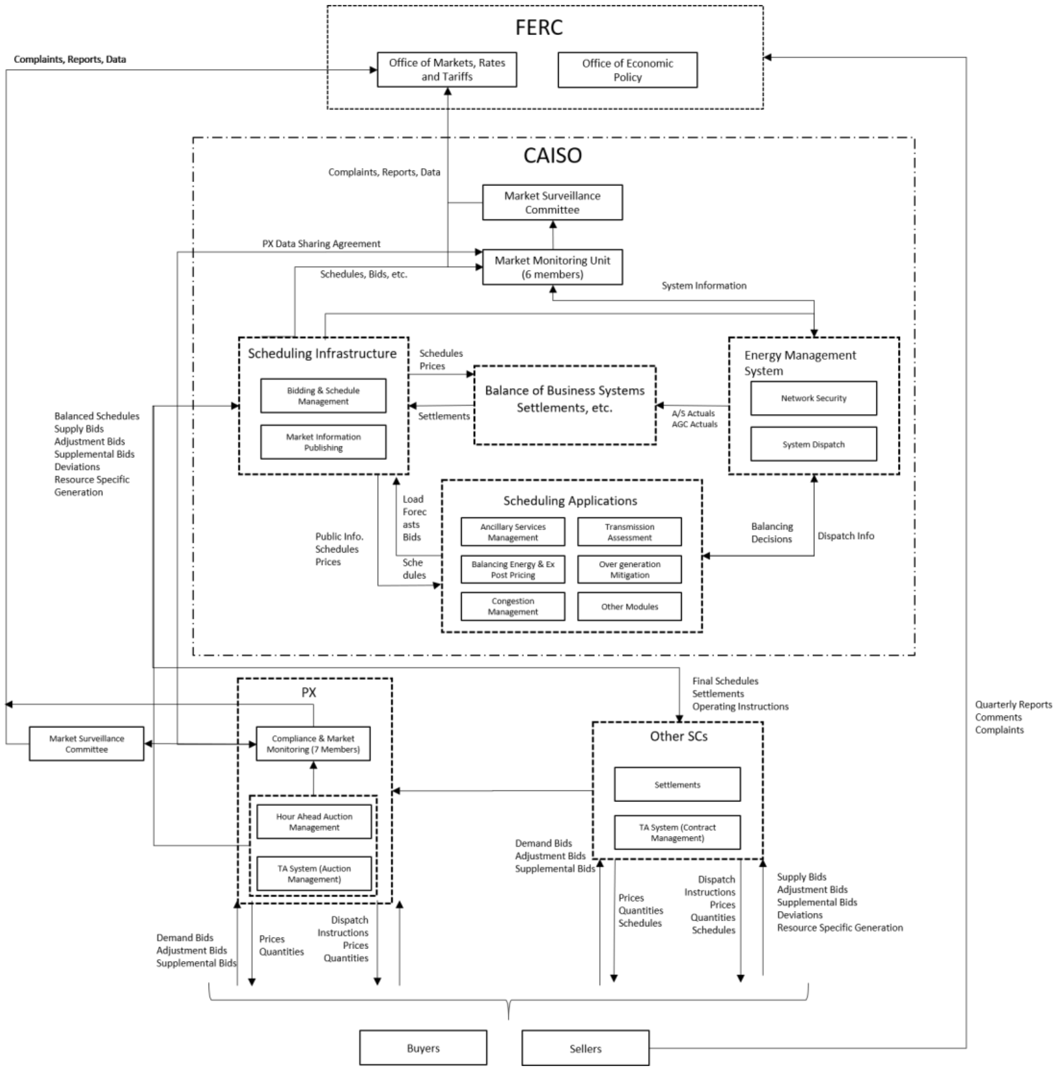

Figure 6-3 – Data Collection and Processing

Figure 6-3 shows how information moves from the markets to the scheduling coordinators, from the scheduling coordinators to the ISO, and from there, to the monitoring units and FERC.[92] Despite the fact that this architecture was automatized and sophisticated (for the late 1990s), it contained severe blindspots. The PX and the other scheduling coordinators only had information from the market processes they facilitated. For example, the compliance department and market surveillance unit at the PX were limited to the TA system that kept the information from the

[92] The figure has been reconstructed from various technical manuals in "ISO Board of Governors and Committee Meeting Files," R400.006, Box 6 and 7, *CSA*.

different auctions at the PX. Apart from quantity and price bids, all scheduling coordinators collected information on the specific locations and capacity of suppliers' generation resources and ancillary market bids, as well as adjustment and supplemental energy bids that enabled their customers to enter CAISO's spot markets. However, there were no protocols in place to validate the integrity of this information. This information was submitted to the ISO via its scheduling infrastructure. Various scheduling applications processed this information, used it for CAISO's internal markets, and sent the resulting schedules back to the SCs. The settlement system combined the information with the real-time system data to determine the final energy transactions. As the figure shows, the internal market monitoring units could access both the real-time system data through the energy management system and the information from the scheduling interface. While the former contained all information submitted by SCs, the latter consisted of the technical information submitted through the physical infrastructure of the grid system (i.e., real consumption, energy flows on specific lines, etc.). But even though the ISO had the most extensive insight into the market and the physical electricity system, these streams of information were limited in important ways. The monitors had no insight into the operations of the different scheduling coordinators apart from what was submitted to the ISO. SCs had only a few reporting requirements to the ISO that pertained to its credit rating and various technical aspects of the generation under contract. In case of an emergency, CAISO could issue certain directives that had to be obeyed.[93] But in general, it only had direct oversight over its own markets and relied on voluntary reporting from all SCs. In the last section of the annual report to FERC in 1999, the CAISO described the problem of not being able to get reliable information from the various scheduling coordinators:

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[93] Power Exchange, "Introducing California's New Electricity Markets, Presentation to Market Participants, 1997," George Sladoje, Personal Archive.

> In practice, however, participants might not provide correct or unambiguous data concerning bilateral contracts to the ISO voluntarily, unless they have specific incentives to do so. […] They would have no motivation, however, to report correct bilateral market transaction prices.[94]

Even the relationship with the PX, a closely related sister organization, was difficult. Since the markets at the PX and ISO were closely integrated, the market monitoring teams tried to share information with each other. As the figure shows, the PX shared data on the basis of an informal agreement with CAISO's market monitoring unit. But the data sharing was not without complications. One of the market monitors at the PX explained the problems to me like this:

> M: To be able to see if there is collusion or any problem in the market, you had to look at both the day-ahead market and real-time. But we felt that the data that we had from the independent power producers and what Edison submitted to the PX should be confidential. The head of the market monitoring committee at CAISO wanted this data. But my concern was, if I provide this data, it is not going to be confidential because you are going to have some research students and research assistants on your staff who will look at it. That will be a problem. So that was another struggle: when you separate the two markets and you have a lot of confidential data, how do you handle that separation between the two organizations? [Particularly] if the market monitoring committee of CAISO wants to do their own independent studies, separate from CISO market monitoring department […] At the end, we provided all data to CAISO monitoring unit and they handled [how to share them with] their committee.
>
> G: So, there was a close cooperation between the two monitoring departments?
>
> M: Yeah, the two departments worked okay with each other. The problem was how to keep the data secure and confidential when you provide it to some people outside of the organization, like the committee.[95]

So, even CAISO, which had by far access to the most data, was missing crucial information from the SCs and had difficulties obtaining all of the data from the PX. It also had limited information on the physical electricity system because CAISO's authority to monitor energy flows was limited to the control area it managed. The rest of the Western Interconnection, including

[94] CAISO, "Market Surveillance Report 1998," pp. 7-19/20.
[95] Ferdinand M., Interview, 02/19/18.

transmission systems of municipalities, was largely invisible to the ISO. The energy management system relied on voluntary reports whose integrity the operators could not ascertain.

Again, the only centralized regulator who had the authority to oversee the entire market was FERC. But FERC did not even have an independent market monitoring unit until 2001. Market oversight was in the hands of the Office of Markets, Tariffs, and Rates (OMTR) and the department for Economic Policy.[96] As the figure shows, FERC did not collect much data directly. It merely received quarterly transaction reports from all sellers of wholesale energy. Even this data was never systematically evaluated before the crisis. In the aftermath of the crisis, the staff admitted that the information the agency had collected prior to the crisis did not actually allow them to determine whether any rules had been violated.[97] It was later determined that the offices operated without a clear strategy for oversight. A postcrisis report by the General Accounting Office of the U.S. described how FERC was caught off guard by California's energy crisis: "In October 1999, the director of OMTR said '[w]e have to decide what we want to do with markets, how much resources we want to devote to the different views, what information will we need from outside the building to do our job, what type of IT hardware and software will we need to do that, what type of skill sets of people will we need.' In August 2000, when FERC hired a director for OMTR's Division of Energy Markets, these details had still not been determined."[98]

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[96] Between 1997 and 2001, FERC was restructured according to the "FERC First" initiative. This initiative tried to optimize the agency to the new market conditions. Offices changed names and responsibilities shifted, but according to one of my interviewees, the initiative was mostly window dressing. Not much of the actual workflows changed. This was confirmed by a report of the General Accounting Office from 2002. GAO, *Concerted Action Needed*, 37. The report stated that the changes had not produced improvements in the oversight activities. The OMTR was the product of FERC first.

[97] "Letter from Donald J. Gelinas, Associate Director, FERC Office of Markets, Tariffs and Rates, to: All Jurisdictional Sellers and Non-Jurisdictional Sellers in the West, March 5, 2001," *FERC* PA02-2-000, p. 1.

[98] GAO, *Concerted Action Needed*, 37.

In the absence of an active monitoring strategy, the agency relied on information from California's market monitoring units that filed reports, data, and complaints when they noticed problems. Market participants could also file complaints, evidence, and reports with FERC. The agency therefore reacted primarily to complaints brought to them from the outside. When problems in the market arose, stakeholders had to file complaints with FERC, which then opened regulatory proceedings to determine the best course of action. These decisions were made not by economists, but either by lawyers in the General Counsel's office or the staff of the chairman of the commission. The proceeding was assigned to an administrative law judge and proceeded on the basis of several rounds of filings. Accordingly, the cases could take months and years to be processed. A complaint was filed, the judge reacted to it, and opened the docket for comments. After anyone interested in the matter filed their comments, the commission's staff reviewed and summarized the filings, and that provided the foundation for the judge's decisions. FERC rarely developed independent analyses of primary data, preferring to collect the opinion of the monitoring units, stakeholders, or independent experts. Occasionally, FERC started independent investigations that were carried out by the Office of Economic Policy. But the department was primarily responsible for policy questions and did not have the resources to screen all electricity markets in the U.S. regularly. As the report by the General Accounting Office observed:

> To support its responsibilities for regulating and monitoring competitive markets, correcting anticompetitive situations, and promoting fair and open competition, the Commission needs employees with knowledge and skills in the collection and analysis of market data; information technology; and market operations, including expertise in market rules and structures, competitive pricing, commodity trading, and risk management. According to senior FERC officials, the agency lacks adequate numbers of staff with these competencies and has had trouble attracting and retaining such staff.[99]

[99] Ibid, p. 56.

As the report shows, FERC was woefully underprepared for the role of the centralized oversight regime that can oversee the entire market process, check its conformity with the required market mechanism, and constrain the system back into line with the blueprint.

The entire oversight structure had been designed to collect and process information that was necessary to run the electricity system. It was an impressive organizational structure. The operators collected the information they needed to give dispatch instructions and settle market transactions. But there was very limited information collection that would have enabled the different controllers to determine whether bids were genuine offers to sell or attempts to game the system. For example, the false export schedules simulated that generation was physically located in California but actually came from outside CAISO's balancing authority. In principle, it would have been possible to force every generator in California to verify production schedules and penalize deviations beyond contingency levels. But such information was never collected.

The observational problems were not merely a function of the way the market monitoring units collected information. They were deeply embedded in the design of the market process itself. To detect market power, it would have been necessary to observe when a generator was bidding above marginal cost. But the PX and CAISO auctions were effectively one-bid auctions. A generator would submit a step function of price/quantity pairings for different hours; that is, they had to determine a single price for a given quantity at a given point. Strictly speaking, their marginal cost of production would have been the immediate cost of running the generator at that level. But generators did have fixed costs, such as the cost of maintenance, startup costs, no-load costs, or the cost of building the generator in the first place. As already outlined, generators had no other option but to fold these costs into their bids. This made the determination of the "true" marginal costs extremely difficult and opened the possibility for generators to argue that their bids did not reflect market power, but costs that the regulator had not considered. One example is the legitimate price spikes for generators that only run a few hours a year. Since the design of the auctions collapsed a variety of temporal horizons of asset value into a simple bid, it created a fundamental ambiguity for the interpretation of these prices. Since you could evaluate the foundation of the prices along different temporal trajectories, they became inherently ambiguous from an economic perspective. Ambiguity was folded into the foundation of the system. Accordingly, even though CAISO had complete data on system conditions and production processes in California, the monitors had difficulty distinguishing market power from scarcity. In sum, the control structure was fragmented, did not work with a clear goal, had limited powers of intervention, and was unable to observe the market process at the level of detail that was required. The design flaws created very high requirements for control of the market process in order to align with requirements for reliable grid management, yet the markets were opposed by a control structure that could meet none of these requirements. Even with working markets for forward contracts and a diversified retail market, this structure would have sooner or later led to a crisis.

6.5. Conclusion

The California system had several design flaws: The temporal logic of the market perpetually pushed the system to a point where market power emerged and put the markets at odds with the reliable operation of the system. The separation and equality provisions drove the interactive complexity of the markets up. It created mismatches between the physical reality of the electricity network and its representation in the market. The simplified network representation in the markets created additional mismatches. Simultaneously, these features made it impossible for the system operator to optimize the dispatch in line with system requirements. These limitations created profitable opportunities for trades that undermined the safe operation of the system. The ability of companies to take on several different positions in the market, the high interactive complexity between market settings, and the highly fragmented, deficient oversight structure allowed companies to circumvent the rules that were meant to deter such trades.

As we have seen, the structure of the California system created vast requirements for ongoing oversight and control. The system was perpetually in danger of sliding off the path to equilibrium. At that point, the system turned against its masters, and the markets began to undermine the reliable operation of the system. But instead of developing a highly centralized, highly powered oversight structure to evaluate the legitimacy of the trades in the structure, the existing oversight structure, though an impressive system of information flows, was optimized only for certain technical tasks.

The possibility of detecting anomalous behavior was minimal, authority to intervene highly insufficient and fragmented, the goals of oversight unclear, and the theoretical tools used to understand the market underdeveloped. This poses two questions, which will guide us in what is to come: Why did the designers create the problematic structural features? And, assuming that they had reasons to do so, why did they not put an oversight structure into place that could have kept the markets in check? The deeper, theoretical question remains: Were the substantial control requirements that we observe in the California markets avoidable or are they a feature of market design more generally? What determines these requirements? Further, could these requirements ever be met or do they bring the problems of centralized planning back into the project through the neglected backdoor of the centralized oversight structure?

We will pursue these questions further as we now move into the second part of the dissertation and ask: What prompted the creation of the problematic design features? While chapter 7 provides an overview of the design process, chapter 8 looks at political decisions, and chapter 9 discusses the technical design processes. Only in the final chapter will we return to the issue of oversight, which will lead to the theoretical conclusions of this dissertation.

PART II: The Problems of Market Design Work

7. From Structure to Expertise: The Design of California's Markets

7.1. Introduction

I will now move the analysis into a different register. So far, I have told a tale that is heavy on structural forces and light on human protagonists and processes. Now, it is now time to look at the experts who built the California system and the practices in which they did so. We will move from the argument about the theoretical properties of market design and the shortcomings of California's system, to an argument about the *expertise* and work that stand behind this failure.

Let me recapitulate the argument so far. In the third chapter, I outlined the two dominant narratives of the California energy crisis. One is a story of economic fundamentals and bad politics. The other is a story of corporate crime and regulatory capture. Both choose sets of events and weave them into cause-effect chains that allow us to trace events during the crisis back to a guilty party. Instead of siding with either of these narratives, I have argued that we should focus on the structural preconditions for the crisis. Treating the case as an instance of failed market design, the immediate causes of the crisis seem less relevant than the structural features that created opportunities and incentives for behavior that derailed the market mechanism.

To prepare the alternative route of inquiry, the fourth chapter traced the intellectual history of market design. I showed that market design is a form of centralized planning rooted in the Socialist Calculation Debate of the 1920s and 1930s. Market designers seek to create institutional infrastructures that configure the logic of market interaction in such a way that the market works like an algorithm that solves an optimization problem under constraints. An oversight structure ensures the continual match between market design blueprint and actual process. Reconstructing the overall aim of market design revealed the central challenge to its success. Market design promises to address the fundamental problems of centralized planning because it combines decentralized decision-making with centralized planning. This theoretically unburdens the oversight regime and alleviates the multiple problems that emerge when centralized bureaucracies have to solve complex and changing tasks in real time. In synthetic markets, most substantial decisions can be made by decentralized individuals who act on the basis of situated knowledge.

The crucial question is what is necessary to make sure that the decentralized decision-making process conforms to the structure of the blueprint? Is the desired market mechanism robust enough for a variety of different behaviors that are *rational* on the local level? This became the guiding question for the analysis of the California system.

In the fifth chapter, I reconstructed the challenge that the physical characteristics of electricity pose to successful market design and then showed in detail how California's system attempted to resolve these challenges. The complex configuration of financial market organizations was meant to find the optimal mix of generation assets to meet demand while obeying a variety of technical constraints in the short- and long-term. Against this background, I then investigated how structural features of the market—in combination with different operating conditions of the electricity system—created incentives for behavior that undermined the desired market mechanism. Once these incentives existed, the market turned against the logic of reliable system operation, and the problems began to feed on each other. This triggered a self-reinforcing, destructive dynamic that eroded the technical foundations of the system and escalated problems further.

The analysis established that structural features of the market design generated high requirements for the oversight regime. Market power was extremely fluid, and illegal trades profited from misrepresentations of the electricity system in the markets, which depended on the real flows of energy in the system. To detect and constrain such behavior, the centralized oversight regime would have needed to oversee all transactions in the market and decide if they violated the basic mechanism of competitive pricing. This, in turn, depended on the transactions' relation to the physical flows of electricity in the system. Meeting this requirement was made more difficult by the high dynamic complexity of the market environment. Instead of responding to these difficulties, the regulatory structure was fragmented, slow, and did not have clearly defined goals. It was unable to observe the entire market and often unable to intervene even if it did.

All of this has set the stage for the rest of the analysis, which will now ask the question: Why was the system designed in this way? Why did its architects decide to put the structures into place that made the market mechanism fragile, and what led to the insufficient oversight structure? To answer these questions, we have to look at the practical design work that took place prior to the opening of the California markets. We have to look at how experts in different processes of market design work arrived at the problematic decisions that led to the structural flaws.

Initially, the intellectual work took place mostly in the academy. Here, economists and engineers could freely design laboratory experiments to test designs of economic machines, write conceptual blueprints, and argue about mathematical operationalizations. As long as this work was not tied into any particular political enterprise, it operated without the pressure to reach decisions. The knowledge production was tied to the longer timelines that are dictated by the career logic of academia, and it was open-ended and open to revision. During the 1970s and 1980s, the first plans for electricity market design developed in a nexus that linked Harvard and MIT with research institutes in California. When market designers got recruited to create California's markets, the parameters of their work changed significantly. As soon as the designers began to work on material decisions, the work became vastly more complex, occurred under time pressure, and involved many different stakeholders.[1] The conceptual blueprint of the mechanism had to be refined and adjusted to very specific empirical conditions. It had to be scaled up or scaled down, had to accommodate changing decisions, and it had to be *sold* in political processes.

Importantly, the composition of the *group* of market designers changed. A market designer is an expert who uses the conceptual tools of market design—economic modeling, control theory, linear programming, game theory, etc.—to develop institutional structures that create the desired market process. As we move to the point when the actual market design efforts in California begin, the group of market designers expands substantially beyond the university. The big utilities shaped restructuring decisively and dominated the technical design debates. They had their own engineers and economists who began to use the tools of market design to develop the organizations in California, as did the regulatory agencies. In addition, some economists and engineers founded specialized consulting companies and were hired to take care of certain design aspects (e.g., Perot Systems integrated different market subsystems at CAISO). Academic market designers provided input as expert witnesses or as independent consultants, but they did not exclusively build the markets.

To capture the social dynamic, I will view the design process in pragmatic terms. Moving out from the intellectual discourses in the university, the creation of the California markets can be disaggregated into different contexts of *work* that took place in small to medium size groups in different venues. In each context of work, the market design experts confronted members of other

[1] Callon has called this the study of "economists in the wild." Callon, "What Does It Mean to Say That Economics Is Performative?" 351.

professions and different conditions for decision making. It is possible to distinguish three domains of market design work: politics, regulation, and technical implementation.[2]

Political negotiations created a legal foundation for the new markets and led to basic decisions about the architecture of the markets. These political negotiations took place in regulatory and political organizations. Technical working groups translated broad conceptual decisions into more and more concrete blueprints. Regulatory processes accompanied this process, evaluated proposals, put the control structure into place, and helped to resolve conflicts of interest.

This work in these three contexts took place between 1993 and 1998. It moved from very basic conceptual issues fraught with interest politics to high-level conceptual descriptions. From there, concrete implementation proposals turned gradually into technical blueprints and became the basis for actual software, hardware, and legal arrangements. The organizational context and the political environment of the design work changed several times before CAISO and PX were incorporated in 1997. Only when the designers moved into the new buildings for the CAISO and PX did the designers begin to hire employees, build electronic infrastructure in new buildings, and put *physical structures* into place.

For about four years, until about 1997, the process of creating California's markets was thus a purely *communicative* endeavor that dealt with an imaginary object called "electricity markets." This imaginary object became more and more concrete as time went on, and conceptual descriptions accumulated at the centers of decision-making. How, then, should we understand this communicative process? How was a highly elusive concept of "electricity markets" turned from a multivalent concept into a single reality, shaped by groups of people with vastly different outlooks

[2] The distinction is somewhat ideal-typical. Issues traveled between venues, and some of the work was distributed across venues. However, the three domains mark decision-making processes that follow distinct logics.

on the world, expertise, and institutional locations? How did these contexts arrive at the decisions that would lead to the fatally flawed structure of the final design?

Each of the subsequent chapters will tackle one dimension of the design process to answer these questions. Though the chapters will focus on the genesis of problematic decisions in California, they will also rely on targeted comparisons with the creation of PJM's markets where the same issues were often decided differently. In each chapter, I am going to analyze how specific groups of market designers—engineers, economists, system operations experts both inside and outside the university—arrived at design decisions in concert with stakeholders, politicians, and regulators. I will reconstruct how the experts worked on the resolution of the design issues and how their methods and epistemic frameworks guided them within different decision-making contexts.

However, the analysis will not simply ask why particular decisions were made. It will also ask what would have been necessary to realize the intellectual project in each sphere of decision making. I will try to isolate conditions for the success of market design in each sphere and then ask why they were not fulfilled. This will establish why California's market design problems can be understood as a failure of *expertise*: the way the decision-making processes were organized and the way experts went about making decisions was inappropriate to the task at hand.

The basic hypothesis that guides this investigation is that the market designers were fragmented into different intellectual communities who did not recognize some of the interpretative differences between their respective approaches. This engendered different kinds of *blindspots* with respect to the larger intellectual project. In combination with problems to establish jurisdiction over questions that were central for the success of market design, these blindspots led to problematic decisions.

In my analysis, two competing hypotheses will lurk in the background. The first hypothesis can be found in some of the research that views the California crisis as the result of a corporate conspiracy. According to this reading, the entire design process was dominated by power marketers who rigged the system for their own benefit. The design process is therefore not a story about expertise, but a story about regulatory *capture*. A second explanation is more closely aligned with the narrative about the crisis as a product of economic fundamentals. It suggests that the design process was a story of *incompetence*—the regulators, politicians, and stakeholders did not know what they were doing and underestimated the tremendous power of economic forces. Describing the flailing of politicians and regulators during the crisis, Frank Wolak said, "I remember going: wow, economics is powerful."[3] In the analysis, I will discuss the evidence that supports and contradicts these alternative hypotheses, as I am going to make a case to support my own argument.

The present chapter lays the foundation for the analytical work ahead. I will begin by providing a sketch of the design process and identify where the different problematic decisions originated. Then, I identify the market designers and the foundation of their expertise. First, I will outline the general background of electricity restructuring in the U.S., and then move to the process in California, which was triggered by the national developments. In a third step, I will trace the roots of electricity market design in the university and show how it leads to two subtly different perspectives on market design. Specifically, I show how the work in joint workshops at Harvard and MIT during the 1970s and 1980s led to the first ideas for electricity market design. I then show that the mathematical tools of control theory and the conceptual framework of homeostatic control theory obscured certain differences in the economists' and the engineers' approach to market design. This led to two distinct types of expertise, one based on economics and one based on

[3] Interview with Frank Wolak, 03/16/2018.

engineering. The intellectual project of market design effectively fragmented into two versions, though this did not become apparent at the time. The discussion sets up the foundation for chapters eight to ten, which will reconstruct the different design processes and develop the argument about the failure of expertise.

7.2. The Origins of Restructuring

The roots of electricity market restructuring go back to the 1970s. At this point, the traditional industry structure began to disintegrate. This dissolution unfolded in a contentious process that has been reconstructed in detail by many different scholars. The most complete account can be found in Richard F. Hirsch's *Power Loss*.[4] The story involves transition costs and contracts, rent-seeking behavior, jurisdictional issues, market power, and political skirmishes. For the present context, only a few key facts are important.

At the beginning of the twentieth century, utilities managed to strike a deal with the government that protected their industry from competition. The utility consensus was based on the belief that electricity was a natural monopoly. Big utility companies were best able to develop the technological infrastructure of large-scale power plants, transmission grids, and distribution systems that would produce increasingly cheaper energy for all consumers. In exchange for their non-competitive franchises, they promised the provide ample and reasonably priced energy. Customers, in turn, promised to pay rates that would enable utilities to cover their costs and make a "fair profit" necessary for expansion. PUCs at the state level received broad powers from the government to make sure that both sides fulfilled their promises.[5]

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[4] Hirsh, *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System*.
[5] Ibid., 11.

The 1973 oil crisis led to higher fuel prices. Combined with the twin evil of higher inflation, electricity rates increased significantly to cover the utilities' costs. Technical challenges made the situation worse: at the end of the 1960s, economies of scale on traditional power plants had been largely exhausted. For decades, power had gotten cheaper. Now, it got dramatically more expensive. In addition, the environmental movement alerted the country to the dangers of traditional energy sources, powerfully illustrated by the catastrophic accident in the Three Mile Island nuclear power plant in 1979. The cost overruns on the construction of dangerous nuclear power plants and the increased price of electricity sewed doubt that the regulatory consensus could still deliver on its original promise. At around this time, the first ideas for the deregulation of electricity markets started to float around economics and engineering departments at MIT and Harvard.[6] The specter of free markets began to raise its head in the utility industry.

What ultimately tipped the scales toward restructuring was the 1978 Public Utilities Regulatory Policies Act (PURPA).[7] As part of an effort to address the oil crisis of the 1970s, PURPA set various incentives for energy conservation and natural gas use. Little noticed was the creation of a new class of non-utility generators, so called qualifying facilities (QFs). These QFs could build small power plants and cogeneration facilities. Section 210 of PURPA required that the traditional utilities had to purchase electricity from the QFs at prices that reflected the avoided cost by utilities—i.e., the cost they would have had to cover if they had produced the electricity

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[6] The U.K., Argentina, and Norway deregulated their markets prior to the U.S. While the U.K. experience had some influence, the market designers on the East Coast seem to have paved their own distinctive way to build electricity markets. Peter Navarro, "Electric Utilities: The Argument for Radical Deregulation," *Harvard Business Review* 74, no. 1 (1996). Accordingly, I am going to focus entirely on the U.S. experience when I talk about the market designers and their intellectual project.

[7] Isser, *Electricity Restructuring in the United States: Markets and Policy from the 1978 Energy Act to the Present*, 81.

themselves.[8] Though no one anticipated it, this rule created a vast market reaction. Using new technologies that were highly efficient at a small scale and profiting off extremely high administrative costs borne by the large utilities, a market for QFs emerged that soon led to significant amounts of excess capacity. This was nowhere as true as in California, which reacted to the supply shortages of the 1970s by aggressively encouraging the growth of QFs.[9]

The financial success of QFs sent a strong message: if independent power producers are able to produce cost-effective, reliable supplies, electricity may not be a natural monopoly after all. Beyond feeding into doubts about the efficiency of large utilities, the law created a large group of special interests with a strong desire for real competition. This group began to lobby aggressively for rules that would put them on the same footing as utilities and asked for less restrictions on their generation business. Since they were able to build cheaper power plants than the utilities, regulators increasingly heeded their call for "open access" to the utilities' transmission systems.

The QFs depended on the utilities' grid to "wheel" their power to customers. Utilities, who did not want to buy QF power, increased their service fees until the QF energy was more costly than their own, effectively blocking them from entering the market. As the QFs protested this discrimination, a new vision for electricity markets emerged. Academic observers and regulators surmised that the problems could be solved by creating a competitive market for generation that was separate from transmission services. In such a market, QFs would have equal access to the transmission grids of the utilities.[10] Though the first proposals were limited to the generation sector and wholesale transactions, voices in the industry soon called for retail deregulation as well. In

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[8] Hirsh, *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System*, 89-100.
[9] Hogan, "Electricity Market Restructuring: Reforms of Reforms," 106.
[10] Ibid., 107.

retail markets, end users would be able to choose their suppliers, thus putting pressure on utilities to improve services.

Inspired by the experiment to create electricity markets in England and Wales in 1989, the Congress then passed the Energy Policy Act (EPAct) in 1992. It extended the scope of QFs and increased the group of wholesale generators that could compete with the traditional utilities. Importantly, these companies could be affiliates of the traditional utilities and would be spared the usual restrictions under the regulation for holding companies.[11] Utilities could thus begin to develop generation assets that operated separately from the main company. The act also required utilities to give third parties access to their transmission system in order to facilitate wholesale trading and competition. Finally, it allowed states to introduce retail competition if they chose to.

The intentions behind this law had been limited. It was meant to create room for increased competition at the margin. As the rules about affiliates indicate, utilities were supposed to retain their monopoly franchise. The QFs were merely supposed to compete more effectively with the utilities, thus leading utilities to invest more prudently than in the past. Prior to the emergence of the QFs, limited wholesale markets had already existed in loose power pools (e.g., PJM) and through bilateral transactions "on the margin"—small amounts of over-production that would be sold to adjacent service territories.[12] The EPAct intended to merely ease QFs participation in these relatively marginal markets. But this original intention was soon eclipsed by the dynamic the law triggered.

[11] These restrictions had been put into place in the wake of the Great Depression in 1935, when a couple of spectacular scandals revealed the financial fragility of holding company systems designed to control vast interstate electricity systems. Georg Rilinger, "Corporate Conspiracies and Complex Secrets: Structure and Perception of the Insull Scheme in 1930s Chicago," *American Journal of Sociology* 124, no. 4 (2019).
[12] Lambert, *Creating Competitive Power Markets: The P.J.M. Model*.

One side of this story took place within individual states; the other took place at FERC. In the early, 1990s FERC had to translate the EPAct into a regulatory framework. The crucial question was how to define and accomplish the goal of "open access" to the transmission grid because without it, utilities could simply dictate terms of trade that put the QFs at a disadvantage.[13] Between the EPAct and 1996, FERC started a regulatory process to solve this question. After several rounds of stakeholder filings and technical conferences, FERC passed Order 888, which widened the scope of the EPAct by setting up a framework in which any generator should be able to receive open access to the transmission grid. Each utility would have to provide transmission services to these competitors, whose quality was comparable to the services they provided to themselves. This effectively separated the transmission function from the other parts of the utility business. This separation set the stage for a much more radical transformation of the electricity industry than anticipated by the EPAct. Unbundling transmission services from generation and distribution created the baseline for the introduction of retail competition and the demolition of utility's monopoly franchises. It created the legal foundation for separating production, transmission, and distribution into different kinds of companies and markets.[14] California's push for deregulation occurred roughly around the same time FERC began to develop the implementation of the EPAct, around 1992.[15]

7.3. The Creation of California's Electricity Markets

The creation of California's electricity markets unfolded along three different trajectories. The first set of events played out before the CPUC. In early 1992, the CPUC asked its planning

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[13] Interview with Bethanie M., 03/15/2018.
[14] Hogan, "Electricity Market Restructuring: Reforms of Reforms," 108-9.
[15] Interview with Bethanie M., 03/15/2018.

staff to evaluate the recent history of power company oversight. The rates were very high in California, and there were worries that they might choke the fledgling development of the new computer industry. In the 1980s, the commission had already deregulated the telecommunications and natural gas industries. Since these efforts were perceived as successful, they wanted to evaluate whether the electricity industry could be subjected to a similar transformation. The legislative activities at the federal level created a favorable environment for such an enterprise. The commission published its report in 1993. It soon became known as the "Yellow Book" because it featured a remarkably ugly, bright yellow cover.

The authors concluded that the current regulatory framework was not adequate anymore. Since the 1970s, the PUC's regulatory approach had slowly assumed a complicated and ineffective hybrid structure. While utility rates were still set on the basis of cost-of-service principles, the payments to QFs, demand side management efforts, and the operation of the nuclear power plant, Diablo Canyon, followed standards of performance-based ratemaking. These standards aimed to reward utilities for increases in efficiency with higher rates. The two paradigms generated conflicting incentives, which typically prompted the creation of additional rules. In addition, the CPUC often developed separate solutions to local problems, creating a maze of administrative processes that no one seemed to understand completely anymore.[16]

The fragmented and complex process of regulatory oversight confronted an industry that had made bad investment decisions in the past. Based on flawed predictions about the development of oil and gas prices, overly expensive generation capacity had been added with tremendous cost overruns. PG&E, for example, had insisted on developing the technology for their nuclear reactor

[16] Hirsh, *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System*, 249-50.

in-house, which led to cost overruns, delays, and avoidable errors—or so argued consumer representatives. Despite these lapses of judgment, the utilities managed to justify the expenses before the PUC. This enabled them to increase the rates repeatedly and pass the costs on to the consumers. That this had been possible suggested that the regulatory process needed to be reformed urgently. In the face of high rates, a contradictory regulatory process, and a glut of oversupply from qualifying facilities, the utility consensus had eroded.

The authors of the Yellow Book now considered several ways forward. Besides minor adjustments to the performance-based ratemaking, one of the options was a radical restructuring of the industry. In the next few months of 1992, the radical option was chosen as the most attractive one. Non-utility QF companies accounted for about one-third of California's electricity production—more than in any other state. Since they wanted unbridled access to the utilities' power markets, the Independent Power Producers (IPP) formed a powerful coalition in favor of radical restructuring. Throughout the 1980s, California had begun to aggressively implement conservation efforts, such as demand-side reduction growth and higher efficiency standards for new generation facilities. Instead of simply expanding the supply to keep up with demand, California subscribed to the idea that efficiency gains and demand reductions were preferable.[17]

These measures cut into the profits of both industrial energy users and utilities. Conservation threatened utilities' sales, and when the state set incentives for the utilities to enact these measures, the costs were transferred to industrial consumers, who already faced higher bills than in other states.[18] To the industrial users, restructuring promised the ability to contract with

[17] This was one of the reasons why the supply shortages in the late 1990s were overlooked. Much capacity actually consisted of "negawatts," i.e., reductions in demand that obviated the need for additional capacity. Marcus and Hamrin, "How We Got into the California Energy Crisis," 1-2.
[18] Duane, "Regulation's Rationale: Learning from the California Energy Crisis," 488-9.

unregulated generators from IPPs at much lower rates. They effectively wanted to get away from the socialized costs of demand-side management and utilities' inflated rates that went back to bad investment. Meanwhile, Enron was using considerable funds to push for radical restructuring as well.[19]

Perhaps the decisive factor for the radical decision was the internal division of the utilities. While SCE and SDG&E were weary of changes and lobbied to protect their monopoly, PG&E came around to the idea long before the others did. The company had tried to push back on the deregulation of Natural Gas and lost some of their political influence in the process. As one of my interviewees put it, "As [radical restructuring] gained momentum at the commission, we could see that the writing was on the wall."[20] Accordingly, PG&E tried to get ahead of developments, preferring to shape rather than oppose restructuring. With the utilities divided, business interests and IPPs in favor of restructuring and prestigious companies like Enron pushing for deregulation, the course was clear. After about a year of lobbying, debates, and analyses, the CPUC decided to become the first state with competitive markets for energy. The outcome of these debates came to be known as the "Blue Book," which was published in 1994.

The Blue Book established that California was going to fully embrace the project of creating electricity markets as the trailblazer for the rest of the country. The Blue Book contained a rough proposal that was based on the electricity markets in the U.K. It opened a formal procedure toward a regulatory decision to implement the plan of the Blue Book. It is with the initiation of this formal procedure that the market design process started because the various stakeholders now

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[19] In 1998, Enron paid about $500,000 to lobbyists and experts who worked for the CPUC and the legislature. The other power marketers did not get into the electricity game until 1997. Despite the later revelations, there can be no doubt that the power marketers' influence was eclipsed by that of the other industry groups on the state level. Isser, *Electricity Restructuring in the United States: Markets and Policy from the 1978 Energy Act to the Present*, 237.
[20] Interview with Brian S., 03/13/2018.

had a chance to oppose the proposal and suggest their alternative designs. As part of this procedure, stakeholders and the general public could file comments. The commission also held formal hearings at its offices in San Francisco and Pasadena. It was during these proceedings that the most basic decisions about the design of the California markets were debated and finally set into stone. This process lasted from the publication of the Blue Book in April of 1994 to January of 1996, when the CPUC published a "Preferred Policy" decision on the new market structure.[21]

Throughout, the debate crystallized around variations of two fundamentally different proposals, first explicitly proposed in May of 1995. The defenders of the "direct access" model argued for a bilateral contract market that would operate separately from grid management, while the defenders of the PoolCo system argued for a centralized auction house that integrated market activities with system operations. While the formal process launched by the Blue Book was relatively amicable in the beginning, the different interests soon came at loggerheads. The republican governor, Pete Wilson, sent two of his closest staff members to mediate the conflict between the strongest interest groups. In September of 1995, they finally settled on a deal that came to be known as the "Memorandum of Understanding" (MOU). This document proved crucial for everything that happened later. It was very short, offered a new vision for the new markets, and became the de facto foundation for the CPUC proceedings. The MOU described the separation of the PX and ISO as well as the existence of bilateral contracts between generators and individual customers. This requirement would later lead to the invention of scheduling coordinators because the MOU also required the strict separation of different markets from grid management:

> The ISO should *not* participate directly in the purchase or sale of power beyond its short-term balancing and reliability function. All users of the transmission systems (including

[21] The initial decision occurred in December of 1995, but was amended in January of 1996.

> the Power Exchange) shall communicate their schedules and nominations to the ISO pursuant to mandatory protocols which it shall establish.[22]

Most importantly, the MOU established that the ISO would have to treat the PX markets in the same manner as the bilateral contract markets:

> Bilateral contracts will be scheduled with the ISO and will not be subject to the bidding or economic dispatch requirements of the Power Exchange. Generators and/or generation aggregators will submit preferred schedules to the ISO which will be responsible for integrating them with schedules provided to support Power Exchange transactions in a *fair* and *nondiscriminatory* fashion.[23]

This passage, though phrased in a way so general as to be ambiguous, had an important implication: the schedules of the contract markets could not be optimized relative to the activities in the Power Exchange. If the ISO had been able to simply aggregate and optimize all transactions relative to technical requirements, it would have discriminated against less liquid (and therefore efficient) markets. To prevent the ISO from making one or the other market more efficient through rescheduling, the ISO had to implement the schedules as it received them, i.e., “integrating them” rather than optimizing.

As discussed in the last chapter, it was precisely the separation of the ISO from the PX in combination with the need to treat different markets equivalently that put limits on the ISO’s ability to develop an efficient real-time dispatch. Making adjustments to the incoming schedules ad hoc at the ISO also created the foundation for the arbitrage opportunities that would later lead power marketers to circumvent the anti-speculative rules of the ISO. But most importantly, it was the foundation for the considerable complexity of the California markets: by separating the markets

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[22] “Memorandum of Understanding on Joint Recommendations Among California Manufacturers Association, California Large Energy Consumers Association, Independent Energy Producers, Californians For Competitive Electricity and Southern California Edison Company, December 14, 1995,” Box 18, Folder 43a, *CPUC*, p. 4. My italics.
[23] Ibid, 5, my italics.

into different organizations and creating a firewall between the markets and the grid management, the proposal made the job of the oversight structure exceedingly difficult.

Unlike systems in the UK and the eastern U.S. where the ISO managed both markets and grid management, the California system established the need for a complex back and forth communication between the ISO and the various market institutions. The political process thus created a problematic baseline for the development of the markets. It is the first set of problematic decisions whose genesis we need to understand. It will be the center of attention for chapter eight.

The process before the CPUC is important for a second reason. It was during the early debates of the Blue Book that the issue of long-term planning for investments ('integrated resource planning') fell off the table and the markets were composed around the logic of spot markets. As discussed in the last chapter, the inability of the market architecture to get the timing of investments right was the main structural flaw that predisposed the system toward the exercise of market power based on the spot market logic. The system would always experience boom and bust cycles that pushed the markets toward conditions where the basic logic that enables markets to find the least-cost economic dispatch would not work anymore.

In California, the alternative to trusting the markets to regulate investments was called "integrated resources planning." Prior to deregulation, the general approach in California had been to build demand forecasts and then develop plans for the creation of new generation facilities. The CEC was responsible for developing the forecasts, which were called "Biennial Resource Plan Update." The market would then price these additions. Starting with the Blue Book, the CPUC wanted to replace the Biennial Resource Plan Update with a market mechanism to incent the creation of new generation capacity. As the process continued, the parties increasingly agreed that the price signals of the spot markets in the power exchange would be sufficient for companies to make investment decisions in generation assets.[24] The decision to replace the long-term planning with wholesale markets was not based on a specific market design—it was one of the core reason for restructuring in the first place. The ability of markets to allocate the risk of poor decisions to entrepreneurs and therefore shield end users from their effects was one of the driving factors during the negotiations.

Yet, as we have seen, electricity markets are structurally unable to provide the slow and constant expansion that is necessary to keep the system afloat. Since this is a problem that derives from the temporal orientation of financial markets, there is no definitive design solution to this problem; there is no completely market-based alternative to a regulatory approach such as "integrated resource planning." We are thus dealing less with a problem that concerns the design of the markets than a problem with the design of the regulatory structure surrounding the markets. Accordingly, the crucial omission occurred in the processes that led to the development of the oversight structure rather than in the decision to create the markets in a particular way. Even though the decision to get rid of the long-term planning process goes partly back to the political process, I will postpone the decision until chapter ten, where I discuss the creation of the regulatory framework.

While the CPUC considered the new proposal, the state government in Sacramento had realized that the changes discussed by the CPUC would require legislative action. In 1995, the legislative process in Sacramento began to develop the law that led to deregulation, AB1890. The design process thus bifurcated, with one part playing out the CPUC in San Francisco and another

[24] The preferred policy statements says, "Trends in the market-clearing prices would allow investors to determine the cost-effectiveness of incremental supply and thus facilitate long-term investment decisions." Decision 95-12-063 (December 20, 1995) as modified by D.96-01-009 (January 10, 1996), California Public Utility Commission, R.94-04-031, p. 33.

playing out before the State Assembly in Sacramento. Senator Jim Brulte officially sponsored the bill, but it was a democrat from San Diego, Steve Peace, who pulled the strings. He was the chair of the Senate Energy, Utilities, and Communication Committee and took control over the wording of the bill as well as the negotiation of the political compromise. Eventually, at the end of 1995, the CPUC concluded the Blue Book proceeding with a majority decision that closely implemented the vision of the MOU. The legislative process built on this proposal and began to gather the political support for the new bill by attaching a variety of different additions to it. These additions and amendments largely amounted to protections and special payoffs for various interest groups that needed to be appeased. Most importantly, the political process determined the specific nature of the retail price freeze and the rate reductions for end users, which rendered competition in the retail markets nearly impossible.

The secondary literature has tended to focus on the legislative part of the story. One reason for this focus is that the political deals at the Assembly led to the maligned retail price freeze and the 10 percent rate reduction. In the attempt to guarantee lower rates to retail users, the politicians effectively insulated consumers from the price risk of the spot markets and blocked the creation of robust retail markets, which could have created a demand response. A second, more prosaic reason for the focus on the legislative story is that it has novelistic elements. In the early days, when restructuring was only an idea, the whole process looked like a futile revolution of the young against the old. Steve Peace and Jim Brulte were young men, seen as upcoming political talent. Meanwhile, powerful lobbyists argued against deregulation, and the older senators in the Assembly were democrats with firm convictions and cherished beliefs in regulation.[25] Sacramento's world of politics thus thought that the project would not get much support and would die in the

[25] Interview with Jonathan L., 04/04/2018.

water. But then, in a surprising reversal of fortunes, more and more weighty players got on board, and Steve Peace suddenly stood at the helm of a process that would transform an entire industry.

Peace was a colorful personality. In his past life, he had worked in Hollywood and directed the cult flick "Attack of the Killer Tomatoes." He was known for his combative personality. To push the bill through the Assembly, he held marathon public sessions in which all stakeholders had to work on a single bill until deep at night. The last eighteen days before the vote, in August of 1996, later became known as the "Steve Peace Death March." He would ridicule representatives who disagreed with him, caustically admonish those who spoke without expertise, and kick out dissenters, asking them to hash out their differences in private negotiations or leave altogether. A lawyer described Steve Peace like this:

> He became convinced that this was a good thing to do, and he became convinced that it was a big career move for him to be the ramrod for this. So, he basically bullied everybody, the utilities, the commission, the legislature, the governor's office, to try and make this thing go, and of course, he did put it into effect in AB 1890. But he was the kind of personality where if you didn't agree with him, he'd literally scream at you until you stopped and went away.[26]

In the background, there was much back and forth to get the various different interests on board with the bill leading to a variety of payoffs to environmental groups, impoverished customers, and other interest groups. In the end, the bill was passed unanimously in the Assembly, a victory beyond compare. As a legislative aide put it: "[a unanimous vote] never did occur in anything that I ever dealt with that was of a major consequence, [and it happened] in both houses. Maybe there were compromises […], but this happened just by the will of persuasion. […] No one thought the thing was going to pass, but it passed, and the governor signed it."[27]

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[26] Interview with Manfred D., 01/18/2018.
[27] Interview with Jonathan L., 04/04/2018.

Since the world of utility regulation is not exactly a fountain of riveting tales about heroic deeds, the legislative history of AB1890 became the stuff of legends in the world of California politics and often takes center stage in the narratives of the crisis. But as interesting as the legislative process may be from the perspective of political tactics and personalities, it mattered relatively little for the structure of the markets.

As I have already argued in the last chapter, the significance of the retail freeze has been overestimated. Since electricity systems will feature largely inelastic demand until the technological foundation of the industry changes, a more enlivened retail market would have done little to combat the structural problems at the heart of the market design. The various qualifications of the cost-recovery guarantees and the different provisions to make the different interest groups happy also did not change the structural features that stand behind the incentives for problematic behavior.

From a structural point of view, the bill practically implemented the CPUC decision of 1995 as revised in January of 1996.[28] Since I am most interested in the conditions that made the crisis possible rather than the factors that precipitated its onset, the analysis will focus on the regulatory and political process that led from the Blue Book to the MOU, and from there to the preferred policy decision of 1996.

As important as the political decisions of the MOU were, they occurred on a high level of generality. Most politicians and lawyers had little or no understanding of the complex activities that went into the maintenance of the grid. Few understood even the purpose of a system operator. Accordingly, the political struggle rotated around money, stranded costs guarantees, and consumer

[28] This has generally been acknowledged by the literature. The reason for the relatively limited change was that the governor was putting pressure on the legislature to move ahead with the CPUC proposal. Isser, *Electricity Restructuring in the United States: Markets and Policy from the 1978 Energy Act to the Present*, 241-2.

and environmental protections. This left most of the consequential design decisions up for grabs—to experts working on the technical implementation of the blueprints. This is the second and often neglected trajectory of market design work. This work began very soon after the political process started.

Early in 1994, when the utilities realized that the restructured system would be a reality, they started to organize working groups that would hammer out the details of the proposals that were being debated in San Francisco and Sacramento. Initiated by SCE, these small gatherings of engineers and technicians morphed into working groups and then slowly transformed into a set of regular meetings with increasingly stringent procedural structure. In 1995, these meetings became known as the WEPEX (Western Power Exchange) process. The WEPEX process was run by the three incumbent utilities. As the provisions of AB1890 became increasingly certain, the process grew and included more and more stakeholders. It was here that the basic decisions of the political process were slowly translated into full proposals, procedural protocols, and technical analyses.

After the law AB1890 passed in 1996, the WEPEX process transformed once again. David S. Freeman was appointed trustee of the CAISO/PX and the WEPEX process was reconstituted under a trust advisory committee (TAC) led by Freeman. As soon as CAISO/PX assumed formal existence in May of 1997, the TAC stakeholders elected a board of governors, and the first employees were hired. At this point, the creation of the markets moved within the walls of these organizations and continued until the markets opened in 1998. So, the technical implementation moved from WEPEX to TAC to CAISO/PX, becoming more concrete at each step.

Substantially, the process determined the protocols that would govern the relationship between the bilateral markets, the PX, and CAISO. During WEPEX, first drafts were created, which were subsequently translated into the legal language of the tariffs, organizational routines, computational protocols, etc. WEPEX and TAC thus created the protocols that generated the arbitrage opportunities between the different markets as well as the market complexity that would create the oversight problems during the crisis. Further, it was during the WEPEX process that economists, engineers, lawyers, and other stakeholders decided to develop the zonal model of congestion management based on blueprints for a transmission capacity market. As we have seen, the decision to use a zonal model ended up creating opportunities for a whole host of games that played on the difference between the physical reality of energy flows and its simplified market representation. The WEPEX/TAC process and its decisions will be the topic of chapter 9.

As the technical and political processes unfolded, the regulatory environment shifted. Since CAISO/PX would operate wholesale markets, jurisdiction shifted from CPUC/CEC to FERC as soon as these bodies came into existence. Starting in 1996, all decisions about the market structure needed to be justified to, and approved by, FERC. To retain some control, California instituted a separate oversight entity, called the "The Electricity Oversight Board," which started to hold the trust advisory committee accountable starting January 1, 1997. However, due to the jurisdictional shift, this entity lost most practical significance after FERC began to regulate the design efforts. The last trajectory of design work that led to the California markets thus occurred before FERC, where all design decisions had to be justified. As the primary regulator of wholesale markets, it was FERC's responsibility to develop monitoring regimes that would ensure the proper functioning of the markets. Accordingly, we have to look to the proceedings before FERC to explain the deficiencies of the control structure. As we have seen, the structure was fragmented, and slow and had neither the ability to observe the entire market nor intervene in case problematic behavior emerged. In addition, the control structure was unable to intervene on behalf of long-term resource adequacy. As outlined before, the regulatory structure would have had to implement some mechanism to ensure the excess of capacity necessary to ward off market power. These problems will be the topic of chapter 10, which will analyze the regulatory process that led to the creation of the flawed oversight structure.

We thus end up with overlapping contexts of design work that can be split into political, technical, and regulatory domains. These processes were related to each other in a semi-hierarchical way: political decisions set up the baseline against which the technical processes operated. Initial decisions about the control structure at FERC imposed a trajectory of subsequent adjustments on both state and federal levels. This presentation is of course schematic. The technical discourses fed back into the political discourses and so did the regulatory discourses, mutually constraining each other as more and more decisions accumulated and reduced the freedom for future decisions. As I trace the origin of the problematic design features, there may be some shifts between venues. However, in each case, the ultimate decision followed the logic of one of the three domains of market design work. In that sense, it makes sense to speak of a hierarchy of decision-making.

Before turning to the different domains of market design work in California, we have to establish who the personnel were. Therefore, I will therefore now who the market designers were and how they divided into groups with distinct forms of expertise. This makes it possible to analyze the different domains of market design work as practices where market designers interacted with members of other professions such as lawyers, politicians, regulators.

7.4. The Market Designers and Their Goals

Market designers were just one of the professional groups that contributed to the creation of California's electricity markets. Since this dissertation is interested in the conditions of market design failure, it is therefore necessary to specify the group of market designers more clearly and delineate the nature of their expertise. In this chapter, I will argue that the California market design experiment was shaped by two distinct types of market design expertise. One was characteristic for engineers and one was characteristic for economists. However, the fundamental difference between the camps was obscured beneath the surface of a similar set of mathematical tools and a shared conceptual framework. I will show how the common conceptual framework emerged at MIT/Harvard during the 1970s and trace it to California. I will then discuss how the project fragmented into two distinct types of experts who were appeared united under this conceptual framework.

A market designer is an expert who uses the conceptual tools of market design—economic modeling, control theory, linear programming, game theory, etc.—to develop blueprints for institutional frameworks that can realize a market mechanism with desired attributes. Market designers view the market as an information processor and market mechanisms as synthetic algorithms that solve optimization problems.[29] These algorithms are composed of software and strategic interactions between individuals. Their logic needs to be enforced by means of institutional design.

Experts who do not have this perspective on markets and use different techniques do not qualify as market designers in the present context. Lawyers, for example, may write legal rules for institutions that implement market design blueprints, but they are not market designers. Their expertise is shaped by the imagination of markets that is embedded in the law. This imagination has some roots in economics but is ultimately distinct from it. It is based on different standards of

[29] In electricity markets, this is true even for market designers who use game theory as the allocation problem dictates an optimization framework. For the differences in the mathematical treatment of design problems, c.f. Mirowski and Nik-Khah, *The Knowledge We Have Lost in Information: The History of Information in Modern Economics*, Chapter 11 and 13.

proof and is used for different purposes than the economic concepts. Similarly, economists who do not view the market mechanisms as the product of explicit institutional design do not qualify as market designers.

While this definition excludes some economists who contributed to the creation of California's system, it expands the group of market designers beyond members of the university. Once the design project got off the ground in California, market designers began to emerge in several different institutional contexts. The three utilities dominated the WEPEX/TAC process. They had their own engineers and economists who brought to bear a market design perspective on the project. For example, Ziad Alaywan and Jim Macias formed the liaison between PG&E and WEPEX. They were both certified engineers with additional training in economics. Alaywan had a degree from Berkeley's Haas Business School and Macias from the Harvard Business School. Vikram S. Budhraja represented SCE. He was an engineer with an additional degree in systems operations research. Despite developing market designs with reference to the academic market design traditions, these experts worked primarily for utilities and were guided by the priorities of these organizations. Similarly, independent consultants and consulting firms brought in market designers who were committed to the larger intellectual project but were not part of the university proper. The regulatory agencies also had their own economists and engineers with expertise in market design.[30]

What was the nature of the expertise that these market designers brought to bear on the design challenge? The answer to this question has two parts. First, it is possible to isolate a clear intellectual trajectory of electricity market design as practiced in California. Second, this

[30] At FERC, the Office of Economic Policy housed several economists who had market design expertise and kept close connections to the Harvard/MIT nexus.

intellectual trajectory developed two types of expertise whose differences were not readily apparent. Let me begin by presenting the intellectual trajectory that informed the market design project.

The search for the intellectual foundations of California's electricity market design project does not lead to an economics department. Instead, it takes us to the classrooms of MIT's engineering workshop on "Homeostatic Control" in the academic years of 1977–78, almost fifteen years before the creation of California's markets.[31] These workshops gave a diverse group of scientists free license to dream about the future of electricity systems.

Until the late 1960s, the utility industry had improved efficiency mainly by optimizing economies of scale. At that time, opportunities to improve the thermal efficiency for large power plants all but vanished and economies of scale no longer allowed gradual rate reductions. The workshop tried to envision what might be done to use the existing capacities more efficiently. Throughout the 1980s, these workshops developed a comprehensive vision of electricity market design. Several lines of influence tie these workshops to the creation of the California markets in the 1990s.

The first line of influence is straightforward. Several members in the MIT/Harvard nexus entered California's design process directly. Paul Joskow at MIT, for example, wrote recommendations for PG&E. Harvard's William Hogan worked for SDG&E as well as Enron. His work stood behind most of the proposals that SDG&E submitted to the CPUC and FERC. In 1988, Richard Tabors and Michael Caramanis, members of the original workshops, founded Tabors, Caramanis & Associates, a consulting firm for market design. They, too, were hired, first by stakeholders and later by CAISO when the organization got off the ground. In addition, the regulatory

[31] Of course, there were other efforts to describe market designs for electricity in Europe and the U.S., but the MIT/Harvard connection proved decisive for the creation of the foundational work by Schweppe (in engineering) and Joskow/Kahn (in economics).

community in California had close connections to Hogan's Electricity Policy Group, which served as a national reservoir for debates among the leading voices in the electricity sector.

Some of the connections between California and the workshops were *institutional*. They developed long before the Blue Book proceedings of the 1990s. Research that came out of the Harvard/MIT workshops was primarily funded by federal agencies such as the DOE. But as early as 1982, different institutions in California joined the efforts. The CEC and the California Department of Public Utilities oversaw projects to test the feasibility of engineering proposals conceived in the context of the workshops. SCE and PG&E funded experiments to develop differentiated metering technologies that would allow end users to react to time sensitive rate changes in their service territories. Their employees took leading roles in the implementation of these experiments and created ties to the Harvard/MIT nexus that solidified during the next decade.[32] When market design in California began, these connections led market designers inside the utilities to draw from the expertise at the East Coast.

The last line of influence was indirect and extended from the universities and research institutes in California to the East Coast. The Electric Power Research Institute was of central importance for California's market design process during the 1990s. This institute is an independent, nonprofit organization with federal funding and several branch offices. But the main laboratory is in Palo Alto and the members have close connections to Stanford and different schools at the University of California. Most of the technical solutions to California's design problems were developed, discussed, and advocated within the larger context of this institute.

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[32] Fred C. Schweppe et al., *Spot Pricing of Electricity* (Boston: Kluwer, 1988), xiv.; F.C. Schweppe, M. Caramanis, R.D. Tabors, J. Flory (1982): "Utility Spot Pricing: California," prepared for: Pacific Gas and Electric and Southern California Edison; MIT Energy Laboratory Report No. MIT-EL 82-044, December 1982. John Flory helped design the Power Exchange and was involved in the research that led to "Spot Pricing for Electricity."

The institute's directors, Hong-po Chao and Stephen Pack, were collaborators of Robert Wilson. He is a professor at Stanford and one of the founding fathers of game theoretical market design. He was the PhD adviser of Alvin Roth. In an interview about the influences that shaped his perspective on market design, Wilson said: "Another formative experience was at the Electric Power Research Institute in a section led by Steven (sic) Peck and Hung-Po Chao, working with them and my co-consultant Shmuel Oren."[33] Through them, Wilson (and Oren) became heavily involved in the creation of the protocols for the PX and the ISO auctions. In turn, he brought Vernon Smith and Stephen Rassenti from the University of Arizona into the WEPEX process to test market designs in an experimental electric power market simulation model.[34]

Even though market designers like Wilson, Peck, Huntington, and Chao formed an independent group in terms of their institutional affiliations—they had all been educated at California's top university departments—they had close connections to the Harvard/MIT nexus and built on the work that came out of the original workshops. The academic world of market designers was relatively small in the 1990s, and the group of experts who considered electricity market design was even smaller. Apart from organizing and attending design conferences with the designers from the East Coast and meeting them at the Harvard Electricity Policy Group, the scholars engaged with each other's work and frequently acknowledged feedback from each other.[35] There is thus a

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[33] Alvin E Roth and Robert B Wilson, "How Market Design Emerged from Game Theory: A Mutual Interview," *Journal of Economic Perspectives* 33, no. 3 (2019): 135.
[34] WEPEX/TAC Steering Committee Meeting, January 8, 1996.
[35] For example, in Paul L. Joskow and Jean Tirole, "Transmission Rights and Market Power on Electric Power Networks," *The RAND Journal of Economics* 31, no. 3 (2000)., Joskow and Jean Tirole acknowledge Robert Wilson and Hogan. In the articles that sketch the design for the California congestion management system, the authors explicitly acknowledge Hogan for "many incisive comments and constructive suggestions." Hung-Po Chao and Stephen Peck, "A Market Mechanism for Electric Power Transmission," *Journal of Regulatory Economics* 10, no. 1 (1996): 25. In 1997, Hong-Po Chao and Hillard G. Huntington organized a conference about the design of competitive electricity markets, where many of the design issues in California were discussed. Again, the most important members of the Harvard/MIT nexus joined the representatives from the Energy Institute. Hung-Po Chao and Hillard G. Huntington, eds., *Designing Competitive Electricity Markets* (Boston: Kluwer Academic Publishers, 1998), 1-2.

direct line of influence that points from the Harvard/MIT workshops in the 1970s and 1980s to the design project that would unfold in California a decade later.

What, then, was the vision of electricity market design that came out of these workshops? Initially, the debates on "Homeostatic Control" had little to do with market design. It was 1977, and few people were thinking about the creation of markets for electricity. Among the many engineers and operations researchers who attended the workshops, four scientists were particularly central: Fred Schweppe, Richard Tabors, Mike Caramanis, and Roger E. Bohn. As Tabors remembers, their research interests and backgrounds could not have been more diverse:

> We had Schweppe who was originally a control theory guy. He started out his career sort of worrying about rockets. He was an electrical engineer but, professionally, he ended up worrying about rockets going up, and where they were going to come down. Mike Caramanis was an operation research guy by training. He and I have been together working on, of all unlikely things, population. The population movements when he and I were together at Harvard. The third person is Roger Bohn. Roger was with Mike and me at Harvard. He was an undergraduate at Harvard who worked on a little bit of operations research, you know the math major type. Then, he came to MIT into the Sloan PhD and stayed on the math side of things. But in between Harvard and coming to MIT to grad school he'd worked with an engineering economics and consulting firm that focused entirely on energy down in Washington DC.[36]

Tabors had an undergraduate degree in biology and studied geography as well as economics for his PhD. Between research on rockets, population dynamics, energy systems, and the geographic structure of economic activities, they made for an unlikely team. But even though they worked in four different disciplines—engineering, operations research, economics, and management—they shared an interest and a common language:

> We had an overlap on the energy side. All of us could talk optimization and control theory. Some people could actually do it. Fred could do it really well, Michael could do it really well, Roger was okay on it, and I could talk it but couldn't do it. On the economics side, Michael, Roger, and I were capable of doing economics […]. Fred understood the math, and he certainly understood supply and demand at 50,000 feet. But when it got down to

[36] Interview with Richard Tabors, 04/18/2018.

> how you combine them, that wasn't Fred originally—we basically all had to teach each other what we needed to know.[37]

Their ability to use the language of control theory and energy systems created a bridge between their different projects and they began to collaborate with each other as well as other members of the workshop. Control theory is a set of mathematical techniques that are common in both economics and engineering. The techniques are used to describe the properties of continuously operating, dynamic systems. These systems can be described with linear or nonlinear differential equations. Control theory helps designers develop models of "control actions" that keep the system within acceptable parameters. It effectively measures an error, i.e., a discrepancy between desired outputs and current outputs, and then applies a corrective action described as a control function. The instruments of control theory can be used for all systems that include feedback loops.[38] Incidentally, both markets and electricity systems can be described and studied with the tools of control theory.

In the 1980s, several participants of the workshop, including Schweppe and Tabors, published the first, programmatic statement for a philosophy of "homeostatic utility control." It provided the conceptual foundation to draw out this mathematical similarity. Though the concept faded into the background over time, it is significant for the development of electricity market design.

Homeostasis is a concept that was first developed in biology and describes the existence of a state of equilibrium between the interdependent parts of an organism. For example, it is used to

[37] Interview with Richard Tabors, 04/18/2018.

[38] It is therefore a natural tool for market design. Since control theory provides a mathematical framework for conceptualizing issues of ongoing feedback-control in non-linear systems, it is mainly a way to define problems. Linear and non-linear programming—and other numerical techniques to find solutions to systems of differential equations by approximation—can often be used to *solve* optimal control problems. Weber, *Optimal Control Theory with Applications in Economics*, 253-4.

capture the mechanisms that allow the body to retain a steady temperature despite changing environmental conditions.[39] A balance of internal adjustments between parts of the system retain a stable system state.

Before the workshop on homeostatic systems, the utility industry had always followed the philosophy that the supply of energy simply had to adjust to whatever customers did.[40] Since consumers used energy without any way to consider the conditions of energy production, the supply side always needed to react to whatever was happening on the demand side. Having to deal with completely unresponsive demand was costly and inefficient. It required large amounts of "spinning" reserves—plants that are running without load and can quickly link into the system. As I have already observed in chapter 5, the large gap between lowest and highest possible demand also required vast amounts of excess capacity, capacity that was not used most hours of the year. The workshop participants wanted to tackle these inefficiencies.

The programmatic paper tried to articulate a vision for "[…] an electric power system in which the supply systems and demand systems work together to provide a natural state of continuous equilibrium to the benefit of both the utilities and their customers."[41] In other words, the authors wanted to coordinate consumption and production in a process of mutual adjustment that would retain an efficient balance between both sides—a global equilibrium with desirable efficiency characteristics. If demand adjusted to supply and supply to demand, variation would decline

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[39] The research had a distinct connection to cybernetics, which emerged in the same nexus and gave rise to system's engineering. Ross W. Ashby, *An Introduction to Cybernetics* (London, UK: Chapman & Hall Ltd, 1957); Norbert Wiener, *Cybernetics or Control and Communication in the Animal and the Machine*, vol. 25 (Cambridge, MA: MIT Press, 1965).
[40] Fred C. Schweppe et al., "Homeostatic Utility Control," *IEEE Transactions on Power Apparatus and Systems*, no. 3 (1980).
[41] Ibid., 1151.

and excess capacity could be reduced both in terms of spinning reserves and in terms of installed capacity.

At the time, the philosophy of homeostatic control was intended as a speculative vision: “Homeostatic Utility Control is a concept which looks forward to the utility systems at the turn of the coming century.”[42] Nonetheless, the speculation extrapolated from a technological innovation that was about to hit the industry: “The concept of Homeostatic Utility Control utilizes […] the revolutionary developments occurring in the fields of communication and computation to develop an efficient, internally-correcting control scheme.”[43] The invention of solid-state control devices in the 1970s promised some measure of automatic communication between consumers and producers. A so-called “Frequency Adaptive Power Energy Rescheduler” (FAPA) would measure changes in the standard frequency of the electric power system (60 Hz) and use this information as an indicator for the availability of supply. If not enough energy is in the system, the frequency of the A/C current may decrease for brief intervals. If the FAPER picks up on a frequency loss, the device can switch off a machine to reduce load on the system. This kind of automatic load response was the foundation of Homeostatic Utility Control Theory. The gist of the theory was far ahead of its time. Take the following quote from the 1980s paper, for example:

> The most sophisticated customer scheduler is the general-purpose computer which is programmed specifically for the explicit needs of the customer. They would be installed in many of the larger commercial installations and almost all industrial installations. They would allow extensive automatic control features as well as sophisticated input-output devices for human interaction.[44]

Today, almost forty years later, “smart grids” and the emerging “internet of things” begin to realize precisely this idea with decades of delay. If electric appliances can communicate with

[42] Ibid., 1155.
[43] Ibid., 1151.
[44] Ibid., 1154.

each other as well as with generators, the utility's electricity system can internally optimize the balance of use and production relative to a variety of external parameters, such as human preferences. The Homeostatic Control Theory thus centered on the idea of a mutual adjustment between supply and demand based on automatized communication procedures between new control devices. It is crucial to note that the original vision emphasized *automatic* adjustments; electronic devices would exchange information about supply and demand. The system was meant to balance *itself* in a complex interplay of signal processing—hence it was called "homeostatic." The idea was ahead of its time because it proved too costly and unwieldy to for such communication devices during the next decades.

But the theory introduced a couple of core ideas that were to become the foundation of electricity market design. First, production and consumption now appear as parts of a large machine whose mutual relation needs to be optimized. Second, this was supposed to happen in a process of mutual adjustment, driven by the exchange of *information* between a variety of devices that represent consumers and generators.

From the very beginning, this conceptual framework was intertwined with economics. Given the possibility of communication between consumers and generators, papers in the workshop ponder what kind of information might guide the adjustment. The answer was simple: a spot price would carry all relevant information. The engineers thought that the spot prices would reflect the true marginal cost of providing energy at a given location at a given time. The fluctuating prices would signal if generation was in short supply or if there was ample supply. This signal could be used to adjust consumption and guide the system to a position where consumption converged at the level of most efficient production. Since the costs of production were known, it was not necessary to have a market. If you could just calculate the costs and then automatically adjust all consumption with FAPA devices, no one needed to make any decisions, and competition was not necessary. Nonetheless, the idea to use spot prices created an entry point for market design. In one of the first papers, the engineers wrote: "The spot prices provide an economic stabilizing mechanism that tends to keep the overall supply-demand system in equilibrium: as consumption goes up, so does price, which tends to reduce consumption while increasing production. This smooths out the unanticipated demand variations over time."[45]

If electricity systems can work as homeostatic systems, then price signals that indicate the cost of production can help them achieve homeostasis. The mutual adjustment between production and consumption, guided by machines communicating prices to each other, rendered the operation of the electricity system equivalent to the operations of a perfectly competitive market. These markets are themselves nothing but a homeostatic system—supply and demand constantly react to each other, constantly balance the overall market process toward equilibrium. The Homeostatic Control Theory thus created a common foundation for the work of engineers and economists. It established a formal similarity between the homeostatic balancing of the electricity systems and perfectly competitive markets. Since perfectly competitive markets now seem to perform the same task as the utility, which is optimizing the relationship between the machines in the system, markets might well replace the utility and its potentially inefficient, self-serving, and complacent bureaucracy.

In the next ten years (between 1977 and 1987) this idea was developed further. Several students developed PhD theses to aspects of homeostatic control theory, carrying the idea from the engineering departments into the world of academic economists. Roger Bohn wrote his PhD thesis about spot pricing for electricity at MIT. Located in the business school, he was closely associated

[45] Ibid.

with economists who were interested in the prospect for electricity markets. Bohn's supervisor in the Sloan business school was Richard Schmalensee, and his advisor in the economics department was Paul Joskow, a student of Edward Kahn who took part in early experiments of market design. Together, these two economists would publish a highly influential defense of restructuring for electricity in 1983.

Markets for Power uses ideas from transactions cost economics to analyze different restructuring proposals and obstacles to their realization. It is written in nontechnical language and considers regulatory, political, and economic factors that matter for restructuring over and beyond purely technical issues. The economists offer a measured assessment of the prospects for electricity markets and do not advocate full-fledged deregulation of the industry. Instead, they advocate for very limited use of markets in the wholesale segment of electricity systems integrated carefully with the role of grid management. Despite their hesitant endorsement of deregulation, Joskow's and Schmalensee's book became the academic touchstone for policy proposals in a variety of states and before FERC.

In 1988, Bohn, Caramaris, Tabor, and Schweppe brought the different strands of research in the workshops together and published *Spot Pricing for Electricity*. This book developed a basic concept for locational marginal pricing of electricity and became the technical foundation for restructuring. It applied a rigorous engineering perspective to the problem of electricity market design.[46] Together, the two books created a clear perspective for electricity markets and the steps to

[46] A at several points the book quotes William Vickrey, who had written on the question of congestion management and explicitly considered the Homeostatic control theory as well. William Vickrey, "Efficient Pricing under Regulation: The Case of Responsive Pricing as a Substitute for Interruptible Power Contracts," ed. Columbia University (New York1978).

their implementation. They combined the perspectives of economists and engineers and formed a comprehensive vision for electricity market design.

However, the common framework of homeostatic control theory also obscured certain differences between the economists and engineers. The framework was closely inspired by the conceptual vocabulary of cybernetics. Its inventor, Norbert Wiener, had defined cybernetics as the science of "communication, control, and statistical mechanics, whether in the machine or in living tissue."[47] From this perspective, a system consists of components that are linked in a dynamic interplay, processing inputs to produce outputs. Communication structures make it possible to observe the system's processes, monitor and adjust its operation.[48] Cybernetics studies how the system's control and information structure coordinate the interplay to achieve a dynamic equilibrium in which the different parts are aligned to produce the desired outcomes.[49]

Often described as the first framework to understand human-machine interactions, this perspective blurs the difference between a generator and a market participant making a decision about a generator.[50] The "steersman" who oversees the system is just as much part of the system as that which he or she controls. And the steersman can be a human just as well as a machine.[51] From the cybernetic perspective, the electricity system may be an integrated process in which pieces of

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[47] Wiener, *Cybernetics or Control and Communication in the Animal and the Machine*, 25, 11.
[48] This is also called "second-order cybernetics" because it is the attempt to understand how systems can be observed through a structure that it itself cybernetic. The term was introduced by Heinz v. Foerster Heinz Von Foerster, *Observing Systems* (Seaside, CA: Intersystems Publications, 1981). It features prominently in the most important sociological theory that emerged from cybernetics: Niklas Luhmann's System's Theory. Luhmann, *Theory of Society*, 1.
[49] C.f. the introduction of Wiener, *Cybernetics or Control and Communication in the Animal and the Machine*, 25. Wiener discusses the connections to electronics on pp. 6-10, and particularly the connection to the invention of the modern computer. After cybernetics had become a discrete scientific endeavor, the perspective influenced electrical engineering via the subfield of systems engineering.
[50] The original theory derived from Wiener's attempts to develop an automatic antiaircraft predictor during the Second World War. Human and machine here meld together into a combined entity.[50]
[51] David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics* (Baltimore, Maryland: Johns Hopkind University Press, 2002), 4-7.

machinery dynamically interact with each other to achieve a homeostatic equilibrium of all parts. Or it may be a system of machines whose interaction is guided by the decentralized decisions of market players who implement a complex algorithm of mutual information exchange. While the former idea implies a centralized utility that orchestrates the dynamic interplay of communicating machines, the latter implies a market system in which the machines have been swapped for traders. Obscured beneath the veneer of the shared conceptual framework, these differences matter for the nature of the electricity market design project.

To most market designers, the match between engineering and economics seemed harmonious. In the period between 1977 and 1988, the technical publications demonstrate an entwinement of economics, engineering, and system operations research. The market appears as a coordination device that can be designed to meet the requirements for the balancing of a homeostatic system of many different generation assets, wires, adjustment hardware, and consumers. This increasingly tight connection between the economists' vision of perfectly competitive markets and the engineering vision of electricity systems as communicating machines is visible in some of the introductory sentences to *Spot Pricing for Electricity*:

> There is a need for fundamental changes in the ways society views electric energy. Electric energy must be treated as a commodity which can be bought, sold, and traded, taking into account its time- and space-varying values and costs. This book presents a complete framework for the establishment of such an energy marketplace. The framework is based on the use of spot prices.[52]

The book followed the economic theory of market design and views markets as a tool that can be used to achieve the homeostatic balance of the electricity system. Prominent market designers from economics soon joined the debate.[53] Noting that utilities use spot prices in algorithms

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[52] Schweppe et al., *Spot Pricing of Electricity*, xvii.
[53] Joskow and Schmalensee, *Markets for Power: An Analysis of Electrical Utility Deregulation*, x; Vernon L. Smith, "Currents of Competition in Electricity Markets," *Regulation* 11, no. 2 (1987).

to calculate and minimize the incremental cost of production for the most expensive generator in the system, Vernon Smith writes:

> This procedure [i.e., Schweppe's spot pricing mechanism, G.R.] incorporates large amounts of information into simple price signals, just as a market might do, and it provides the basis for an economic dispatch center, or regional energy exchange. Such an exchange could serve the same function as an exchange where gold, corn, pork bellies, or any other commodity is freely traded.[54]

This quote is revealing. While Smith thinks that the spot pricing of electricity can be used to build a "regional energy exchange," he did not consider the spot pricing method itself to represent a market process. He thinks it merely works *as if it was* a market ("as a market might do"). This quote points to the fact that there was a subtle difference in the way engineers and economists/system operations researchers wrote and spoke about the markets. What, then, was the difference that was obscured by the use of the cybernetic language?

While the engineers continued to hold onto the idea that prices are a *tool* to coordinate the interactions between machines within the larger electricity system, economists increasingly tended to separate discussions of markets from grid management. Both sides agreed that markets had to work within the structure of the electricity system, but economists isolated discussions of market dynamics from discussions of the things that happened in electricity systems. This had important consequences. Since the engineers thought about the markets as part of a larger system, they transposed their vision of control on the markets. As the electricity system itself, the markets would require constant adjustments, administered by a centralized entity.

Yet, the nature of this oversight and control was different from that of economists. This followed from the second feature of the engineering perspective. Since markets are parts of the electricity system, they are simply conduits for information that generators and consumers transmit

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[54] "Currents of Competition in Electricity Markets," 26.

neutrally. In other words: actors appeared as FAPA devices and are equivalent to machines sending information about marginal cost and demand. This is particularly visible in the original book by Schweppe et al. Their spot pricing mechanism was written to be compatible with a single utility that wants to dispatch its generators from a central location in response to customers' price reactions. In such a system, the price the customers have to pay depends entirely on cost even without competition—mainly, the marginal cost of the generator and the cost of network transmission.[55] The spot pricing mechanism computes these prices *ex post* on the basis of metered use, revealed transmission, and generation costs. This, so the assumption goes, would lead to an adjustment of demand in response to previous cycles of use.[56]

Later in the book, they consider how to expand this framework to a deregulated market environment, but even then, competition is an assumed background condition rather than something that has to be explicitly designed. The main question is how a system of information exchange can converge on a desired solution that takes all aspects of the technical dispatch into consideration. For example, when Schweppe et al. introduce the theoretical market participants, they write:

> The Market Coordinator […] sends each generator a spot price and each generator self-dispatches itself by generating if the spot prices paid for electric energy exceeds the plant's marginal operating costs. A perceptive reader might say, "Such generator self-dispatch and central utility dispatch are theoretically equivalent." Such a reader would be right.[57]

Here, we clearly see that the creation of spot prices is simply an information device that leads generators to plan their dispatch. The market coordinator determines the spot price on the basis of supply and demand information and generators then *react* to it—without explicit

[55] Schweppe et al., *Spot Pricing of Electricity*, 31.
[56] Ibid., 51. Viewed in terms of long-term changes in the pattern of use, they could therefore assume *elastic* demand in the development of their market mechanism.
[57] C.f. Ibid., 113-14.

competition. The central design question then becomes how a system of information exchange converges on a feasible solution. The information from consumers and generators is assumed to be accurate because they simply communicate their condition, like FAPA devices. Ongoing control and oversight is then necessary because of the complex permutations of possible states in the transformation of the dynamic system of energy flows. It is not necessary to constrain manipulative behavior.

Steven Stoft, an economist who worked at UC Berkeley's Energy Institute and advised PG&E's market design team, described his perception of the engineering mindset to me like this: "In engineering you have all these transformers and wires and transistors and whatnot that you arrange, and they do what you want them to do. And [the engineers] keep thinking they can arrange people and tell them what they're supposed to do and they'll do it." He later wrote an introduction to *Power System Economics*, which was meant to introduce the economic perspective to engineers.

In an interview with Vikram Brudhraja, who was SCE's lead engineer on the market design team, the engineering mindset became apparent as well, though he gave it a different spin. When I asked him whether he had thought the models that economists brought to the design process in California would enable successful grid management, he replied:

> From an engineering standpoint, things were working great the way they were. [What we were trying to do] was a market experiment and it was a negotiated solution. All of our efforts were directed at getting it designed in a way that would be fair and reasonable because obviously engineering principles cannot be violated. Electricity is all physics, it's going to continue to operate on the laws of physics, and you can't make those bend with economics.[58]

In other words, he thought that the engineering realities were the overriding concern for the creation of the market structure. The market designs by economists—results of difficult

[58] Interview with Vikram Brudharaja, 02/02/2018.

compromises—had to be adjusted in such a way that they met engineering criteria and enabled grid management. Again, the market appears as a subsidiary process in the larger electricity system, which has to be coordinated on the basis of physical laws.

Many other engineers expressed similar sentiments in my interviews. They complained that economists did not understand the true requirements of economic dispatch. The real key to the whole thing was how to build an infrastructure of communication and control that would actually sustain the operation of the vast, complex technical infrastructure from one moment to the next. The engineers thus had a rather distinct view of the electricity market design project. As parts of the larger system, markets are conduits for information sent by machines that need to be coordinated across the system. The main design question is how the system of information exchanges can be organized to optimize the dispatch of electricity relative to *all* technical complications across *all* physical locations.

This perspective turns out to be different from that of economists. They tended to separate the discussion of markets from the discussion of grid management. This is visible in debates about what should be "included" in the market—the market appears as an external entity that absorbs features of the electricity system it then coordinates. The markets themselves can then be analyzed in isolation. Joskow and Schmalensee, for example, analyze different scenarios for restructuring almost entirely in terms of incentives that competing firms face under different conditions, not in terms of the communication architecture that feeds into the needs of grid management.[59] The subtle separation between markets and electricity system leads to different perspectives on the nature of actors and the requirements for control.

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[59] For example, see the conclusion of the efficiency analysis: Joskow and Schmalensee, *Markets for Power: An Analysis of Electrical Utility Deregulation*, 176-78.

Throughout the 1980s, the economic perspective on electricity market design focused increasingly on how incentive structures could be designed to facilitate the kind of competition that would harmonize with grid management. The focus was on the question of how willful players can be made to conform to a particular logic of interaction. For example, criticizing the view that a centralized calculation of spot prices is equivalent to a competitive market process, the economist Peter Cramton wrote: “This view does not recognize that the schedules derived from an optimal power flow (OPF) program are no better than its inputs. In fact, suppliers can and do treat the program as a device whose outputs can be manipulated by the inputs they provide in the form of purported cost functions, availabilities, etc.”[60] Here we clearly see the economists’ view that market design is about creating markets as separate entities that are organized around incentive structures.

Economists’ tendency to separate the rules for the interactional logic in the market from the activities of the grid operator meant that they thought about control differently than their colleagues. Control of the market mechanism was provided by the institutions that configure the market mechanism by organizing the incentives for players. Though these institutions are themselves centralized regulatory structures, they create processes that *self-regulate* if the incentives are set correctly. The institutions must thus merely protect the structure of incentives that generate the pure market mechanism. This leads to a distinct style of analysis in which the designers reason backwards from the desired equilibrium result: they identify a market mechanism that leads to a particular equilibrium outcome and then show how a given set of institutions configures a logic of

[60] C.f. Peter Cramton, "Efficiency Considerations in Designing Electricity Markets," (Ontario, CA: Competition Bureau of Industry 1998), 3. The report is almost entirely about the question of how procedural rules can be defined under different market architectures to get the incentives right; ibid.

interaction that gets you there.[61] If there is a straight path from a set of rules to a particular outcome, the market mechanism can be realized if these rules are realized.

In that sense, the economic perspective on the market was not unlike the Leibnitz's idea of preestablished harmony: once all the cogs and wheels are in the right place and the market is wound up in the right way, it will steadily march toward equilibrium. Or as Ziad Alaywan, the chief engineer for PG&E, put it. When economists discover that there is a problem with the markets, they "would say: 'well the problem will solve itself if you basically put all the incentives in the right place'. But they don't understand the nature of the grid."[62]

Thus, economists thought about control as enforcing incentives in a market that absorbs certain features of the electricity system to coordinate them. And they thought of actors as strategic humans who try to identify profitable opportunities for trade wherever they can. Yet, these philosophical differences remained hidden behind the veneer of the methods and conceptual frameworks that informed the project of electricity market design.[63]

Since the philosophical differences were not apparent, market designers began to divide along a variety of architectural issues during the 1990s. These seemed to hinge on specific technical questions and tradeoffs between different design objectives.[64] The most important debates concerned whether markets should be centralized auctions or bilateral contract markets, whether markets should be pure exchanges or pools, and how congestion management should be

[61] For example, look at the examples that are supposed to explain how the two-settlement system works in Stoft, *Power System Economics,* 213-14. Based on a desirable result, the example shows how the system sets incentives that produce this result.
[62] Interview with Ziad Alaywan 08/31/2018.
[63] Another reason these differences did not become more apparent was that system operations researchers, who have training in both economics and engineering, were located in a space between the two camps. They would think of markets as driven by incentives, but they would also treat the markets as tools for grid management and invoke strong centralized modifications of the market mechanism. This is where the Hogan view of electricity markets can be located. Interview with William Hogan 12/11/2017; interview with Severin Borenstein 04/18/2018.
[64] Cramton, "Efficiency Considerations in Designing Electricity Markets."

organized.[65] All three debates ultimately concern the question of how much control the system operator needs to take on and how much coordination markets can provide. But in the technical publications, this is not readily apparent. The architectural choices seem to hinge on a variety of technical issues rather than philosophical differences about the nature of human actors and the role of markets in the larger structure of the electricity system.[66] As Shmuel Oren put it in a review article, "The dispute centers on the 'how much' questions, on what is essential and what is optional, on the relationship between short-term and long-term efficiency and on the tradeoffs involved in the short-term policy choices."[67]

Nonetheless, the debates match relatively well onto the philosophical differences just discussed. If you view markets as informational infrastructure that organizes how machines talk to each other in the larger electricity system, there is no reason to oppose centralized power pools. The centralization simply makes the coordination of decentralized signals easier. However, such centralization would seem problematic if you view markets as decentralized systems of interaction between individuals whose efficiency is premised on competition. Centralization would constrain competition and decentralized decision-making. This would reduce markets' ability to find the superior solution to the efficiency problem. As prominent as the philosophical differences were, they did not become readily apparent. Electricity market design could thus present a largely united front to the world, with experts disagreeing only on technical details.

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[65] Pools are characterized by a variety of side payments to cover varying costs of generators. Systems of side payments make bids more transparent but they also remove generators' control over how they want to represent their fixed costs in their prices.
[66] For a quick overview Stoft, *Power System Economics*, 204-06.
[67] Shmuel S. Oren, "Authority and Responsibility of the Iso: Objectives, Options, and Tradeoffs," in *Designing Competitive Electricity Markets*, ed. Hillard G. Huntington and Hung-po Chao (Boston: Kluwer Academic Publishers, 1998), 80.

While the academic market designers tended to be system operations researchers and economists, the non-academic market designers tended to fall on the engineering side. Both seemed to pursue the same project as they used the same methods and the same language. They cited each other and worked together. But their visions were subtly different. As they entered the political, technical, and regulatory processes of design work, these differences began to influence the decisions they made in ways that would become quite consequential. How these differences mattered in the processes where the designers had to contend with other professionals and the logic of decision-making will be the topic of the next chapters. I will now analyze the process that led to some of the most basic flaws of the California system: the political negotiations around the Blue Book.

8. Market Design as Politics

8.1. Introduction

In August of 1995, a small group of special interest representatives staged a minor coup against the CPUC. It was a hot summer, and the Blue Book proceedings had been dragging on for several months. Two groups were fighting relentlessly against each other, unable to come to an agreement. The first group had formed during the early months of 1994 when a conservative business foundation invited lobbyists, politicians, and utility executives on a trip to the UK—all expenses paid. Among the travelers were the president of the CPUC, Dan Fessler, and one of his commissioners, Greg Conlon. Fessler was not only a proud advocate of free markets with admiration for Reagan and Thatcher, he was also an avid anglophile, known to affect a mock British accent in moments of excitement.

Their luxurious stay in a hotel in London's Mayfair district proved transformative when Fessler and Conlon met Stephen Littlechild. Littlechild was the primary architect of the UK's approach to electricity restructuring, a powerful man, popularly known as "The Regulator." Mesmerized by his presentation, Conlon and Fessler fell in love with the UK's restructuring model. Upon their return to the States, the travelers formed a tight group of supporters for the UK's model. They stepped up the Blue Book proceedings and advocated heavily for a PoolCo model inspired by Littelchild's approach.[1]

The PoolCo model was based on the British spot market, which was integrated with the operations of the grid operator. The pool would buy electricity from generators, sell it to distributors, and organize the transmission. In contrast to the UK's approach, Fessler's Blue Book did not

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[1] Bill Bradley, "Master of Disaster: How Pete Wilson's Energy Chief Short-Circuited the California Grid," *LA Weekly*, February 14, 2001, https://www.laweekly.com/master-of-disaster/, last accessed 12/05/2019.

propose the complete separation of production, transmission, and distribution functions.[2] They were worried the utilities would not come on board if they had to relinquish ownership of the transmission assets.

This difference proved contentious, created a rift among the commissioners, and gave rise to the second group in the Blue Book proceedings. Commissioners Jesse Knight and Norm Shumway worried that utilities would take control of the pool and use their power over the transmission grid to distort access to the markets. This might turn the pool into an “uber-utility” displacing all competition. Accordingly, they proposed an alternative “Direct Access” model that allowed retail and wholesale customers to choose their supplier on the basis of bilateral contracts. To weaken the utilities, they wanted an ISO that would manage the grid independently of the utilities and merely provide equal access to the transmission system.[3]

Throughout 1994 and most of 1995, the stakeholders were deeply divided between the two models. The industrial users sided with the “Direct Access” group because they thought that a system built around bilateral markets would enable them to contract with cheap qualifying facilities in the Northwest. They, too, were worried about the interference of utilities and wanted an independent market where they could easily contract with the cheapest offers.

The utilities were mainly concerned about cost recovery. A variety of investments had book values that far exceeded their potential profitability in the new markets. The principal concern were two nuclear power plants, whose construction had been a disaster. The development of

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[2] Carl Blumstein and James Bushnell, "A Guide to the Blue Book: Issues in California's Electric Industry Restructuring and Reform," *The Electricity Journal* 7, no. 7 (1994).

[3] Initially, the Blue Book did not clearly differentiate between the two proposals. The commissioners entered majority and minority proposals in the beginning of 1995, but the basic outline of the two alternatives are already visible in the Blue Book. Kevin Porter, “A Summary of the California Public Utility Commission’s Two Competing Electric Utility Restructuring Proposals,” NREL/TP-461-8330, (Golden, Colorado: National Renewable Energy Laboratory, November 1995).

PG&E's Diablo Canyon Nuclear Power plant had started with a cost estimate of $400 million and ended up costing $5.8 billion. Similarly, SCE had initially estimated the costs for the San Onofre plant at $1.3 billion but ended up spending $4.3 billion. The cost overruns were a reflection of various mishaps, and the utilities feared that a market would punish them mercilessly. PG&E decided to throw its weight behind the Direct Access model and thus the interests of industrial customers. In exchange, it received a guarantee that it would be able to recover these stranded costs. For SCE the situation looked different. Without an existing guarantee, they thought that only a Power Pool could promise cost recovery. They were worried that the industrial users would no longer buy their power in a bilateral contract market. Since this would prevent them from recovering their investments, they were firmly in favor of PoolCo.[4] For similar reasons, SDG&E sided with SCE.

Since there were now two groups of powerful interests with disparate visions, the last months of 1994 and the first few months of 1995 went by with increasingly more hostile attempts to force a decision. The groups tried to put pressure on legislators in Sacramento as well as CPUC commissioners in San Francisco. But neither side could gain the upper hand, and it began to look as if the negotiations were going to fail.[5]

At this point, Governor Pete Wilson intervened. He was getting ready for a presidential bid in the Republican Primaries in 1996 and wanted the positive publicity of successful restructuring. Accordingly, he sent his chief of staff, George Dunn, and his chief economist, Philip Romero, to negotiate a deal between the major parties. The talks took place among a few top insiders from

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[4] Isser, *Electricity Restructuring in the United States: Markets and Policy from the 1978 Energy Act to the Present*, 238. Interview with Jan Smutny-Jones, 10/24/2017.

[5] Ron Russell, "Dim Bulbs: Greedy Out-of-State Profiteers Make Easy Targets, but the Real Villains of California's Energy Debacle Are the Ones under the State Capitol Dome," *San Francisco Weekly*, March 7, 2001, p. 3, https://archives.sfweekly.com/sanfrancisco/dim-bulbs/Content?oid=2141079&storyPage=3, last accessed 12/05/2019.

SCE, CLECA, IPP, and CMA. And so, a small group of representatives began to negotiate the future of California's restructuring project outside the limelight of the public or interference from consumer groups. Jan Smutny-Jones, the representative for IPP, remembered, "Throughout the summer of 1995, we met ... once a week is probably overstating it, every other week is probably understating it. We met a lot."[6] The negotiations took place in CMA's meeting rooms in Sacramento and various hotel rooms.[7] "It was analogous to the Arab-Israeli peace talks," Romero remembered.[8]

At first, the more intimate setting only served to highlight the existing differences. Vikram Budhraja was SCE's representative in the negotiations. He had consulted extensively with William Hogan and the market designers at Harvard. To him, markets and grid management had to be integrated. PoolCo seemed inevitable. Barbara Barkovich, the representative for CLECA remembers their disagreements:

> Vikram comes from that kind of technical background, likes the ideas [of the market designers in the east], thinks that they make sense. [He kept saying:] "Why don't we do this? It's all going to work, right?" And our side is like: "Well, we're not really sure. We haven't been convinced yet, and we want access to the grid. We want to be able to do retail choice. We don't necessarily feel that we need a centralized market."[9]

But despite pushback from the industry stakeholders, Budhraja did not relent. He was so insistent that SCE eventually added John Fielder to the mix, who was more sympathetic to the needs of the large customers. He was willing to move SCE's position closer toward the Direct Access model PG&E and the industrials favored. Barkovich remembers: "With Vikram, there was no moving him. So that's when Fielder came in, and he was more conciliatory and better able to

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[6] Interview with Jan Smutny-Jones 10/24/2017.
[7] Bill Booth and Barbara Barkovich represented CLECA; Keith McCrea and Glenn Sheerin spoke for CMA; Jan Smutny-Jones and Doug Kerner represented IPP; Vikram Budhraja, Alex Miller, and Ann Cohn came from SCE.
[8] O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 17.
[9] Interview with Barbara Barkovich, 08/21/2018.

understand the customer side […]. So, we finally said, 'Okay, if you want a spot market, you can have one, but we want it separate from the grid operator.'" [10]

This offer of compromise marks the crucial moment in the negotiations. Just as the PoolCo group wanted, the industrial customers agreed to a power pool. There would be centralized auctions, and they would be used to help the utilities recover costs. But in exchange for this concession, the pool would have to be separated from the grid management. They wanted to chain the ISO to a minimal role as "traffic cop," who would merely ensure that the markets obeyed technical constraints.[11] Otherwise, so they feared, a more powerful ISO might use the power over the market to discriminate against bilateral agreements. With the guarantee of cost recovery through the pool, both sides seemed happy, and a compromise was finally on the horizon.

Upon hearing the terms of the new agreement, Budhraja redoubled his efforts to object and reiterated that they would need to build markets that were integrated with the activities at the system operator. A senator who had dropped in on behalf for CMA apparently listened to this demand, then slammed his hand on the table and cried, "It's going to be divided or there ain't no deal."[12] The sudden outburst marked the breaking point of the negotiations. As Barkovich recollected, everyone suddenly feared they might not arrive at a decision at all. A compromise seemed preferable:

> Through that long and hot summer, meeting after meeting after meeting, we finally realized that, well that this is always the case. If an issue is really difficult and contentious, do you want to settle, or do you want to let the commission decide? I have settled many cases in my life because the bottom line is when the regulators get it, you have no idea what they're going to do. So, a lot of times, you will settle, that is, you will reach an agreement that is a

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[10] Interview with Barbara Barkovich, 08/21/2018.
[11] One of the negotiators of the MOU explains this in "Hearing Before the Public Utility Commission of the State of California, August 21, 1995, Reporter's Transcript, Pasadena, California, Vol. 32, Pages 4299-4489", Box 71, *CPUC*, p. 4312-3; interview with Jan Smutny-Jones, 10/24/17.
[12] O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 18.

> compromise because you feel better about that than having five people have your fate in their hands.[13]

And so that was it: to prevent the regulators from making the decision for them, the group drafted a Memorandum of Understanding (MOU) and resolved the fundamental conflict of interest that had blocked the Blue Book proceedings. The document was first signed in August 1995 and filed with the CPUC in September. As soon as the stakeholders agreed, the governor endorsed the MOU and propagated the compromise in San Francisco and Sacramento.

At the CPUC, Fessler was apparently completely blindsided by the MOU. Smutny-Jones remembers: “Fessler was in Sweden […] when all of this came down. And when he got back—he was normally a very formal guy—he apparently erupted at people and swore them up and down the aisle.” Prior to his departure, there had been two proposals, and Fessler’s PoolCo model had still been the contender at the CPUC. But when the MOU appeared, the existing proposals were simply pushed to the side.

Without delay, PG&E endorsed the MOU. The power marketers, represented mainly by Enron, supported the MOU proposal as well. They could foresee that the separation and equality provisions would introduce significant inefficiencies into the communication between the markets and the system operators. Since their business model was premised on resolving such problems as intermediaries, they supported the proposal.[14] Upon returning to the U.S., Fessler’s PoolCo model was therefore all but dead, and the proceedings had been put on to different tracks. He had no other option but to relent and open a formal channel that allowed the parties to file the MOU as a new, alternative model for restructuring.

[13] Interview with Barbara Barkovich, 08/21/18.
[14] Stoft, "What Should a Power Marketer Want?" 36.

Since the MOU brought consensus among the most powerful interests to some of the most divisive issues of the Blue Book proceedings, everyone saw it as a breakthrough accomplishment. The market design process could move forward. Not only did the MOU become the foundation for the CPUC's "Preferred Policy Recommendation" at the end of 1995, the governor's influence in Sacramento ensured that it also informed the core of AB1890, the law that provided the legislative foundation for restructuring. Even though it had been hashed out in the backroom dealings of a tiny group of special-interest representatives, the MOU was the most transformative document of the political process.

As much as the MOU was a political success, it was a complete disaster from the perspective of market design. It proposed a hybrid model that combined features from both the PoolCo and Direct Access proposals. The utilities would be guaranteed cost recovery through a pool-based exchange, but there would *also* be bilateral markets for direct access. To make sure that all these markets would operate on equal footing, the MOU mandated a strict separation between the ISO, the PX, and the other markets. To prevent the ISO from discriminating against less efficient market places, it was also not allowed to engage in optimization tasks that could have interfered with the operation of the markets.[15]

As I have discussed in chapter six, these design features—the separation and equality provisions—constitute one of the major design flaws of the California markets. They introduced a

[15] This is what stands behind the phrase "Generators and/or generation aggregators will submit preferred schedules to the ISO, which will be responsible for integrating them with schedules provided to support Power Exchange transactions in a fair and nondiscriminatory fashion." See "Memorandum of Understanding on Joint Recommendations Among California Manufacturers Association, California Large Energy Consumers Association, Independent Energy Producers, Californians For Competitive Electricity and Southern California Edison Company, December 14, 1995," Box 18, Folder 43a, *CPUC*, p. 5.

variety of discrepancies between the way markets and grid operation worked and thus created the incentives for illegal arbitrage businesses that derailed the intended market mechanism.

Market designers recognized the problems immediately. Soon after first versions of the MOU began to circulate in the Blue Book proceedings, market designers began to comment on the hybrid model. They were uniformly aghast.[16] Regardless whether they belonged to the engineering or the economic camp of electricity market design, they urgently and vigorously opposed the two provisions of the MOU in personal interactions, published work, and expert testimony. Whenever asked, they repeated the objections throughout the WEPEX/TAC process to implement the markets as well as the legislative process in Sacramento.[17]

Their concerns derived directly from the design philosophy underlying the original work by Schweppe et al. Since generation and transmission are always two sides of the same coin, it is *physically* impossible to truly separate markets and transmission management.[18] Any attempt to do so would be fictional. Whatever agreements were made in relation to the fictional separation would have to be corrected during real time operations later on. If the ISO was not allowed to optimize the schedules, how could the required optimization be accomplished? Whatever the

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[16] The market designers in the two camps (engineers/economists) each shared an "epistemic culture" and had a relatively unified basic vision of how these markets could work even if they internally disagreed on a variety of issues that divided them over the direct access vs. poolco debate. Epistemic cultures refer shared practices of knowledge production that can cut across disciplines and viewpoints. These cultures amount to the "epistemic machinery" of science. This refers to collections of ways to collaborate, conceptualize entities, classify them, and approach them methodologically. This gives rise to socially distinct ways of creating knowledge. Karin Knorr-Cetina, *Epistemic Cultures: How the Sciences Make Knowledge* (Cambridge, MA: Harvard University Press, 1999), 10-11.

[17] William W. Hogan, "A Wholesale Pool Spot Market Must Be Administered by the Independent System Operator: Avoiding the Separation Fallacy," *The Electricity Journal* 8, no. 10 (1995); Steven Stoft, "California's I.S.O.: Why Not Clear the Market?" ibid.9 (1996). Eric Woychik, "California's Schedule Coordinator: Market Maker with Advantage, November 26, 1997," in Conference Proceedings: "Opportunities in the New Electricity Marketplace: the Race For the Customer," CONF-980380, Banff (Canada), 22-24. William W. Hogan, "Rethinking W.E.P.E.X.: What's Wrong with Least Cost?" *Public Utilities Fortnightly* 136 (1998). Larry Ruff, "The California PX Auction: Whatever Happened to the ISO and Why Should Anybody Care," UC Power Conference, March 10, 1997; "Statement by Charles R. Imbrecht before the FERC, Technical Conference on the WEPEX Applications, August 1, 1996," FERC Docket ER96-1663.

[18] Stoft, *Power System Economics*, 204.

actions of the ISO would be, they would not resolve the optimization problem of least-cost dispatch because they were not allowed to "correct" the markets. This meant the new system would never find the ideal dispatch that the markets were meant to find.

The market designers suggested that the MOU provisions made no sense, would create an inefficient system that would disproportionately serve the interests of speculators, and potentially impact system reliability. While no one could anticipate quite how violently the MOU's design features would interact with the supply shortages during the summer of 2000, the message was clear: do not implement the MOU or the system will not operate efficiently. The proposal had no basis in economic theory and was in such blatant contradiction to the understanding of the market design experts that some referred to the political process as a "looking-glass world."[19]

This was not merely the position of academic market designers. We already saw that SCE's Vikram Budhraja opposed the separation rule during the MOU negotiations. But even designers who were only indirectly linked to the Harvard/MIT nexus came to the conclusion that the provisions of the MOU were a disaster. Consider the CEC's reaction to the MOU; the analysts at the agency write:

> In our view, the MOU signers have failed to demonstrate that this forced separation [between markets and ISO] makes any sense, that it solves some real problem, or that it makes the system operate better, more efficiently, or more fairly. […] Moreover, our analysis suggests that the separation could be used as a pretext for denying the ISO the necessary tools and means to solve the congestion problem efficiently, while allowing arbitragers to exploit the resulting inefficiencies.[20]

Published less than a month after the agreement, these comments are eerily prescient. They pinpoint the problems associated with the two decisions clearly and predict accurately what the

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[19] For example, Steven Stoft, the author of Power System Economics. Interview with Steven Stoft, 12/11/18.
[20] "California Energy Commission Comments on the Memorandum of Understanding October 2, 1995," Box 19, Folder 1, *CPUC*, p. 5.

consequences would be: manipulative games designed to profit from technical inefficiencies. In short, the MOU made eminent political sense, but not technical sense. The market design experts vehemently opposed the equality and separation provisions in a variety of venues and were ignored. They came and told the politicians: "Do not do that or the markets will collapse." And the politicians went ahead anyway, and the markets collapsed.

It is important to put this decision into perspective. The whole project of restructuring was premised on the ideas of electricity market design that had first developed at Harvard and MIT and were then elaborated in the larger world of academic research. Politicians began to consider restructuring after academic research had suggested it might be possible. The CPUC and the MOU signatories initially followed the vision of electricity market designers. The two original proposals followed the existing academic research relatively closely. Further, market designers were asked to testify as experts, and the participants of the Blue Book proceeding asked them extensive questions. The entire project was thus cast as a project of market design. Yet, when the political compromise was available, the MOU signatories ignored the unanimous warnings of the experts completely. This poses a clear empirical question: Why did the politicians ignore the market designers?

Behind this empirical question stands a deeper issue. How should we think about the relationship between projects of market design and the political processes just described? The MOU was an example of brazen and unmitigated interest politics.[21] It had all the bells and whistles of

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[21] The MOU kept the general public in the dark and barreled over the concerns of public interest groups. Ron Russell, "Dim Bulbs: Greedy Out-of-State Profiteers Make Easy Targets, but the Real Villains of California's Energy Debacle Are the Ones under the State Capitol Dome," *San Francisco Weekly*, March 7, 2001, p. 3. Ron Russell, "Dim Bulbs," *San Francisco Weekly*, March 7, 2001, https://archives.sfweekly.com/sanfrancisco/dim-bulbs/Content?oid=2141079&storyPage=3, last accessed 12/05/2019. Particularly strong und useless protestations to the MOU by public interest representatives can be found here: "Joint Motion for Consideration of Framework for Restructuring in the Public Interest and for Further Public Process; Joint Response to Memorandum of Understanding, Submitted by UCAN, Union of Concerned Scientists, TURN, Sierra Club, et al., October 2, 1995," Box 18, Folder F-454, *CPUC*, p. 2.

backroom dealings, large stakes, and the relentless pursuit of monetary interests. Given that there is a clear political rationale for the MOU, we might wonder: Is this not simply a case where "political" dealings ignored the "technical" truth of the designers? After all, there can be no doubt that the politicians *should have* listened to the market designers—the separation and equality provisions did create structural conditions that enabled the California crisis. Are we not simply back to the same old story that politicians made irresponsible decisions that caused the crisis?

I want to suggest that this simple story is deceptive. It rests on a strict distinction between "technical" and "political" that is as popular as it is problematic. Market designers frequently invoke the distinction to aver themselves of the California crisis. Consider this quote by the market designer Peter Cramton, who explains the electricity crisis as a consequence of political compromises:

> Just as one should be hesitant to fly on an airplane designed by a committee of stakeholders, one should be hesitant to trust electricity designs that are built from consensus among interested parties. Like airplanes, electricity designs should be largely the work of experts focused solely on the objectives of the market. The compromise inherent in the design should reflect the optimum balance among competing design objectives, rather than a distributional compromise among those with conflicting interests.[22]

Cramton suggests that the political process corrupted California's design process. Experts should have built these markets because design decisions should be made by weighing competing design objectives rather than stakeholders' interests. He argues, in other words, that the way stakeholders created the MOU as a compromise between special interests violated the preconditions for successful market design. As soon as the "technical" decisions of market design are polluted by

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[22] Cramton, "Electricity Market Design: The Good, the Bad, and the Ugly," 1.

"political" games, the enterprise will fail. The secondary literature contains many such admonitions of political decision-making in California.[23]

However, a moment's consideration shows that this neat distinction underlying the engineering analogy is a sleight of hand. Not only would an extreme implication of this position be that market design is inherently incompatible with democratic processes; it ignores that any large-scale technological project, including airplane design, involves more than just technical decisions. The construction of a new airplane is subject to fierce interest politics between producers, regulators, buyers, and governments. But lo and behold: most airplanes fly reliably anyway.[24] And just like engineering, market design is never just an intellectual or technical activity. It is always also a political project.

It is therefore not possible to simply disassociate market design from politics and attribute the failure to politics. We have to characterize the failure in California more precisely. Clearly, market design is compatible with interest politics in some ways—it always plays out in political contexts. But under what conditions is this so? In what way do the decisions in California violate the role that market designers have to play in politics for the project to succeed? Answering this question requires the development of a counterfactual that allows us to assess under what conditions the political process would have been compatible with the intellectual vision of the designers. What role exactly *should* market designers play in political contexts?

To develop the counterfactual, we have to first explore what market design as politics looks like and how it relates to the intellectual ambitions of market designers. This is the topic of the

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[23] E.g. Isser, *Electricity Restructuring in the United States: Markets and Policy from the 1978 Energy Act to the Present*, 233.

[24] Consider, for example, the engineering history of Boeing's commercial aircrafts. Philip K. Lawrence and David W. Thornton, *Deep Stall: The Turbulent Story of Boeing Commercial Airplanes* (New York: Routledge, 2017). Political and strategic considerations shaped engineering decisions on an extremely granular level.

first section. I argue that political discourses ponder questions that are open-ended and general. They mix normative, technical, and evaluative issues and allow for a variety of different specifications further down the road. Since market designers' advice is informed by models that envision the prospective market system as a whole, the advice implies a unitary decision maker who can realize the world of the model. But since the models are based on *idealizing* assumptions, they are flexible and can be revised as democratic processes change the baseline conditions. They can also be made compatible with a variety of different assumptions. This means that the advice of market designers is *flexible* to political compromise.

The *limits* of this flexibility lie at the point where political decisions make the *methodology* of market designers inapplicable to the design task. This is the case when decisions break the connection between the definition of an optimization problem and the market design, i.e., when political decisions prevent market designers from linking their market mechanisms to the problem they are supposed to solve. This was precisely the consequence of the MOU decisions—there was no way to solve the market design problem once markets were separated from grid management and the grid management was not allowed to optimize the market results anymore. The first section thus establishes what kind of role market designers should play in political discourses: if they are able to exercise control over decisions that concern the very applicability of their methodology, market design is compatible with political decision-making. The distinction between technical questions and political questions is thus the distinction between questions that can be hashed out within the methodological framework of market design and those that cannot. This leads to the next question: Why were the designers unable to exercise jurisdiction over these kinds of questions in California? And what does this tell us about the limits of political market design work?

In the third section, I show that market designers suffered from a lack of jurisdiction because they did not have exclusive control over core concepts of their expertise. Lawyers, politicians, and other economists all had competing professional and common-sense ideas about concepts like markets, efficiency, and competition. When market designers' claims contradicted these common-sense notions, they were not perceived to have special authority to define these concepts. Their advice stood unmediated next to the competing claims of other experts. Formal economics here became a victim of its own success. One of the reasons why economics is usually seen as the most influential social science is that its concepts have spread into every part of the administrative state. However, this influence precisely undermines the authority of economic experts—their expertise no longer stands uncontested.

The next question is, then, how *can* market designers establish jurisdiction under these conditions? How do market designers gain footing for an attack on the authority of other professions who try to control the same concepts? I approach this question from a comparative perspective and look at how the experts managed to do so during the PJM negotiations. In this situation, market designers managed to establish authority over the same issues the MOU debated. I first show that the context of decision-making was more homogenous than in California. The political debates took place among utility executives who shared a common baseline understanding of the engineering realities of electricity systems. In this context, the market designers could appeal to a common baseline for the evaluation of claims to demonstrate that they knew something the executives did not. To establish jurisdiction, the experts thus had to perform a paradoxical move: they needed to appeal to something the executives knew to demonstrate what they did not know. By demonstrating to the executives their own ignorance, the market designers simultaneously established their possession of the missing knowledge and thus gained jurisdiction over the crucial market design questions.

In the last section, I show why such a move was impossible in California. The CPUC commissioners and stakeholders used divergent standards to evaluate claims about markets. There was no common framework of reference for the evaluation of claims. Accordingly, there was no baseline of proof that the experts could have appealed to. Absent such a baseline, competing claims about the markets were standing next to each other without mediation, and the political process devolved into the pure *do ut des* of interest politics. Since interest politics only requires parties to have an idea of what will be beneficial to them, it is not necessary to reach any agreement on the joined project. Accordingly, contradictory views were not resolved, and market designers' attempt to assert their superior knowledge led nowhere. This, then, is the first sense in which the California crisis can be understood as a failure of expertise: the designers were unable to enforce even the minimal control over the political process that would have been necessary for the project of market design to succeed. This suggests that market designers will be more successful if the political process concerns issues in which the methodology of market designers can be readily applied. This is the case when the markets are already in place, and market design is merely an issue of reforming them. In that case, the flexibility of market designers' models assures basic compatibility with democratic decision-making.

8.2. The Role of Market Designers in Political Negotiations

The separation and equality provisions of the MOU were the product of political negotiations. Market designers opposed these provisions but were ignored. One reading of the California crisis therefore suggests that the crisis was the consequence of politicians' ignorance. Interest politics, so the argument goes, prevailed where technical decisions should have taken place. It is true that the MOU decisions were problematic, but to understand *why* they were problematic, it is not enough to invoke a simple distinction between “technical” market design and “political” negotiations. The success or failure of market designs cannot be disassociated from politics. It is simply misleading to suggest that the MOU decisions were “purely” political and that they had nothing to do with the “technical” concerns of market design. The MOU decisions need to be understood as an expression of problems faced by market design *as* a political project. To understand what went wrong in California, we therefore have to establish what role market designers *should* play in political processes. We have to ask: Given what market design looks like as a political process, what role do market designers have to play for the project to succeed? Once we know what market design as politics looks like, we can determine in what way the political process went awry and to what extent we can understand the equality and separation decisions as failures of market design.

In political processes, market designers appear as experts who give advice on their own behalf and on behalf of stakeholders. Sometimes politicians listen to them, sometimes politicians do not listen to them. The crucial question is: At what point do market designers have to be able to decide political questions on the basis of their expertise? And at what point do political compromises between competing interests suffice for market design to succeed? To answer the question, we thus have to draw a line between those parts of the intellectual project that are amenable to political compromise and those that are not. In other words, we have to introduce a distinction between political questions that are open to compromise and technical questions that require politicians to defer to market designers.

However, this is a dangerous course of argument. Sociologists are rightly wary of distinctions between technical and political matters. Consider, again, the quote by Cramton. On a strong reading, the quote implies that market design is incompatible with democracy. It is a technical enterprise through and through that can only be accomplished by experts: "Like airplanes, electricity designs should be largely the work of experts focused solely on the objectives of the market."[25] This is, of course, an old, technocratic conceit. Sociologists routinely understand such claims as power plays.

Any market design allows for alternative specifications, and each specification has different distributional consequences.[26] There is also an "instrumental gap" between a given market design and its implementation.[27] Both entail the need to make discretionary decisions that have consequences for a variety of stakeholders. This makes design decisions inherently political. By claiming that something is not a political but a technical question, market designers therefore simply make a *political* move to assert their power. This leads sociologists to reject firm distinctions between inherently technical and inherently political issues.

The usual course of action is to simply shift to a different question. Instead of searching for a valid distinction, sociologists ask how the boundary between political and technical is constituted as itself a product of political contestation.[28] The performativity literature has recently

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[25] Cramton, "Electricity Market Design: The Good, the Bad, and the Ugly," 1.

[26] The danger of the "rule by experts" is a very old topic in sociology and critical theory. It is perhaps the primal fear of the Frankfurt School and a long tradition of science policy studies. For one of the oldest versions of this story in the U.S., see Don K. Price, *The Scientific Estate*, vol. 253 (Cambridge, MA: Harvard University Press, 1965). Market design clearly poses the danger of subverting democratic processes—as a project in social engineering it *is* a technocratic enterprise and naturally aims to remove issues from democratic decision-making. For an insightful analysis in the context of matching markets for public schools: Zoë Hitzig, "The Normative Gap: Mechanism Design and Ideal Theories of Justice," *Economics & Philosophy* (2019).

[27] Anna Alexandrova, "Making Models Count," *Philosophy of Science* 75, no. 3 (2008).

[28] Politics transgresses into science and science transgresses into politics, each side influencing the other. Sabine Maasen and Peter Weingart, eds., *Democratization of Expertise? Exploring Novel Forms of Scientific Advice in Political Decision Making* (Dordrecht, NL: Springer, 2005), 6; Helga Nowotny, "Democratising Expertise and Socially Robust Knowledge," *Science and Public Policy* 30, no. 3 (2003).

begun to argue that we should understand market design as a political enterprise through and through.[29] Observing the highly political debates over design features, these authors argue that we should not think of the resulting infrastructures as more or less successful translations of blueprints into reality. Rather, the market infrastructures are the product of political negotiations that are mediated by the language of economics. Market design knowledge becomes part of the processes that create markets by shaping the political struggle over rules.[30] All design decisions have a political dimension and what "works" is a function of what configuration of rules, actors, material infrastructures, and discourses can be stabilized over time.[31]

However, this approach makes it difficult to think about market design in terms of conditions for success and failure because it pushes the analytical perspective one step back.[32] Assuming

[29] This research is inspired by the "markets as politics" literature (e.g., Fligstein, "Markets as Politics: A Political-Cultural Approach to Market Institutions"; Bourdieu, *The Social Structures of the Economy*.) It understands the structure of markets as a consequence of broadly political processes. Property rights, rules of exchange, unwritten norms, and cultural context are all potential objects of political contention between stakeholders. Fligstein, *The Architecture of Markets: An Economic Sociology of Twenty-First-Century Capitalist Societies*.

[30] The literature can be differentiated by how much weight the studies give to politics. One line of research sees real markets as "in vitro" experiments that are slowly moved from the laboratory into reality. Callon, "Civilizing Markets: Carbon Trading between in Vitro and in Vivo Experiments," 538. Politics is a "mode of representation" that shapes how steps in this translation are made, but at the core, the creation of the market is still a technical project. Mark B. Brown, *Science in Democracy - Expertise, Institutions, and Representation* (Cambridge, MA: MIT Press, 2009), 167-68; Bruno Latour, *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge, MA: Harvard university press, 1999). In contrast, another line of research emphasizes the primacy of politics. Economic theory appears as an epistemic framework used in political negotiations. This framing establishes the basic terms guiding the interpretation of relevant policy issues. The abstract theoretical entity "market" delivers criteria of equity and value that shape how parties argue about the markets that are being constructed. Breslau, "Designing a Market-Like Entity: Economics in the Politics of Market Formation," 831-32; Mirowski and Nik-Khah, "Markets Made Flesh: Performativity, and a Problem in Science Studies, Augmented with Consideration of the F.C.C. Auctions"; Santos and Rodrigues, "Economics as Social Engineering? Questioning the Performativity Thesis." Politicians ultimately make decisions about market rules and they follow a fundamentally political logic. See also the contributions to the special issue in *Consumption, Markets & Culture:* Franck Cochoy, Pascale Trompette, and Luis Araujo, "From Market Agencements to Market Agencing: An Introduction," *Consumption Markets & Culture* 19, no. 1 (2016). The articles in this volume seek to re-focus performativity studies on the political activities of those who shape markets.

[31] Koray Çalışkan and Michel Callon, "Economization, Part 2: A Research Programme for the Study of Markets," *Economy and Society* 39, no. 1 (2010); Fabian Muniesa, Yuval Millo, and Michel Callon, "An Introduction to Market Devices," *The Sociological Review* 55, no. s2 (2007).

[32] This constructivist reading of the struggle between science and politics spans work on expertise. Maasen and Weingart, *Democratization of Expertise? Exploring Novel Forms of Scientific Advice in Political Decision Making*; Peter Weingart, "Scientific Expertise and Political Accountability: Paradoxes of Science in Politics," *Science and*

that the process is politics all the way down, we are now trying to understand what kinds of tasks and problems market designers are trying to control by asserting their jurisdiction.[33] But we can no longer ask what kinds of decisions *need* to be controlled for the project of market design to *succeed* as specified by the designers. Success is simply defined by what market designers manage to control. To develop a counterfactual, we have to take seriously the idea that there may be questions about market design that are genuinely not open to political compromise but need to be controlled by experts.

Now, the question is how a sociologist, who is neither a market designer nor a politician, could possibly determine this boundary.[34] I will try to solve this problem by identifying a *minimal* distinction between technical and political questions in political processes. I will do so by identifying the nature of questions that political processes negotiate and the kind of advice that market designers give in these contexts. The advice relies on assumptions that must be realized by the political process for the advice to be valid and the market design project to succeed. Accordingly,

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Public Policy 26, no. 3 (1999); Brown, *Science in Democracy - Expertise, Institutions, and Representation*; Peter Haas, "When Does Power Listen to Truth? A Constructivist Approach to the Policy Process," *Journal of European Public Policy* 11, no. 4 (2004); Harry Collins and Robert Evans, *Rethinking Expertise* (University of Chicago Press, 2008). See also the sociology of professions Andrew Abbott, *The System of Professions: An Essay on the Division of Expert Labor* (Chicago: University of Chicago Press, 1988). and work in Science and Technology Studies Nowotny, "Democratising Expertise and Socially Robust Knowledge."; Sheila Jasanoff, "Science, Politics, and the Renegotiation of Expertise at Epa," *Osiris* 7, no. 1 (1992).

[33] The concept of "claims to jurisdiction" goes back to Andrew Abbott's work on professions. Professions claim responsibility for certain types of work. They diagnose problems and then develop chains of inference that point to particular treatments for these problems. To be able to do so, they level claims to jurisdiction against other professions who try to do the same thing. These claims play out in front of different audiences and involve the use of abstract systems of knowledge. The strategic moves that allow professions to succeed are patterned. These insights form the background of the present discussion. C.f. Abbott, *The System of Professions: An Essay on the Division of Expert Labor*, 35-52. Gil Eyal argues for separate analytical treatments of professions as groups of experts and expertise. To him, *expertise* is not a matter of simply knowing how to perform a particular kind of task according to technical criteria. Instead, it is a way of talking "[…] about the intersection, articulation and friction between science and technology on the one hand, and law and democratic politics on the other." Gil Eyal, *The Crisis of Expertise* (New York: John Wiley & Sons, 2019), 20. The analytical approach to expertise studies how this process stabilizes control over specific tasks.

[34] Gil Eyal makes this point in relation to Collins's and Evans's attempts to define what constitutes "genuine" expertise. C.f. *The Crisis of Expertise*, 9,19; Collins and Evans, *Rethinking Expertise*.

we can derive conditions for the success and failure of market design as politics by looking at the nature of the advice that designers give in political processes.

As we saw, political negotiations took place in a variety of formal and informal settings. Substantially, they dealt with exceedingly general and broad issues. The parties before the CPUC discussed how competitive markets could be created on the retail as well as the wholesale level, how environmental programs and transmission updates could be implemented in the new environment, how general access to the markets might be guaranteed for all users of electricity in California, and how to make sure that the markets would produce low rates while keeping up with growth in demand at declining costs.[35]

These questions concern two different levels of market design: market structure and architecture. Questions about market structure refer to properties of the market that are closely tied to ownership and technology. These features are not dependent on any particular system of institutional rules or exchange relations. The cost-structures of generators, concentration of ownership, or the legal rules for investment are examples of structural issues. A typical question would be: Should utilities divest their generation assets? Or who should own the transmission grid? In contrast, decisions about market architecture refer to questions about the nature of different submarkets and their linkages. Typical questions are: Should markets be organized as a pool or as bilateral markets? How should the obligations created in one market be treated in another market?[36]

Most of these architectural and structural questions are not exclusively functional, but have normative and evaluative dimensions.[37] They concern issues of fairness and equity just as much

[35] Blue Book, p. 12.
[36] Stoft, *Power System Economics*, 74-82.
[37] This was explicitly recognized in: Blumstein and Bushnell, "A Guide to the Blue Book: Issues in California's Electric Industry Restructuring and Reform."

as technical feasibility. For example, structural questions about the necessary reserve requirements for utilities could be interpreted in a variety of ways. Reserve requirements dictate how much generation capacity a utility needs to keep available, but disconnected from the grid, to serve demand in emergency situations. First, the question can be framed as a tradeoff between reliability and rates. The question, "How safe is safe enough" is a value judgment. Second, this could also be framed as a question of fairness. Is it fair to impose extra burdens on large producers? Third, the issue can be seen as a matter of technical feasibility: the level of available reserves influences how much market power can influence prices.

Apart from being amenable to a variety of different evaluative perspectives, these questions were also indeterminate. Any decision in the political process would require a long path of increasingly more detailed concretizations before actual market structures begin to operate. They were therefore compatible with a variety of different alternative design structures. Since the questions were open-ended, multivalent, and indeterminate, the proposals, comments, and counter-proposals filed before the CPUC mix a variety of different concerns and talk about the questions in broad, generalizing ways.[38] There are few proposals that contain hard numbers or evidence-based research.[39] Stakeholders argue for their positions by drawing variously on arguments about feasibility, fairness, the correct value judgments, and supposedly neutral "facts" about the industry, about how markets work, about what matters.[40]

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[38] They are simply competing ways to express "policy concerns;" ibid.
[39] The Union of Concerned Scientists complains about the lack of evidence presented and the reliance on "conventional wisdom" in "Comments of the Union of Concerned Scientists on the Commission's Proposal Governing Electric Services Industry Restructuring, filed June 8, 1994," Box 10, Folder F-5a, *CPUC*, p. 9.
[40] See, for example, the table of contents of SCE's initial comments that discuss concerns over fairness, efficiency, reliability, and evaluative issues in separate sections "Comments of Southern California Edison to Order Instituting Rule Making and Order Instituting Investigation dated April 20, 1994, filed June 8, 1994," Box 10, Folder 5a, *CPUC*, p. i-iii.

The market designers enter these processes as a distinct group of experts. Some stakeholders hired the designers to contribute to their working groups and testify on their behalf. Some market designers entered the proceedings on their own behalf. Regardless of their status as participants, they were only ever one voice among many, presenting one way to frame the issues among many. Rhetorically, the texts of the market designers often recognize this advisory role. They use formulations that put them at a distance from the political process. For example, Joskow and Schmalensee write in the voice of disinterested advisors who provide input to politicians weighing different options: “The deregulation scenarios we discuss provide a framework for evaluating competitive opportunities and for examining the implications of deregulation for economic efficiency.”[41] Alvin Roth lists one of the three functions of economic experiments poetically as “whispering in the ears of princes.”[42] The market designers here appear as neutral (or slightly shady) arbiters who do not make decisions, but informs them. However, this does not tell us anything about the role that they would need to play for market design to succeed.

To make some headway on this front, we need to consider the nature of their advice more concretely. Market designers derived their advice about structural and architectural questions from highly stylized, theoretical *models*. The two types of questions required slightly different types of advice. For structural questions, the basic toolkit of neoclassic economics sufficed. Here, the designers were supposed to give advice about the basic features of the industry that had to shift in order to accommodate competitive markets. The designers took existing empirical data about the industry and then estimated models that assumed a generic market structure. By changing the

[41] Joskow and Schmalensee, *Markets for Power: An Analysis of Electrical Utility Deregulation*, 93.
[42] Alvin E. Roth, "Laboratory Experimentation in Economics," *Economics & Philosophy* 2, no. 2 (1986): 246.

assumptions about the variables of interest, they could then derive a variety of concrete predictions about necessary structural features that fed into the decision-making process.

For example, the question of how many generation assets the utilities would have to divest depended on the level of market power different amounts of generators would give them. So, market designers were asked: How much do the utilities have to divest in order to guarantee a competitive environment?

To answer the question, the economists assumed a standard Cournot model of oligopolistic competition. In this generic market, players are perfectly rational and make output decisions for the production of goods with linear marginal costs. If the market consists of a single moment of transactions and all firms know the output decisions of their competitors as well as the aggregate demand, they will also know the *residual* demand that they can satisfy. With respect to this residual demand, they can act as a monopoly and produce exactly enough to maximize profit. If this occurs before the marginal cost of production equals the market price, the Cournot equilibrium is not efficient.[43] No real market looks like Cournot's model, yet the thought construct offers an axiomatic way to think about the interplay between oligopolistic producers.

In a next step, the designers used the model to develop divestiture recommendations. They took historical data about the cost structure of the existing generators and demand in California at different times and estimated the model for different levels of assumed divestiture. Using these estimates, they derived an index that told them at what level of market concentration the residual demand would reach a level that rendered rational output decisions consistent with marginal cost.[44]

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[43] Paul Bellaflamme and Martin Peitz, *Industrial Organization - Markets and Strategies*, 2nd Edition ed. (Cambridge, UK: Cambridge University Press, 2015).
[44] C.f. for example Severin Borenstein et al., "Market Power in California Electricity Markets," *Utilities Policy* 5, no. 3/4 (1995). Here, the authors discuss different modeling strategies for market power and how to select the best models for the conditions in California. For a description of the desired modeling technique for impacts of proposed

This specified the necessary level of asset divestiture. The market designers thus used a generic model of strategic interaction and historical data to arrive at a precise policy proposal.

Arguments about the correct market architecture looked slightly differently and required the use of a different methodological toolkit.[45] Again, architectural questions concern the organization of different markets and their linkages. To determine which configuration of markets would be best for California, the designers developed stylized models of market interactions that would fit the empirical constraints while producing desired aggregate results. William Hogan, for example, submitted a toy model that explained how a centralized market would use bids from buyers and suppliers to calculate the locational marginal costs at each node or 'bus' in the system and thus resolve the issue of transmission pricing.[46] His example uses a network with only two, then three, nodes and convenient numbers to make the logic of transmission pricing clearer.[47]

The example illustrates why the ISO needs to handle congestion management and integrate it with the activities of buyers and sellers in the auction markets. Here, a simplified model of two markets is used to derive an example that shows how the institutional structure would work and why alternatives would not. The toy model provides a "proof of concept." It shows why one class of solutions to a general problem is valid, while another is not. Even though this is an essentially different way to derive advice from models, both types of advice rely on stylized models.

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policies, c.f. "Comments of the Union of Concerned Scientists on the Commission's Proposal Governing Electric Services Industry Restructuring, June 8, 1994," Box 10, Folder 5a, *CPUC*, p. 9-10.

[45] Martin Bichler, *Market Design: A Linear Programming Approach to Auctions and Matching* (Cambridge, UK: Cambridge University Press, 2017), 3. In the past, market design and its more theoretical subfield, mechanism design, have relied on calculus and associated techniques of analysis. This is now sometimes referred to as the "pre-Newtonian" approach to mechanism design, though much work continues to use these tools. Rakesh V. Vohra, *Mechanism Design: A Linear Programming Approach*, vol. 47 (New York: Cambridge University Press, 2011), 4.

[46] Hogan's technical exposition can be found in "A Competitive Electricity Market Model," which is referenced in: "Hearing Before the California Public Utility Commission, Reporter's Transcript, San Francisco, June 15, 1994, Vol. 2, Pages 299–596," Box 69, *CPUC*, p. 17. A simpler example is discussed on p. 11.

[47] For another example, c.f. William W. Hogan, "Nodes and Zones in Electricity Markets: Seeking Simplified Congestion Pricing," in *Designing Competitive Electricity Markets*, ed. Hung-po Chao and Hillard G. Huntington (Norwell, MA: Kluwer Academic Publishers, 1998), 35-38.

Both types of advice rely on assumptions that are *not* met by the empirical context. Neither the toy models nor the Cournot models reflect how real electricity markets did or would work entirely. This was partly a function of the historical moment. Since the political debate occurred when the old industry was still in place, and since no other country entertained plans similar to California's, most questions could not be answered with empirical studies. Idealizing assumptions were thus a practical necessity. But the high degree of idealization also had to do with the nature of the political questions. They were pitched at a level of abstraction that was too general to devise experiments.[48] To use experiments, it had to be possible to reduce questions to either/or propositions that could be translated into sets of individual treatments. But each decision allowed for a variety of possible implementations, and many structural and architectural decisions were co-dependent, i.e., influenced each other's market processes.

In the political process, the market designers thus used models in a way not dissimilar to the way Max Weber's ideal forms.[49] The models were inspired by knowledge about the electricity industry in California as well as general mechanisms familiar to economic theory. But they did not immediately represent any particular empirical context.[50] Instead, they served as tools to formulate implications of decisions under given assumptions. For example, you could ask: Let us assume we have a market for passive transmission rights with the properties X, Y, and Z. What would happen to competitive prices if a player had market power in the generation market?[51]

[48] The difference is akin to that between the creation of a simple physical model that simulates the impact of gravity on a suspension bridge and an engineering model that simulates the effects of wind, soil, materials, etc. on static properties of a specific bridge design. Roth uses this example to illustrate the difference between theoretical mechanism design and practical market design Alvin E. Roth, "The Economist as Engineer: Game Theory, Experimentation, and Computation as Tools for Design Economics," *Econometrica* 70, no. 4 (2002): 1342.
[49] Weber, *Economy and Society - an Outline of Interpretative Sociology*, 18-22.
[50] Daniel M Hausman, *The Inexact and Separate Science of Economics* (New York: Cambridge University Press, 1992), 77-81.
[51] Shmuel S. Oren, "Economic Inefficiency of Passive Transmission Rights in Congested Electricity Systems with Competitive Generation," *The Energy Journal* (1997).

Now, what does this kind of advice imply for the success and failure of the market design process? How does the work of designers as political advisers fit into the overall project? When deriving political decisions from abstract models one makes an implicit assumption about the decision maker. Normally, economists use models as heuristic devices to organize empirical research.[52] As long as the model is used as a way to organize an interrogation of empirical material, the idealizing assumptions are not harmful. Since the data can push back against the model and reveal where it is wrong, it can improve empirical understanding.

This is the usual way economists justify the use of economic models: they are heuristic tools to explore complex and opaque relationships that exist in the data only in highly mediated form. But in the context of market design, we are no longer evaluating economic models in explanatory terms. The models are now used to make decisions about interventions in the world designed to realize the predictions of the models by design. Accordingly, the advice has to be evaluated on its pragmatic virtues: What has to be the case for a political decision to be compatible with the design project as expressed in the advice of the experts?

As soon as the model is used to inform decision making, its predictions depend on a basic correspondence between the world and model as a whole.[53] The advice amounts to statements of the form: "Decision X will have desired consequence Y if conditions 1…n obtain." The higher the idealization, the longer the list of conditions. The longer the list of conditions, the more consistency is required from the decision maker because they need to change the world in accordance with all

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[52] Today, most explanatory economic research occurs on the level of "application," where the model is estimated with empirical data. Here, assumptions can be relaxed and economists seek to explain where reality does not conform to the theoretical model (and why) and where it does.

[53] Geoffrey M. Hodgson, "On the Problem of Formlism in Economics," in *Economics in the Shadows of Darwin and Marx: Essays on Institutional and Evolutionary Themes*, ed. Geoffrey M Hodgson (Chelenham: Edward Elgar, 2006); Tony Lawson, "On the Nature and Roles of Formalism in Economics: Reply to Hodgson," in *Ontology and Economics: Tony Larson and His Critics* (New York: Routledge, 2008).

conditions. Accordingly, advice that is derived from highly idealized models seems to require a unitary decision maker who can make all decisions in line with the model. But there are two sources of flexibility that derive precisely from the high level of idealization.

First, models can easily be adjusted to a variety of different assumptions. Since they are not dependent on empirical facts but arbitrarily chosen assumptions, the models can be altered to systematically "reason through" a variety of different conditions. This explains why market designers have long been aware of, and comfortable with, the idea that market design has a political dimension. It is common practice to consider whether designs are "robust" to a variety of changes or alternative conditions that will be introduced in political processes. The designs must work under different "parameters" and be robust to modifications to the institutions themselves.[54] There are also attempts to accommodate uncertainties a designer might face into the models. For example, market designers can adjust their models to limited information about the environment by optimizing the mechanism across a spectrum of possible environments.[55]

More applied market designers have also established practical guidelines that take politics into account. They attempt to develop designs that are "detail free," namely, the mechanism should not depend on too many stringent assumptions. Designers also strive for mechanisms that are as simple as possible. This makes sure that permutations of possible behavior are well understood and that users can quickly learn how to "use" the market.

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[54] For example, the prominent auction theorist argues that the need for political compromises has to be anticipated by the designers. Auctions need to be designed to be robust to rule changes that occur as consequences of political discourse. The example he uses are politician's requirement to create certain minimum bids to make sure that the results will not fall below a particular price and avoid political embarrassment. Paul Klemperer, "Using and Abusing Economic Theory," *Journal of the European Economic Association* 1, no. 2-3 (2003): 286-87.

[55] This is a very recent concern in market design studies. Of course, they always speak of uncertainty in terms of random variables. The space of possible outcomes of the future is known; we are simply uncertain about which state will obtain. For a review, see Carroll, "Robustness in Mechanism Design and Contracting."

Another way to make the mechanisms flexible is to develop several different solutions for alternative specifications of the problem and then let politicians choose.[56] These are all examples of ways market designers can relax the implicit need for a unitary decision maker on the level of conceptual work. It derives from the fact that the high level of idealization that is implicit in the model makes its assumptions *malleable*.

A second way market design becomes flexible and open to political compromises is by updating the models to developments during the political process. On a very general level, market designers conceive of markets as dynamic systems that are characterized by logics of action (decisions or strategic interactions). The conceptual work takes place in the world of control theory, linear (and dynamic) programming, and game theory. As a recent textbook put it: “Market design typically starts out as a mathematical programming task concerned with the design of an appropriate objective function, of appropriate constraints for the overall allocation, and of activity rules and with the definition of a bid language that lets bidders express their preferences in a succinct way”[57]

An objective function is a description of an optimization problem where a numerical value is supposed to be maximized or minimized. It captures the structural relationship between several variables that contribute to the numerical value of interest, as well as constraints on the values these variables can take. The activity rules describe what market participants can do. They render the expressions of preferences compatible with the way the objective function is defined and thus enable the computer to calculate the optimal solution. As outlined before, this turns the market into

[56] This is one of the prime advantages of experimentalist approaches because they can directly assess how rule modifications affect allocative outcomes in the laboratory. The design can then present a “menu” of configurations to politicians, e.g., Grether, Isaac, and Plott, "The Allocation of Landing Rights by Unanimity among Competitors."
[57] Bichler, *Market Design: A Linear Programming Approach to Auctions and Matching*, 3.

an algorithm, which processes inputs to find optimal outputs according to the logic of a linear program (i.e., through a systematic trial and error search for optimality conditions).

However, it is usually possible to change the definition of the objective function or to find a different set of institutions that can solve the problem. Both behavioral rules and problems can be adjusted almost arbitrarily. Flexibility is not just an advantage of mathematical modeling, but also of experimental economics, where the laboratory setting can be used to tweak rules and optimize the relation between activity and optimization problem to fit a variety of specifications. The designers can therefore usually react to developments in the political process by simply changing the theoretical structure from which they derive their solution. The reliance on abstract and idealizing models both creates the assumption of decisions that are sequentially consistent with the model, but it also allows great flexibility to react to external changes.

The question is therefore where exactly the methodological flexibility ends. This is the point where market design moves at odds with interest politics and requires market designers to define the spectrum of possible decisions.[58] It is possible to give a formal definition of this point. At the very least, market designers have to retain control over questions of *where a political decision would render the tools of market design inapplicable to a problem whose definition is fixed*.

In other words, decisions count as technical if a political compromise would render the expert knowledge inapplicable from the perspective of the relevant experts.[59] Specifically, this

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[58] Here, I am broadly following the distinction between expertise and experts that Gil Eyal suggests in "For a Sociology of Expertise: The Social Origins of the Autism Epidemic," *American Journal of Sociology* 118, no. 4 (2013): 877. Market design is a form of expertise, and we need to establish “what does it take to accomplish a task” before we can evaluate whether the political process undermines the expertise of market designers in a meaningful way.

[59] Consider as a simple example the foundering of Sweden’s warship Vasa in 1628. Built as a symbol to the power of Sweden’s king and intended as flagship to his armada, it foundered after only 1400 yards into its maiden voyage. The ship was so poorly constructed that it did not even make it out of the harbor. Citizens looked on from the docks, as a moderate wind caught the sails. The ship first swayed violently and then sank quickly. An ad hoc inquiry revealed that the vice admiral Klas Fleming had ignored the warnings of the ship builders who suggested that the

means that the experts become unable to address the given definition of a problem with the set of tools that are available. Though this is an *almost* tautological criterion, it provides a guideline for the evaluation of electricity market design processes.

First, we have to look for problems whose definition is not flexible. The technological infrastructure of electricity production and transmission often provides such constraints on the formulation of design problems. For example, assume the design question is: Should the ISO oversee a centralized pool or should there be bilateral markets? By virtue of how electricity systems work, the answer to this question has to take the technical requirements of grid management under consideration. Whatever market mechanism the designers might propose must link activity rules of a market mechanism (for a pool or a bilateral market) to an optimization problem that contains the technical requirements of grid management as constraints.

Now, if a political compromise were to break the link between activity rules and optimization problem, the methodology of market designers would simply no longer apply. The designer could no longer make any statements about the relation between interactions in the market and the desired outcomes because they would not be able to control all activities that would contribute to

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upper structure of the hull was too heavy. He had demanded that it be completed anyway—and so it was. His decision was influenced by a political rationale: Gustav II Adolf, urgently needed the ship for a war. The result was a public relations scandal that has stayed with us until today. The decision whether or not to increase the weight on the upper structure of the hull was *technical*, not political because there was no way that the experts could accomplish the task to build a warship with the methods at their disposal after the decision had been taken away from them. The professional knowledge about how the task could be accomplished did not admit for political interference because all known methods required a particular weight distribution. The admiral thus overruled the experts on a technical question, and that was the reason the ship sank. If the decision had been about anything that the ship designers could have accommodated from within their methodological approach, it would have been a political decision. What is crucial is this: in another context, the decision to change the weight distribution by adding more cannons to the upper decks could have been political. If modern ship builders had been constructing a ship without sails, they would have had methodological tools available to work around the problematic weight distribution. In that context, the number of cannons on deck would have been a political decision. It was only in terms of the practices of ship building in Sweden of the 1620s that the issue was nonnegotiable and therefore technical. The case is a simple and intuitive example because there was not much disagreement about the problem itself. If there is disagreement about the task, the applicability of the knowledge itself becomes contestable.

the solution. Neither source of flexibility would help the designer: building internal flexibility into the models only works when it is possible to specify how activities relate to the optimization problem. Changing the optimization problem afterwards is not possible, because it is fixed by material features of the electricity system.

The MOU decisions had precisely this character.[60] They served as an answer to the question of what the relation between the ISO and the markets should be. But the separation and equality provisions put the designers into a position where they became unable to formulate rules for the markets that could have solved the optimization problem at the heart of the markets. Together, the separation and equality provisions of the MOU split the definition of admissible market behavior from the coordination of generation facilities. The markets would create schedules for the dispatch of generators and the ISO would implement them.

However, the optimization problem of finding the least-cost dispatch ultimately *has* to be solved by the ISO in real time. The true power flows and operating conditions of generators are only available close to real time. Accordingly, any market design must relate the activities in the markets to the solution of the optimization problem at the ISO. The two MOU provisions prohibited the ISO from optimizing the market schedules. There was thus no guarantee that the activities in the different markets would describe a global solution to the objective function, which was tied to the activities of the ISO. The behavior in the PX and the bilateral markets would follow separate sets of rules. The equilibria of these forward markets and their interrelations could be described

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[60] An alternative explanation is that market designers' claims constituted an attempt to control jurisdiction over an issue that was inherently political, perhaps on behalf of some stakeholder. This argument has been made particularly for experts who testified on behalf of Enron. For example: "Trading Truth: A Report on Harvard's Enron Entanglements," *Harvard Watch Report*, January 31, 2002, https://www.dunwalke.com/resources/documents/ArticleScans/Sized/Harvard_Watch-Trading_Truths.pdf, last accessed 12/01/2019. This argument was advanced repeatedly. I will disregard it here since the MOU clearly worked in favor of the power marketers and the market designers (including Hogan) *objected* to the MOU provisions.

with the standard tools of economics, and market design could find ways to optimize them internally. However, the markets would be divorced from the problem of real time dispatch. The objective function of the optimization problem, which was necessarily tied to the work at the ISO, was thus divorced from the definition of the markets *and* the ISO was prevented from solving the objective function. This "broke" the fundamental connection between the description of the design problem as an objective function and the activity rules. This explains why the MOU never had a referent in economic theory —there was no way to model the mechanism of the MOU with the tools of market design. The design decisions of the MOU were effectively beyond the reach of the designers' methodological tools.

A member of the office of economic policy at FERC with close ties to Harvard's working groups remembers a conversation he had with one of FERC's commissioners after he saw the California proposal: "I told him, I couldn't tell him exactly how it was going to fail, but there were so many points of failure in the market design that it just almost had to fail. I mean, the probability was 99 percent that it would fail, but I couldn't tell them exactly how it would fail."[61] He was not sure because the proposal exceeded the parameters of market design—it did not conform to the basic logic of inference that allows market designers to go from the definition of a problem to a solution. In political contexts, market design experts need to be able to reclaim jurisdiction over questions that concern the very application of their methodology. The MOU presents a case where the experts were unable to do so, and the political process of market design undermined the intellectual project.

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[61] Interview with George N., 02/09/2018. The commissioner confirmed this story in a separate interview. Interview with Bill M., 02/15/2018.

In sum, we have now identified the conditions for the success and failure of market design as politics. As expert advisers, market designers must be able to take control over questions that concern the applicability of their methodology. Otherwise, they can adjust their frameworks to the unfolding compromises. Since most decisions in political contexts are too general to determine the institutional rules that actually govern the markets, the conditions for the success of market design are minimal: as long as the political process does not violate the ability to address the problems in terms of the market design methodology, the process can move along. Note, however, that political decisions may create high burdens for technical design work—the further the political decisions move the structure and architecture away from simple designs, the more demanding the design work will become in the next step.

A question for future research is whether and under what conditions political decisions will *overwhelm* the technical work if they are consistent with market designers' advice but not directly informed by it. For now, we just note that the MOU provisions violated the basic applicability of the market design methodology. They thus constitute a failure of market design as politics. The next question is why this happened. Why were the market designers unable to control jurisdiction over the questions that rendered their very expertise applicable to the issues at hand?

8.3. Economics as a Style of Reasoning

Popular writing just as much as sociological research identifies economics as the most influential social science.[62] This influence extends along several different lines. As a university

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[62] Daniel Hirschman and Elizabeth Popp-Berman, "Do Economists Make Policies? On the Political Effects of Economics," *Socio-Economic Review* (2014); Michael J. Reay, "Academic Knowledge and Expert Authority in American Economics," *Sociological Perspectives* 50, no. 1 (2007); "The Flexible Unity of Economics"; Marion Fourcade-Gourinchas, "Politics, Institutional Structures, and the Rise of Economics: A Comparative Study," *Theory and Society* 30, no. 3 (2001).

discipline, economics has significant prestige. It counts as the queen of the social sciences and even manages to sustain a (tenuous) hold on the label “hard science.”

The influence that economists can exercise through institutional positions outside the university reinforces and enables this elevated position. In the U.S., the profession of economics developed alongside the administrative state. Not only do economics departments teach skills that are entry requirements for a variety of positions in government, the administrative system of the U.S. continues to rely on the conceptual vocabulary of economics to make decisions.

The economy as an analytical entity that can be studied and manipulated with the tools of economists emerged in a development that linked the profession of economics with the evolution of the American state.[63] In addition, the Law and Economics movement has linked the development of law intricately to the reasoning of economists. This constitutes a third line of influence: as a cognitive infrastructure, economics shapes the way political, regulatory, and legal decision-making proceeds. It serves as an epistemic framework or a “style of reasoning” that shapes how problems are defined. It produces criteria for answering them and determines what kinds of arguments are acceptable.[64] Even if politicians or lawyers follow a pure calculus of power, economics shapes how interests can be expressed, what counts as a legitimate position, and what kinds of arguments are available. The language and conceptualizations of market designers thus mediate political negotiations.[65]

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[63] Daniel Breslau, "Economics Invents the Economy: Mathematics, Statistics, and Models in the Work of Irving Fisher and Wesley Mitchell," ibid.32 (2003); Fourcade, *Economists and Societies: Discipline and Profession in the United States, Britain, and France, 1890s to 1990s*.

[64] The three types of influence are distinguished in: Hirschman and Popp-Berman, "Do Economists Make Policies? On the Political Effects of Economics," 2.

[65] This is something the performativity literature has increasingly stressed in recent years. Breslau, "Designing a Market-Like Entity: Economics in the Politics of Market Formation."; MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets*; Santos and Rodrigues, "Economics as Social Engineering? Questioning the Performativity Thesis."

In the context of the MOU negotiation, these three lines of influence were present. The creation of electricity markets was a project that clearly appealed to the logic of economics. Market designers at the country's most prestigious universities had developed blueprints that spelled out how the task could be accomplished. The designers could invoke the professional prestige of the Harvard/MIT nexus. They could also speak with authority because the language of economics provided the cognitive infrastructure for the debates. But despite all this influence, the market designers were ignored. Based on the outsized influence of economics found in the existing literature, we would expect that the politicians should have listened to the market designers here. If not here, where else?

The expectation of economists' influence is based on the general suggestion that the different lines of influence complement each other. But this does not have to be the case. The use of economics as a "style of thought" can run counter to economists' ability to reclaim expert status in regulatory and political proceedings. This has to do with the social logic that underlies a claim to expertise. As Niklas Luhmann once pointed out, "an expert is a specialist to whom one can put questions that he is unable to answer."[66] This quip points to two core characteristics of expertise. First, expertise is knowledge that is in the exclusive possession of the expert. Second, since the audience does not have possession of this knowledge, it has to *trust* that the expert knows what they are talking about. To be accepted as an expert, the audience must *recognize* that the expert has knowledge the audiences do *not* have—that is the basis of Luhmann's joke. If the audience trusts that the experts know something they do not, then they also do not know what questions the

[66] Quoted in: G. Bechmann, "The Rise and Crisis of Scientific Expertise," in *Expertise and Its Interfaces : The Tense Relationship of Science and Politics*, ed. G. Bechmann (Berlin: Ed. Sigma, 2003), 23; Eyal, *The Crisis of Expertise*, 25.

expert will be able to answer and which ones they will not be able to answer. An expert therefore has the power to talk about things they do not know anything about.

What matters here is the role of ignorance: for a question to be recognized as narrowly technical, the audience must be unable to mobilize strong intuitions about the right answer. The domain of knowledge that addresses the question must be seen as separate and isolated from common sense.[67] If the experts control a domain of abstract knowledge that is thoroughly separate from the language available to audiences, it is also easier to hide the ambiguities, uncertainties, and divisions that exist within scientific work. Hardly anyone doubts quantum physics. Partly, this is because quantum physics rarely shows up in political processes and therefore rarely feeds into decisions. But the other reason is that people do not generally have strong intuitions about answers in that domain of knowledge.[68] It is readily visible as a domain of knowledge that is separate from common sense. Conversely, if there are strong intuitions about the answer to a question, it is harder to establish expertise as a separate domain of knowledge.

This is the key to the problem the market designers were facing in California. Due to the success of economics in providing a general, cognitive infrastructure for politics and law, the domain of market design knowledge was not easily recognizable as a separate form of knowledge. There were two ways economics as a “style of thought” blurred the expertise of market designers.

First, the presence of a common sense mythology of free markets overrules economic knowledge as a distinct form of expertise. The Econ 101 vision of frictionless markets, perfect

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[67] This is consistent with the observation that economists are most successful in influencing policy questions when these questions are narrowly technical and economists agree on the correct answer. Weingart, "Scientific Expertise and Political Accountability: Paradoxes of Science in Politics"; Haas, "When Does Power Listen to Truth? A Constructivist Approach to the Policy Process"; Hirschman and Popp-Berman, "Do Economists Make Policies? On the Political Effects of Economics."
[68] Eyal, *The Crisis of Expertise*, 46.

rationality, information and efficiency, has diffused from the introductory economics classes into popular culture and from there into the bedrock of common sense.[69] Practically anyone in America can talk about the benefits or ails of the mythic entity that is “the” market.

The prevalence of free-market rhetoric was particularly strong during the 1990s, which has also been coined the “age of market triumphalism.” It was the time that the Soviet Union collapsed, Fukuyama proclaimed the “End of History,” and Clinton professed his belief in the infinite growth of the American Economy. Governor Wilson and CPUC president Fessler both adhered to this ideological vision of the market. “I have concluded,” Wilson stated simply in 1993, “that the market can be trusted to engage in the planning, development, and deployment of electric-generation capacity in California.”[70] He never spent much time elaborating how.

Fessler became the president of the CPUC even though he had proudly proclaimed in public that he did not know much about the electricity industry. Besides being close friends with Wilson’s wife, his main credential was that he was very taken with the basic idea that “the” market meant higher welfare, more efficiency, and a brighter world.[71] During the Blue Book negotiations, he stated his fundamental belief that “the competitive model to me means that electricity is a commodity to be traded in an open, transparent market. And competition ultimately means that customers will have the benefit of choice.”[72] The power of such statements lies in their generality: they come without qualifications and amount to the conviction that a market is always preferable

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[69] James A. Aune, *Selling the Free Market: The Rhetoric of Economic Correctness* (New York: Guilford Press, 2002).
[70] Cited in: Bill Bradley, “Master of Disaster: How Pete Wilson’s Energy Chief Short-Circuited the California Grid,” *LAW*, February 14, 2001, https://www.laweekly.com/master-of-disaster/, last accessed 12/05/2019. 2001-02-22/news/master-of-disaster/ (last visited June 11, 2012).
[71] Duane cites unpublished research on the rhetorical devices used during the CPUC stakeholder meetings. Duane, "Regulation's Rationale: Learning from the California Energy Crisis," 490-1.
[72] “Hearing Before the California Public Utility Commission, Reporter’s Transcript, Los Angeles, June 14, 1994, Vol. 1, Pages 1–298,” Box 69, *CPUC*, p. 7.

to regulation regardless what companies might do in them. The Blue Book proceedings are littered with confident invocations of this generic market ideology.

Particularly stakeholders without any formal training in economics venture blanket statements about the way that the new markets were going to work. A panel discussion in 1994 provides a striking example. The speakers were asked to address the virtues and pitfalls of direct access. The basic idea behind this proposal was to organize forward markets primarily as bilateral contract markets. These contract markets would simultaneously liberate the wholesale and retail side of the industry.

At some point, the vice president of a cement company joins the discussion. He justifies the support for the proposal like this: "We believe that facing competition will provide the greatest incentive for the utilities to get their costs down […] generation costs will be driven down in the same way the competition provides us a very strong incentive to continuously reduce our costs, our operating costs."[73] His argument is based on the supposition that competition in the electricity industry would work like in the cement industry. Arguing against the need for central coordination, he later compares the proposal to other markets:

> Under the competitive market structures proposed by many parties […], we believe that we can obtain the level of reliability that we need in the market. We now buy either natural gas or coal or petroleum coke for kiln fuel in whatever combinations we desire at any location in the United States. Price, quality, supply, and service guide us to the winning vendor. We have had not had any difficulties getting fuel in this free market.[74]

Not only does the speaker have no background in economics or electrical engineering, he speaks about the relationship between markets and system reliability in reference to market settings that share none of electricity's special characteristics. To make his argument plausible, he invokes

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[73] "Hearing before the California Public Utility Commission, Reporter's Transcript, San Francisco, September 16, 1994, Vol. 11, Pages 1792-2082," Box 70, *CPUC*, p. 1856.
[74] Ibid, 1857.

concepts of economics—competition, efficiency, free market. But their meaning remains implicit, vague, and disconnected from either the discipline of economics or the specifics of the electricity industry.

For an even clearer ideological statement, consider the comments by Mr. Wilkinson, the chairman of the department store Robinson's-May. His statements invoke nothing but the common sense of the speaker and is not backed by any economic theory. Yet, he has a clear opinion about the desired organization for the markets. Confidently he pronounces:

> […] there is no reason to complicate a competitive market with mandated market structures when the open market can serve to regulate itself. For instance, the pool proposals […] do not serve to increase the competitive nature of the market. […] By acting as a clearing-house, a pool would act as the sole purchaser for suppliers, sole provider for the end user. The pool would act as a stabilizer. But instead of stabilizing it at the lowest possible cost consideration, [it would] stabilize it at an average cost, which will benefit some at the expense of others.[75]

No economist—certainly no market designer—would make such statements about the relation between prices and cost. They would first specify the auction design of the pool to establish where the market clearing prices would be located. Similarly, the claim that the market regulates itself contradicts the most basic statements of economists on the matter. Precisely because electricity is not an ordinary commodity, there are a variety of potential market failures that need to be compensated through regulatory measures. Even the experts who developed the direct access proposals, and for whom Mr. Wilkinson advocated, would not have agreed with his blanket statements. Nonetheless, his arguments were clothed in the same language that the experts used. The only difference was that his statements were not disciplined by the practices of the underlying science. They drew from the reservoir of common sense instead.

[75] Ibid, 1871.

There was a second even more consequential way in which the expertise of market designers became blurred. Different types of formal economics undergirded a set of competing forms of expertise. As an academic discipline, economics is internally differentiated into a variety of subfields with different approaches and assumptions. To the outside world, these internal differences are often obscured by the shared methodological toolkit.[76] But different fields tend to use central, shared concepts in different ways. The “market,” for example, can interchangeably refer to abstract mechanisms that sets prices, evolutionary processes the weed out the unfit, perfect machines that produce welfare, as laboratories of progress, or as disseminators of information.

Similar instabilities concern central ideas like competition and efficiency. Is competition a way to reduce market prices? Or is it a tool of innovation? Does it lead to marginal cost pricing or concentration of industry? Both? On one reading, competition means to observe what other companies are doing and carefully position oneself in relation to these activities. On another reading, competition is an abstract condition. Companies look inward to reduce their prices, only aware where the price level in the market is. The effects of competition are similarly contested: while some see competition as ruinous because it requires companies to engage in strategies that undermine their long-term profitability, others see it as the core of the march to long term equilibrium.

Economics is not just internally differentiated. Adjacent disciplines in policy, business, and law schools have developed their own unique techniques of economic analysis.[77] For example, the Law and Economics tradition provides a distinctly legal way to think about institutional arrangements in economic terms. The same is true for cost/benefit analysis in policy schools. The different

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[76] Reay, "The Flexible Unity of Economics."
[77] Fourcade and Khurana, "From Social Control to Financial Economics: The Linked Ecologies of Economics and Business in Twentieth Century America."; Joni Hersch and Kip W. Viscusi, "Law and Economics as a Pillar of Legal Education," *Review of Law and Economics* 8, no. 2 (2012).

organizational environments integrate economic techniques into their own forms of inquiry and develop independent takes on central concepts, techniques of analyses, etc. To the extent that they look at electricity markets, they can credibly claim to be experts. This explains why a variety of economists and lawyers with different backgrounds entered the Blue Book proceedings, even though they were no market designers.

William H. Booth, for example, was a regulatory lawyer working for CLECA and other customer groups. In his testimony, he presents results from an empirical study that is firmly rooted in the utility economics of the past era. He goes into great detail to show that the current rates do not represent the true costs of utilities. Based on models that are based on an old style of institutional analysis designed to evaluate rate claims by utilities, he then derives arguments about efficiency gains in competitive markets. The arguments simply assume that markets generate the pressures to price generation capacity at the operating plus investment cost, as rate makers would. But, as we have seen in chapter six, different auction formats push the market clearing prices to different levels. The advice is rooted in an economic model and pertinent to the discussion, but it is entirely derived from an old style of institutional analysis, which has nothing to do with the framework of market design.[78] Similar examples can be found everywhere in the hearings. For example, after market designer William Hogan presented his design proposal, he was followed by a consultant with an MBA degree, an Industrial Organizational professor, and finally, a law professor.[79] They all derived advice from different types of economic analyses, rooted in different types of expertise.

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[78] "Hearing Before the California Public Utility Commission, Reporter's Transcript, Los Angeles, June 14, 1994, California, Vol.1, Pages 1–298" Box 69, *CPUC*, p. 93-96.
[79] "Hearing Before the California Public Utility Commission, Reporter's Transcript, Los Angeles, June 15, 1994, California, Vol.2, Pages 299 –96" Box 69, *CPUC*, pp.322-372.

Both the existence of common-sense interpretations for economic concepts and the competing types of economic expertise diminished the influence of market designers. Their expertise simply did not become visible as an independent domain of knowledge. Whatever they said was conceptually related to the general discourse. Since core concepts of market design, such as "market," "competition," "mechanism," "efficiency," etc. were up for grabs, practically anyone could proclaim an understanding of the design issues.[80] Once there are too many disparate forms of "economic expertise," any individual expert group will have difficulties asserting their perspective as a separate and self-contained domain of exclusive knowledge.[81] This problem was not just true for the CPUC proceedings, but also for the MOU negotiations.

When I asked Barbara Barkovich what drove the arguments of the participants, she suggested that personal experiences and a particular culture in the western U.S. had been decisive. Describing the negotiations, she said:

> I think that one of the arguments that we made was that in the Western United States, the history of wholesale transactions had always been bilateral. Going back, you know, to exchanges with the Pacific Northwest, um, the Western States Power Pool, which wasn't really a centralized pool, but that the institutions that had grown up in the western United States around contracting for power at the wholesale level had been bilateral. There were no centralized mechanisms. There was a perception that the bilateral transactions were effective.

When I explicitly asked about the role of economics, she said that experience had been more important:

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[80] The situation is similar to the early 1980s, when risk analysis became a dominant topic of public policy discourses. At a time, when excessive concern with unpredictable risks dominated the public discourse in Germany, Ulrich Beck wrote: "There is no expert on risk" Ulrich Beck, *Risk Society: Towards a New Modernity*, vol. 17 (London: Sage, 1992), 29. What he meant was that there was no expert on risk because there were too many. Too many competing experts created the impression that no one knew what they were talking about.

[81] Since they occurred in private, there is no archival record, and we have to rely on retrospective interviews to reconstruct these debates. The negotiators were Bill Booth and Barbara Barkovich for CLECA, Keith McCrea, and Glenn Sheerin from CMA, Jan Smutny-Jones and Doug Kerner for IEP, Vikram Bduhraja, Alex Miller and Ann Cohn for SCE.

> G.R.: When CLECA was developing its opinions, was economic expertise in any way relevant to that? What was the input of economics on the side of those who didn't want the British style PoolCo model?
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> B.B. : I think our focus was on creating a context for retail choice, and allowing there to be multiple suppliers, with the assumption, based on history, that there would be a lot of bilateral transactions, and that what was important, was for everybody to get access to the grid for those transactions.[82]

Asked the same question, Smutny-Jones said: "So, I think what it really was an interest in trying to fuse these two [proposals] together. And I think if you talk to Dr. Hogan or anyone else, they would probably indicate that they had some concerns about the overall viability of this."[83] In other words, the parties to the MOU were aware that the experts disagreed with their compromise.

Yet, this was of no particular concern to them because they did not perceive that the experts possessed authoritative knowledge on the matter. Based on their life in the business, they thought they understood perfectly well how the markets should and could work. Their experiences and general understanding of the issues seemed sufficient to make the design decisions.

The story of the MOU thus suggests that economics may have gotten too influential for its own good. Its diffusion as a cognitive infrastructure has blurred the boundaries of expertise and collapsed the crucial distinction between common sense and expert knowledge. This damages market designers' ability to define problems and lay claim to an exclusive domain of knowledge for the formulation of answers. In other words: economics' influence as a style of thought works against the influence of economists as experts with privileged knowledge.

This, then, provides a first answer to the question: the market designers failed to assert control over the crucial MOU decisions because their expertise was not visible as an authoritative domain of specialized knowledge. The common sense understanding of markets, informed by

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[82] Interview with Barbara Barkovich, 08/21/2018.
[83] Interview with Jan Smutny-Jones 10/24/2017.

business experience and some strands of generalized economic expertise, suggested that the MOU was feasible. And so, the stakeholders moved ahead. But competing claims to jurisdiction over economic questions are a *general* problem. What enables market designers to assert their jurisdiction despite the presence of amorphous economic "styles of thought?" To explore under what conditions market designers can establish jurisdiction, I look to a comparative case, halfway across the country.

8.4. Claiming Jurisdiction: Market Design at PJM

In 1997, seven of eight members of PJM's regional power pool submitted a restructuring proposal to FERC. Prior to the creation of electricity markets, the pool had operated for decades. Founded in 1927, it had slowly emerged from a loose coalition of utility companies in the Pennsylvania, Jersey, and Maryland region (hence the name PJM). In 1956, the members agreed to coordinate a variety of reliability functions with each other—how much capacity was installed, how many operating reserves would be held at each moment, etc. By 1973, the members then introduced the central, economic dispatch of the generation assets in the pool. After decades of slowly increasing cooperation, PJM was turned into an independent administrative entity in 1993. Responding to the same federal developments as California, the utilities decided to go even further and introduce wholesale markets for the trade of electricity. The coordinating offices of the PJM Interconnect would turn into independent system operators, taking full control over the transmission system and real-time dispatch. Just as in California, the utilities spent years with the search for a consensus around a restructuring proposal.

Of the eight members, Philadelphia Electric Company (PECO) had the most contrarian point of view.[84] It proposed an alternative design that was similar to the structure adopted in California. Accordingly, the parties debated some of the same issues as the stakeholders in California. Very early on, PECO proposed the same two provisions that the MOU suggested in California. They argued that some of the disagreements between the utilities might be resolved if they agreed on a rigid separation between markets and grid management, leaving room for a variety of market institutions that would be treated equally.[85] A PECO executive explained why market activities should take place separately from the ISO:

> […] it just seems that the whole system was having an administrator set prices, having prices known after the fact, having these very large scale collections of money from the price differential and then having to create an entirely new set of managed instruments, now FTRs, to dispense with that money. It all seemed like an awful lot of contrivance for things that could arguably be done relatively easily in a bilateral market.[86]

If the other utilities wanted a pool, they thought, it could be introduced separately. Of course, to enable the coexistence of separate markets, they would then have to be treated equally. In other words: PECO had the same idea that the MOU signatories had.

However, while the MOU powerfully redirected the course of the proceedings in California, the outcome was different at PJM. Shortly after PECO executives suggested the equality and separation provisions, the other stakeholders rejected the idea. Just like in California, William Hogan and his colleagues from the Harvard Electricity Policy Group served as experts during these negotiations. Initially, he and his colleagues worked for GPU Inc., but as time went on, they came

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[84] When the seven other utilities finally agreed on a joint course of action and filed their design proposal with FERC, PECO submitted a dissenting application. The filings of the majority can be found in "Restructuring of the Pennsylvania-New Jersey-Maryland Interconnection, July 24, 1996," *FERC* ER96-2516-000. The PECO proposal is: "PECO Energy's Open Market Proposal Re: PJM Restructuring into ISO, August 8, 1996," *FERC* EC96-29.
[85] Interview with Laura Manz, 12/14/2018.
[86] Interview with John Brodbeck, 11/16/2018.

to advise all members. They objected to PECO's suggestion on the same grounds as in California - and at PJM, their advice struck the right chord: they managed to convince the stakeholders that the suggestion was a non-starter. Surprisingly, PECO, too, accepted the argument before it submitted its dissenting proposal into the FERC record.[87]

When I asked why the issue had been so plain to them, a former employee at PSE&G put it laconically: "The PECO argument, as I recall, were viewed as radical and untested."[88] Another participant remembers that the suggestion came across as nonsensical considering how electricity dispatch already worked: "There was no reason to add a power exchange—[what the PX was supposed to do] was already happening. The bids were already being submitted to the ISO. The ISO was already finding the security constrained economic dispatch. It notionally made no sense to add a separate PX, it made no sense."[89] But, of course, this argument would have been equally valid in California where the individual utilities also used security constrained economic dispatch within their service territories. The fact that PJM "was already doing it" was only an obvious riposte if you already accepted that dispatch and markets needed to operate in tight integration. The executives had bought into the expert advice that the market designers gave.

To understand how the PJM members came to trust the expert advice, it is important to consider the wider context of decision-making at PJM. Since the pool operated across several different states, the PUCs were not strongly involved in the restructuring efforts. Restructuring played out in front of FERC. But apart from moderating the debate and providing regulatory guidance,

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[87] PECO's alternative proposal then assumes the Power Exchange would be administered by the ISO: "PECO Energy Co submits Attachment B to reflect Open Market Plan for restructuring PA-NJ-MD Interconnection under ER96-2668 et al., August 8, 1996," *FERC* EC96-2668, p. 7.
[88] Interview with Ben B., 12/04/2018.
[89] Interview with Laura Manz, 12/14/2018. The arguments against market separation also pervade the archival record of the debate between PECO and the other utilities before FERC in docket EC96-29.

FERC only started formal proceedings after the companies filed the restructuring applications. Without legislative efforts from the states and without the formal framework of regulatory proceedings, the utilities could figure out among themselves what they wanted to do.

Between 1993 and 1997 the discussions were largely limited to executive personnel at the eight member utilities. This created an entirely different framework of decision-making. First of all, the process could rely on a long background of technical cooperation. Despite integrating their operations more and more closely over the years, the utilities had always retained control over their generation and transmission assets. This led to a constant back and forth between PJM's centralized dispatch center and the individual utilities. The dispatchers would call member utilities, receive their plans, and tell them whether they had to be adjusted to optimize dispatch. Savings from improvements were split.[90] A market manager who worked for California's PX visited PJM in the 1990s to learn about their settlement rules. He remembered how striking the difference in the culture was:

> I got the impression […] that they had a completely different cultural model. They said, the original PJM came together through a voluntary association of a number of neighboring utilities, trying to save money, working on reliability and things like that […] and then, at the end of the day, they had to work together and their systems had to connect and that's in fact the name of it: PJM interconnection.[91]

The utilities were used to coordinating with each other and had learned for decades how to do so for mutual benefit. The discussions around restructuring took place against a background of mutually beneficial cooperation that had long been focused on guaranteeing reliable and secure system operation.

[90] Interview David Pratzon, 11/13/2018.
[91] Interview with Lawrence Conn, 11/20/2017.

The discussions took place at a semi-formal "administrative committee," later "management committee," that assembled representatives from the eight member utilities and staff from the PJM Interconnection Association.[92] Each utility was entitled to appoint one member to represent its interests. The group of decision makers was not just small, but its composition was also exceedingly homogeneous. A former manager put it to me like this:

> When the VPs got together, it was generally just them or them with perhaps one senior staff member. At that time most utilities were still run by engineers. There were always a lot of technical issues with building power plants, operating power plants efficiently, designing and running the transmission system…. So, people who had the skills to do those things were regarded very highly in utilities. […] So, while you needed to have economists and business experts on your staff […], they were not generally the leadership of the company. Leadership of the company tended to be people who came up through the engineering ranks and were ultimately successful as plant managers and moving on from there. So it was, in a number of the utilities, very much more an engineering background and focus than it was an economics or business focus. [93]

The debates thus took place among a small group of utility executives who had engineering backgrounds and deep knowledge about the technical foundations of their electricity systems. They were unified in their concern for reliability of operations and efficiency gains through optimization of dispatch decisions. Since they had long cooperated to achieve these goals, the spirit of their debates was oriented toward mutual understanding and agreement.

Despite generally losing the arguments, a former PECO employee remembers these meetings fondly: "If I put myself back on those tables, there was an acceptance that not everyone was up to speed. You could ask questions. Someone may make fun of you a little later because of your lack of skill, but we quickly became well known to each other."[94]

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[92] Lambert, *Creating Competitive Power Markets: The P.J.M. Model*, 56.
[93] Interview with Ben B., 04/12/2018.
[94] Interview with John Brodbeck, 11/16/2018.

This does not preclude highly political debates. Depending on how the company operated, what its transmission grids looked like, and how much it stood to gain from arbitrage business, it tended to support a different model of restructuring. In the background, the utilities were trying to marshal other stakeholders to support their position for the time when they would face FERC: industrial consumers, regulatory commissions, and state legislatures. Over time, it was particularly the three large utilities PECO, PEPCO (Potomac Electric Power Company), and GPU (General Public Utilities Corp.) that ran up against each other. Similar to California, the debates considered general questions about market structure and architecture.

With respect to the separation and equality provisions, the discussions were also split in two groups. GPU and PEPCO wanted to adopt a highly centralized design with Locational Marginal Prices (LMPs) that looked similar to the PoolCo approach in California. PECO, in contrast, had bought into a decentralized structure that looked similar to California's Direct Access. PECO's interests were straightforward: "We had a very vigorous wholesale trading operation that specialized in physical power," an executive told me. "The more physical we kept the market, arguably the more money they could make"[95] In other words, the less optimization the system operator engaged in, the more inefficiencies there would be to capitalize on. This position aligned PECO closely with the interests of power marketers. Given the divide between the utilities, the political negotiations were heated. A PECO engineer described a process of constantly shifting alliances with sudden changes of direction and surprising twists:

> There was a lot of politicking and the big politicking was between PECO on one side and PEPCO and GPU on the other side. […] It came down to a continuous debate with the GPU group. GPU/PEPCO began to win adherence. Atlantic City and Delmarva were on their side. At one point, public service was definitely on our side of the table, but before a major management committee meeting …. At five o'clock on the Tuesday they had been 100

[95] Interview with John Brodbeck, 11/16/2018.

> percent with us and at nine o'clock the next day, they were 100 percent with the LMP squad.[96]

Just like in California, backroom negotiations could lead to sudden and surprising changes in allegiances and little acts of betrayal. The archival record that contains the debates between the two sides in formal filings confirm this retrospective account.[97] The debates were just as political as in California, and the administrative committee was trying to find a compromise that would accommodate enough interests to present a unified front to FERC.

Nonetheless, when PECO floated the separation and equality provisions as a potential compromise, the proposal was quickly rejected following the unanimous advice of market designers. The reason they listened to the designers was that the political maneuvers occurred against the backdrop of a shared understanding of the electricity system and a willingness to listen to arguments that touched on issues of reliability. This proved crucial for market designers' ability to establish jurisdiction over issues that touched on the basic applicability of their methods. It allowed Hogan and his colleagues to cut across the political battle lines of the debate when they argued that the separation and equality provisions violated the basic logic of market design.

Regardless of whether they advocated for the decentralized (Tabors and Caramaris) or the centralized market design model (Hogan), the experts had a different standing in the PJM negotiations than in California. How they established this standing comes out in Hogan's recollection of his initial engagement with GPU.

When he and his collaborators first presented their LMP design, the executives at PJM did not buy the argument. Part of the difficulty was that Schweppe's underlying design philosophy

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[96] Interview with Bob R., 11/14/2018.
[97] For example, between the filings of first ideas for restructuring on 7/24/1996 and the next filing in 08/23/1996 the alliance had shifted and the supporting companies were unified against PECO, c.f. *FERC* ER96-2516.

was counterintuitive to them. Hogan's approach relied on a centralized pool to integrate the pricing of generation with its transmission across the grid. Not only did the designers emphasize the need for centralized control, but also the importance of extremely complicated algorithms to estimate thousands of prices for every node in the system. To most executives, this was far away from the intuitions they had about markets.

Just like in California, the executives considered markets the product of private interactions, where people negotiated under a given set of laws to move energy around like gas or corn.[98] This understanding explains why the direct access proposal was so popular in the beginning: despite including complex information exchanges between brokers who facilitated bilateral contracts and the ISO, the proposal built on an intuitive understanding of markets as decentralized contracting. The highly centralized, highly coordinated proposal by Hogan and others seemed unnecessarily complex, bloated, and constraining. Several interviewees on both sides of the issue pointed this out to me, but Hogan described the problem most succinctly. The model that came out of Schweppe's work

> […] was a market design that would meet the test of open access and feasibility and economic efficiency and nondiscrimination and all the other nice things. It would work and it was doable, but it was completely different than what people thought (laughs). So, we had this problem of people coming into the domain [of market design] and making assumptions about what you could do and these assumptions would be sometimes implicit, so they wouldn't even know they were thinking that, and the assumptions were deeply wrong.

Nonetheless, Hogan and his colleagues managed to convince the utility executives who represented seven of the eight utilities. The key was an appeal to the shared background understanding of the electric system. This is visible in Hogan's recollection of how he convinced the

[98] A former FERC commissioner pointed out to me that this was a common assumption. Interview with Bill M., 02/08/2018. The appeal to common sense can be found in PECO's arguments against the LMP model in "Motion to Intervene, Protest, and Request for Relief of PECO Energy Company, August 8, 1996," *FERC* EC96-29, p. 5-7.

executives of GPU to accept his market design proposal based on locational marginal prices.[99] He remembers:

> [I] explained how that would work and their response was: “You are crazy.” They were telling me: “It won’t work what you are proposing, it just won’t work.” […] And I said: It’ll work. […] Bob Arnold decided to assign his smart, young engineer to go do simulations with their power flow models to show that I was wrong. In other words, to construct a counter example. And, it took them about two weeks and then he came back and he said: “I am exhausted.” And, then, they started to think, maybe this actually would work and that was huge a moment because then Bob Arnold was the spokesman for the rest of the people at PJM and said, we’ve tried everything else, maybe we got to talk to that guy Hogan and literally, I remember that speech, it was the “we tried everything else so now we got to talk to him” and that’s when it started to get attention in the industry. And just for your information, the young smart engineer who did this for Bob Arnold is now the CEO of PJM, that’s Andy Ott.[100]

As the quote shows, Hogan got the utility executives to trust him by making a claim about the *engineering* rationality behind his proposal. He effectively argued that his LMP model could be used to generate prices that would be consistent with the flow of energy across the grid. The model would express precisely how much the addition or subtraction of a MW at a given bus would cost in terms of generation and transmission constraints.

He then gave the executives a toy-model version of the market design that explained how the centralized structure related to the underlying characteristics of energy flows on the transmission network. This enabled the executives to evaluate the market design in terms of criteria they were familiar with: how power flows across the grid and how the centralized dispatcher adjusts outputs to optimize the usage of the network. The quote shows nicely how giving them something they could have their engineers evaluate created room for them to admit ignorance: “we’ve tried

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[99] The recollection is supported by other interviews (e.g., Interview with Tim O., 11/15/2018, interview with Stu Bresler, 11/29/2018) and the way frequent citations to Hogan’s work in the majority filings prior to submission of the restructuring proposal. E.g., “Answer of the Supporting Companies to Request for Relief of PECO Energy Company, August 23, 1996,” *FERC* ER26-2516-000, p. 20.
[100] Interview with William Hogan 12/11/2017.

everything else and now we got to talk to him" meant that they did not know what to do anymore, but that they decided to trust Hogan.[101]

In other words, by establishing a visible distinction between the market designers' knowledge and the executive's knowledge on the basis of an appeal to engineering criteria, Hogan established a claim to jurisdiction. He gave them something they could "check" to validate his expertise.[102] This reveals how the "leap of faith" takes place that underlies the recognition of expertise: in order to accept the market designers as experts with unique subject knowledge, the executives had to become aware that there was something they did not know (relation between market design decision and ability to resolve dispatch problem), but that they knew *enough* to know that Hogan knew what they did not know.

By giving them a way to "check" his model, he could gain their trust. He had derived statements from his expertise that the executives could evaluate on the basis of shared standards of knowledge. They did not gain the market designers' knowledge, but they gained a tool to verify its validity at least approximately, thus warranting trust. The same social dynamic occurred on the other side of the debate at PECO, where Tabors et al. argued for a decentralized model. They, too, showed how the expertise applied to technical problems that the executives evaluated within a common framework of understanding.[103] Having established their claim to expertise with the different utility executives, the market designers could now decide on issues that they agreed upon and that touched on the basic feasibility of the design enterprise.

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[101] The need to push back against dominant intuitions about markets is also visible in publications that set out to disprove "folk theorems" around this time: Shmuel S. Oren et al., "Folk Theorems on Transmission Access: Proofs and Counter Examples," *Journal of Regulatory Economics* 10 (1996).
[102] Four executives confirmed Hogan's story in interviews and stressed the close cooperation with him and other members of the MIT/Nexus. Interview with Tim O., 11/15/18; interview with David Pratzon 11/13/2018; interview with John Brodbeck 11/16/2018; interview with Stu Bresler 11/29/2018.
[103] Interview with Richard Tabors, 04/20/2018; interview with John Brodbeck 11/16/2018.

They justified their position with reference to the technical reality the executives understood, even if the reasons had more to do with the constraints of the methodologies they used to solve the design problems. When PECO proposed the radical separation of power exchange and grid management, the experts could reject the proposal as obviously in contradiction with the rationale of market design and provide a technical explanation that the executives would understand: it would simply render the basic task of the ISO impossible. This rendered the suggestion as "obviously" wrong to the executives.

In sum, the experts had to establish that the common sense way of thinking about markets was inadequate and that they commanded over a separate realm of knowledge called "market design." To make this difference visible, they had to appeal to something the executives already knew and cared about. At PJM, every utility had special interests, but they could agree that the new structure had to work reliably, enabling the most efficient use of their joint systems. By arguing that specific market design decisions interacted with this common goal, it became apparent to the executives that market design is itself a highly technical domain of knowledge—that is, because they recognized that they had not known how these decisions interacted with the technical infrastructure they cared about.

When Andy Ott was sent to test the Hogan proposal, Hogan had created a way for the executives to evaluate his expertise on their own terms. Precisely because this was possible, his expertise became visible to them *as something they did not know about.* This entire process of establishing jurisdiction over technical decisions of market design required a specific environment. It required a political process that allowed for focused discussions based on a shared understanding of what was possible and what was not. This made the set of technical criteria available against which the market designers could claim authority. The PJM example shows the general logic of a successful appeal to jurisdiction.

8.5. Failure to Establish Jurisdiction in California

In politics, market design succeeds when the designers are able to reclaim jurisdiction over technical issues. They must be able to frame the options for political compromise in such a way that their methodology remains applicable. For electricity market design to succeed, it must be possible to link activity rules that describe a market institution to the optimization problem the designers are trying to solve.

The MOU decisions violated this basic requirement. Market designers were unable to control the decisions, because they expertise was not recognized. It did not appear as an exclusive domain of knowledge because alternative "styles of thought" and common sense interpretations offered intuitive answers to the dominant design questions. The market designers would have needed to level a claim to jurisdiction over the MOU issues. They would have needed to establish that they had pertinent knowledge about these issues that their audiences were ignorant about. This appeal had to be comprehensible in terms of criteria that make sense to the audiences.

We have seen that the context of decision-making at PJM provided such shared criteria. They provided footing for the experts' claim to jurisdiction. To put it paradoxically: the criteria allowed the utility executives to see what they did *not* know because it related the market mechanisms to technical outcomes in ways that were not obvious to a common sense understanding of markets.

In California, market designers' political audiences neither had a history of mutually beneficial cooperation nor a shared set of criteria to which they could appeal. The CPUC had five commissioners. President Dan Fessler was a professor of contracts law at U.C. Davis. Jessie J. Knight was a business marking executive and Greg Conlon a former director for the accounting firm Arthur Anderson; Patricia Eckert and Norm Shumway were lawyers. Not only were these commissioners close to SCE and PG&E lobbyists, they also had no common set of criteria to evaluate claims during the negotiations, nor was there a history of good cooperation between the different stakeholders. As already outlined, arguments were presented on different levels of abstraction and by appealing to a variety of different normative, technical, or evaluative criteria.

Looking at the record, there are several examples where market designers try to make moves to override the claims of other economists, engineers, or lawyers on the basis of their authority as experts. They try to establish footing by attacking technical implications of unsubstantiated comments. To give just one particularly pertinent example: in his testimony before the CPUC William Hogan tried several times to make a similar appeal as in the PJM proceedings. Responding to the Blue Book in 1994, he states:

> […] in this new era we're going to have the delight in working on a problem where, as my friend Charles Stalon often says, most things that everyone knows to be true, aren't. And because of that change in the world, we're going to have to rethink many of the elements of the operation of the market. I, in my comments, have provided a list of—let me just summarize the headings—of the things that are going to have to be viewed differently because of the nature of competitive markets being different than the traditional cost of service.[104]

He goes on to list a variety of distinctions familiar to the industry that will no longer hold and explicitly says: "The distinction between short-run generation and transmission is false. They are actually parts of the same function."[105] The quote documents an attempt to establish footing for his kind of expertise. Hogan claims that the market design project brings us into a different

[104] "Hearing Before the California Public Utility Commission, Reporter's Transcript, Los Angeles, June 15, 1994, California, Vol.2, Pages 299—596," Box 69, *CPUC*, p. 304.
[105] Ibid, 305.

world. In this world, the basic distinctions that guide the electricity industry are no longer valid. Later on, he talks about the "pervasive" or "workable fictions" of the industry that will no longer suffice. By claiming this, he implicitly also claims to know why they are fiction and how things will *actually* work. He points audiences to features of electricity markets that they do not know about in order to establish that he *does* know about them.[106]

For this claim to expertise to be successful, the audiences would have to recognize that they share a belief in what Hogan describes as "fictions." They would then have needed to be surprised by the beliefs were supposedly wrong and do not apply in this "new era." This moment of surprise would have provided Hogan with an opportunity to demonstrate *why* these beliefs are wrong. This would have enabled him to show how his expertise as market designer reveals this to be the case and how it allows him to resolve the resulting problems. In that case, the audiences would have known that he had expertise that they did not have. This is precisely the kind of move that worked in PJM.

However, it fell flat in California. After Hogan concluded his argument, a law professor, an IO economist, and a consultant testified on the same issue. The presenters invoked precisely the distinctions Hogan previously contested and talked about the new markets in terms that were appropriate to the old world of regulated utilities. They talked about markets as self-regulating entities and as separate from grid management. Such direct contradictions would normally require discursive resolution.

But once the commissioners began to ask questions, they did not compare the different proposals relative to a set of common standards. Instead, they evaluated parts of the proposal on the basis of completely different standards. Their discussion of efficiency provides the most

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[106] Ibid, 314/5.

startling example of the unsettled baseline of evaluation. Hogan claimed that efficiency had to be considered in terms of the search for the optimal dispatch of generation at the least cost. An efficient dispatch always *requires* a certain degree of coordination by the ISO. This claim about efficiency stood in contradiction to the opinions expressed by other economists on the panel, who suggested that markets would be more efficient with less interference by an ISO. While Hogan speaks about efficiency in terms of the dispatch of the electricity system, the other economists speak of efficiency in terms of the allocative outcomes of the theoretical construct of perfectly competitive markets.

But the commissioners did not even notice this contradiction. Each of them was preoccupied with a different kind of efficiency. Conlon was most interested in different ways to stimulate demand response. In his questions, he understood "efficiency" in terms of less environmental pollution. The markets would reduce peak demand and thus allow newer plants to produce the most output.[107] Knight was most interested in how existing practices of innovation at utilities would be affected, thinking about efficiency as *progress* in innovation.[108] Fessler, lastly, wondered about whether markets were antithetical to reductions in consumption and thus the environmental programs the commission was committed to. He thought about efficiency in terms of reducing conflicts between environmental policies and market logic.[109]

Because there was no common standard of evaluation, there was no way that Hogan or any of the other market experts could pitch their claims against each other and expect resolution. He could not appeal to a common baseline of evaluation to contest his fellow panelists. His expertise could not become visible as a separate domain of knowledge because it could not assert itself as

[107] Ibid, 375.
[108] Ibid, 377.
[109] Ibid, 380.

different against a shared background of criteria. Unlike in PJM, where his assertions first caused irritated rejection, then examination, and finally acceptance, they had no direct consequences in California. The commissioners did not even seem to notice the fundamental contradictions between the different statements. Similar attempts by market designers to level claims to jurisdiction appear over and over in the records of both the formal hearings as well as the filings.[110] Each attempt to establish a particular frame of reference for proof and disproof was simply superseded by a different challenge.[111] And without a clear framework of evaluation, the discussion of different proposals became so capacious that practically any position on structural or architectural issues could be clothed in the language of economics. This reduced the debate to the smallest common denominator, which was the pure interest politics of: I will give you X if you give me Y.

The designers' failure to establish jurisdiction becomes particularly visible in Fessler's ironic comment after three academics have elaborated their views for too long: "We have a problem in that it should be anticipated that in dealing with any group of distinguished citizens who are also called experts that it would be possible for them to take anything less than the 21 of the allotted time for the entire period, and perhaps by precluding questions in this manner, one maintains one's posture as an expert."[112] He makes a joke here, but the statement is nonetheless revealing. He sees the market designers as citizens who *pose* as experts. Since the designers had no way to establish authority over questions that pushed the limits of their methodology, they do not enter as real experts. Instead, they just appear as citizens who share one opinion in a sea of alternative

[110] The MOU was not formally entered into the record until September of 1995. But it already features in discussions during hearings in August —much to the discontent of CPUC chairman Fessler, who had been surprised by the compromise. E.g. "Hearing Before the Public Utility Commission of the State of California, August 21, 1995, Reporter's Transcript, Pasadena, California, Vol. 30, Pages 3876-4131," *CPUC*, p. 3899/3900.
[111] See, for example, the CEC's failed attempt to establish criteria for technical vs. political decisions at: Ibid, 4473-76.
[112] "Hearing Before the California Public Utility Commission, Reporter's Transcript, Los Angeles, June 15, 1994, California, Vol.2, Pages 299–596," Box 69, *CPUC*, p. 373.

points of view. The distinction between technical and political became meaningless. This insight prompts some concluding thoughts for the subsequent analyses.

8.6. Concluding thoughts

The success of market design requires that experts assert control over technical questions in the political process. Technical questions are all those questions that affect the basic ability to apply the analytical techniques of market design to a given design problem. For electricity market design, this requires control over questions that touch on the link between the objective function and the activity rules. Since grid management has to be performed by the ISO, market designers must be able to control how market activities relate to the activities of the system operator.

I am not suggesting that this is all that is necessary for market design to succeed. Instead, it is a limiting condition that makes it possible for market designers to stay in the game and help to achieve the goals that animate the intellectual project. If they can avert decisions that violate the basic requirements of their methodological toolkit, they can still work to find institutional solutions to allocation problems relative to the parameters the political process imposes.

However, market designers had difficulties asserting control over the relevant questions at PJM and failed to do so in California. The separation and equality provisions of the MOU were the consequences. Economics as a powerful "style of thought" pervaded the political discussions as ideological common sense understanding and as competing forms of expert advice. The wide and inconsistent use of economists' conceptual vocabulary made it difficult to make market design visible as a distinct and decisive form of expertise.

The MOU debates took place on a high level of abstraction. This contributed to market designers' troubles to establish their expertise. Foundational questions about market structure and architecture resonated more easily with the common sense view of free markets than narrower questions would have. For example, while anyone would agree that a "free market" requires a lot of competitors, the common sense view would offer less intuitive answers about the choice between single-price vs. multi-price clearing rules. Since the questions were general, they also touched almost every stakeholders' interests. Accordingly, the political proceedings featured a variety of stakeholders with competing perspectives and interests. The resulting discussions were characterized by so many competing perspectives, types of expertise, and interests that there was no common denominator to evaluate market designers' claims to expertise. Accordingly, the process quickly reduced to interest politics, leaving analytical and technical consideration by the wayside.

Often, participants of the CPUC's debates explicitly justified an approach that made fundamental decisions before there was hard evidence to support the decision. The justification almost always involved an appeal to *experimentalism*. There was a common belief throughout the creation of the California markets that decision makers could put things into place and revise them later if they proved infeasible.[113]

If something worked politically, you could accept it provisionally, move on, and revise it later. But of course, the foundational decisions of the MOU were not open to revision and even made it into the legislative foundation for restructuring. Since political processes address broad and ambiguous questions, market design can succeed with a variety of different outcomes. In that sense, an appeal to experimentalism may make sense. Of course, there is a caveat: while a variety

[113] A high-ranking official at CAISO put it like this: "We tried in the design to deal with mismatches and holes the best we could. But the thought was that we're going to do the best we could. And then if something came up, we'd change it," Interview with Carla B., 11/22/2017. My interviewees expressed this point of view countless times, both approvingly and disapprovingly.

of political decisions are compatible with the way market design works as a form of political advice, the decisions are not neutral with respect to the technical challenges of market design.

Depending on how far the political decisions move the structure and architecture of the new system away from a simple design, the harder it will be to find workable institutions during technical implementation. I will come back to this issue in the next chapter. As flexible as market design as a political activity is, if a political decision violates the basic methodology of market design, the design project has a real problem. Precisely because the decisions are general and basic, they are not easy to revise. The appeal to experimentalism is therefore not a good justification for uninformed decisions in political contexts.

All these considerations point to the possibility that market designers might be more successful if they limit their efforts to narrower design problems. Market design comes in a variety of flavors. Under one definition, any attempt counts as market design that influences the structure of incentives in a given market environment. For example, market designers may consider if a given rule change to an allocation mechanism would improve a given market environment along a welfare dimension of interest.[114] Here, the discipline presents itself as a form of regulatory intervention because it considers small tweaks to existing rules.

On the opposite side are radical experiments in economic engineering such as electricity markets, markets for environmental services, and markets that provide matching services. They require the creation of new infrastructures, rules, and organizations to manage them. As such, they

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[114] E.g., Daniel Waldinger, "Targeting in-Kind Transfers through Market Design: A Revealed Preference Analysis of Public Housing Allocation," Economics (New York: NYU Furman Center, 2019). He considers how to improve the matching algorithm for a program to allocate public housing to applicants in Cambridge, MA. He identifies a tradeoff between policy objectives with respect to the allocation of public housing (helping the worst off, maximizing welfare gains for tenants). He then uses data on behavior in a given allocation system to reconstruct what tradeoff people in Cambridge would prefer. This reveals what the ideal mechanism would be. He then shows that the system is not optimized to produce this tradeoff, which then leads to suggestions of rule changes that would bring about the mechanism that optimizes the desired tradeoff.

require broader interventions, which then require more complex political processes with the problems discussed above.

So, might narrower forms of market design be more successful? Certainly, they would debate questions that are more tangible than grand plans to restructure entire industries, and they would play out in regulatory contexts that are more focused than the Blue Book proceedings were. If less interests are affected because market design interventions are narrower and if questions can be marked more easily as technical because audiences do not have intuitions about them, market designers could control the terms of the debates more easily than in California or PJM. Then it would be easier to make the political process conform to the requirements of successful market design. So, will narrower design challenges make it easier for market design as politics to succeed? I think not.

Throughout this dissertation, I have emphasized the cybernetic background of market design. The fundamental idea of cybernetics is the ability to create a system with clear boundaries, specified by the logic that governs the interaction of the individual elements of the system. For a given market design to succeed, the designers must be able to create an institutional framework that enforces the logic of interaction envisioned by the model without external disturbances. This basic framework is built into the methodological tools used by market designers. Accordingly, any market design project ultimately needs to create a basic correspondence between the mechanisms of interaction specified by the model and the real market environment. This, however, creates a tradeoff between more and less invasive forms of market design.

The more minimal an intervention is and the more targeted the political debate, the larger the burden on the model the economists use. If it turns out that the existing world is not like the model and the designers do not seek to enforce the assumptions in subsequent decisions, the intervention will not play out as the designers anticipated. In other words: only if the world already looks like the closed systems of carefully defined behavior the economists assume in their models can a limited intervention succeed.

Conversely, a more complex market design intervention potentially has the power to make enough changes in the world to create a close match between model and reality. It can study and control the various ways that reality pushes back against the model. The market designer has a greater chance to make the world into a closed system defined by the behaviors the design assumes. However, these kinds of complex design interventions suffer from the problems discussed in this chapter. They are broken into a complex sequence of decisions, and the most general decisions fall into the purview of political processes where a variety of stakeholders vie for influence. In this context, it is exceedingly difficult for market designers to reclaim jurisdiction.

Accordingly, these design processes *are* vulnerable to political intervention. The more political decisions can occur, the quicker market designers reach the point where politically feasible compromises exceed what is possible from the perspective of market design.

It is here, then, that we can get a more precise understanding of the way market design runs up against the democratic process. Market design is not generally incompatible with politics. Indeed, it always occurs through political processes. But there is a tradeoff between scope and reliability of market design interventions. The broader the scope of the design project, the more vulnerable market designers become to political decisions. The political process can more easily move into contradiction with the model because basic questions that concern the applicability of their methodology are at stake. The narrower the scope, the more easily market designers can enforce the boundary between technical and political questions. But the narrower the scope of the intervention, the less power the economists have to shape the social process. This makes the market designs more vulnerable to deviations of reality from the models. Market design is therefore most likely to succeed if it deals with problems that already presuppose a largely functioning market. Design that aims to reform and improve will be more successful in politics because the fundamental link between methodology and the allocation problem will not be up for grabs. The problems of creating a match between model and reality in technical market design processes will be the topic of the next chapter, which will develop these considerations further.

9. Technical Design Work: WEPEX

9.1. Introduction

Early in 1995, a small group of experts began to meet in conference rooms in California's three large utilities. The engineers, system planners, dispatchers, and lawyers sorted through some of the technical implications restructuring would pose.[1] Initially, the work of the WEPEX group was limited and received little attention from the political process or the public. It was not glamorous, but technically demanding and intellectually obscure—a proven combination to keep politicians at bay.

But over time, the WEPEX process grew in importance. Since technical features of the electricity system were crucial for almost all design issues, the working groups slowly began to absorb all practical questions about implementation. It became the venue where experts translated the general policy proposals into detailed plans for the new markets. It is the place "where arguments took place," as one participant put it.[2] And indeed, some of the most crucial decisions about restructuring originated in these less public, less penetrable, and more complicated proceedings. If the political process conceived California's electricity markets, WEPEX gave birth to them.

Several of the structural flaws identified in chapter six originated in these working groups, specifically, the zonal congestion management system and the protocols that implemented the MOU provisions. These protocols gave rise to discrepancies between the CAISO and SC markets and created the incentives for the illegal arbitrage businesses. WEPEX also invented the concept of "scheduling coordinator" as well as the rules that made it easy for any company to become one. This made it easy for power marketers to play both sides of the market. From a design perspective,

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[1] Interview with Ferdinand M., 02/19/2018.
[2] Interview with Gary Ackerman, 11/17/2017.

the working groups were the breeding ground for some of the worst problems of the California markets. This chapter will investigate the origin of these problems and analyze the design work that took place in the WEPEX process.

Before developing the analysis, a few preparatory moves are necessary. Though the working groups have not left a strong mark in the research on the California crisis, the studies that do discuss WEPEX usually describe it in either of two ways. Some studies view the WEPEX meetings as a derivative *political* process. According to these studies, WEPEX simply spelled out the decisions that came out the political processes.[3] I will argue, in contrast, that WEPEX preserved considerable autonomy from the political processes surrounding it and that it featured a distinct form of technical design work.

Other studies recognize the independence of WEPEX, but argue the decisions were dominated by power marketers who tried to create the flaws they would later exploit during the crisis.[4] I show that this argument has some merit, but needs to be differentiated. Some of the decisions did favor the interests of power marketers., but their influence did not directly extend to the work in the technical teams. While the teams had to work with preconditions that were shaped by political maneuvers of power marketers, the protocols themselves followed the rationale of market designers' technical expertise. The first section develops these arguments by reconstructing the organization of WEPEX and its relation to the larger political process.

Having cleared the ground for a separate analysis of technical market design processes, I then analyze the WEPEX work in two broad steps. First, I explore problems that derived from the division of labor. Since the different teams did not cooperate, the designers did not systematically

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[3] For example, Walsh, *The $10 Billion Jolt: California's Energy Crisis: Cowardice, Greed, Stupidity and the Death of Deregulation*.
[4] For example, Beder, *Power Play: The Fight for Control of the World's Electricity*, 153.

sort through the interdependencies between different parts of the market architecture. This led to divergent and inconsistent operating protocols for the different markets. Even though economists recognized these problems, the division of labor prevented them from solving them. The problematic inconsistency between the operating protocols for the market thus goes back to the division of labor. Engineers on the steering committee put this division of labor into place because they thought market design might benefit from a modularization of work. This belief derived from a mechanistic idea of market failure. It ignored that market participants act on incentives that derive from the combination of all market environments they can enter.

In the next step, I analyze the work in the WEPEX teams. This allows me to account for the flawed transmission congestion system and the problematic rules for scheduling coordinators.[5] In the different teams, designers developed plans for institutional and organizational frameworks that would create a market process as described by a theoretical blueprint. In the first step, I discuss abstractly how market designers develop these blueprints and show that they are liable to blindspots. A blindspot refers to an assumption in the theoretical model of the market mechanism that is (a) in tension with the context of application and that is (b) not explicitly stated.

Though such assumptions differ by the context of application, I show that it is possible to isolate at least three potential blindspots that affect market design *generally*. These blindspots

[5] For this part of the analysis, a caveat is in order. The WEPEX process lasted for two years (1995-97) and dealt with all aspects of the new markets for California. It was complex and featured many different teams working on different issues. To really reconstruct all of the problematic decisions, I would have to look at the work in all different teams. Unfortunately, the historical record of the WEPEX processes is not complete. Only minutes have survived from the original meetings. By far the most complete record consists of technical reports to FERC and the CPUC as well as publications about WEPEX in the trade press. These sources are not well suited to reconstruct the technical work in the teams because the regulatory process was the main avenue for political influence. Many of my interviewees were part of the WEPEX process, but their accounts are retrospective account and therefore not well suited to recover the decision-making processes. To solve this problem, I focus on the creation of the problematic congestion management system. This work can be linked very clearly to a theoretical blueprint, and it touched on the role of scheduling coordinators.

derive from the role mathematical models play in the process of conceptualizing market mechanisms. They refer to assumptions that are implicit to the structural form of economic models and that are artificial. The assumptions are: the *uniformity* of individuals' decision-making process, the *closure* of the mechanism, and the predictability of market *change*. Such blindspots are problematic because they concern parts of the social process that are not reflected in the design but defy the logic of the mechanism. The blueprint effectively ignores features of reality that would have to be neutralized or augmented to realize the mechanism.

In the subsequent analysis, I then reconstruct how exactly these blindspots affected the work in the team that tried to implement the blueprint for transmission capacity markets. First, I reconstruct how exactly this blueprint worked and how it was supposed to address the challenge of transmission pricing. Then, I reconstruct how the Transmission Management team used the blueprints to create the congestion management system. Working to realize the blueprint's explicit assumptions, the team found it impossible to represent the entire complexity of the electricity system in the market. In the search for a workable compromise, they implemented a simplified representation of the system. However, the disparity between the real system and its representation created incentives to violate the blueprints' implicit assumptions. Since the designers did not enforce these assumptions explicitly, the market process eventually violated them. Specifically, I show that the three congestion games and the lax rules for scheduling coordinators correspond to violations of the three implicit assumptions: uniform decision-making, system closure, and incremental change. Before turning to this analysis, I will discuss why WEPEX constituted a distinct part of the market design process in California.

9.2. Technical Market Design Work at WEPEX

Some studies view the technical design work in the WEPEX process as derivative. They claim that WEPEX simply implemented the decisions that came down from the more visible, political processes in San Francisco and Sacramento.[6] Other studies recognize WEPEX as an important domain of market design work, but argue that power marketers dominated the decisions in an attempt to create flaws they could later exploit.[7] If either of these readings were true, the analysis of this chapter would be obsolete. WEPEX could then be analyzed along similar lines as the Blue Book proceedings in the last chapter. Accordingly, it is important to deal with these alternative readings first. In this section, I argue that WEPEX was an independent, third branch of market design work. This work was not entirely apolitical, but it had a distinctly technical character. To establish this premise, I discuss the merits of the two positions in turn. I begin with the argument that WEPEX was a derivative political venue.

The WEPEX meetings started in the early months of 1995 when the three utilities brought together a small group of engineers, system planners, operators, and lawyers. These experts tried to determine how the utilities' three service territories might be integrated into a single system under management of the ISO. This was no easy task because the utilities had developed their systems independently of each other. The electricity system is the world's biggest machine, developed over many decades in a decentralized process of muddling through.[8] Accordingly, the three systems in California embodied different design philosophies, were made with different

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[6] Walsh, *The $10 Billion Jolt: California's Energy Crisis: Cowardice, Greed, Stupidity and the Death of Deregulation*; Duane, "Regulation's Rationale: Learning from the California Energy Crisis." Though he does not discuss WEPEX explicitly, Sweeney can be read along these lines as well, though he emphasizes that the problems were due to the short time frame between AB1890 and market opening. Sweeney, *The California Electricity Crisis*, 38-9.

[7] Beder, *Power Play: The Fight for Control of the World's Electricity*.

[8] How these systems developed initially is the topic of Thomas Hughes' beautiful book, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: JHU Press, 1993).

components, and relied on different strategies for system integration. Initially, the task to integrate them was akin to the project of merging two cars of different build and age into a single machine—if the cars were the size of California. Since this was arduous, technical work, not many people noted or cared about these working groups. At the beginning, the experts merely tried to inform each other about their respective systems and identify the technical difficulties that would be involved.[9]

This changed before too soon. Since the technical characteristics of grid management are connected to most design questions, the work began to expand, and soon the experts considered how the various conceptual dreams that emanated from the CPUC proceedings might be executed. This meant that statements from the WEPEX group entered the regulatory record. As soon as stakeholders realized that the debates had consequences for them, they petitioned to be included in the deliberations of the working groups. Municipalities wanted to know how their systems would coordinate with the larger grid, the power marketers wanted to know how they could interface with the PX markets, direct access customers wanted to know how they would have to interact with the ISO, etc.[10] As more and more participants came to the process, it increasingly became the official domain of all questions about market design. Other working groups then began to spring up around WEPEX. Groups like the Scheduling Coordinator User Group, the Electric Utility Restructuring Forum, and the Research and Development Planning Forum tied experts and stakeholders together.

After more than sixty interested parties had entered the WEPEX process, the utilities found it useful to impose a hierarchical structure on the work. Shortly before the MOU appeared in

[9] O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 16.
[10] Interview with Deb Le Vine, 11/29/2017.

August of 1995, WEPEX constituted itself as the official design process of the CPUC proceedings. A steering committee divided larger questions into different domains of expertise and assigned them to teams of experts.[11] These teams assembled utility employees, stakeholders, market designers, and outside experts. Every few weeks, the steering committee would meet publicly and decide on proposals the teams brought to them.

Over time, the political and regulatory process began to defer practically all questions about implementation to WEPEX. This allowed the WEPEX process to develop substantial independence from the political process. There were two primary reasons for the growing autonomy. One has to do with the kind of questions WEPEX debated. The other has to do with a shift in jurisdiction from the state to the federal level.

Initially WEPEX's autonomy grew because politicians in Sacramento had little understanding of the technical questions that the working groups debated. One of Steve Peace's legislative aides remembered that most politicians thought the technical infrastructure would continue to work as it did before. Markets would simply be layered on top and work according to self-evident principles of competition and efficiency: "It was apparently a given that [the ISO] would play a small last-minute, real-time function that would mimic what the utilities used to do. […] I guess there was a presumption that we would run this thing the way the utilities did."[12] This meant that the politicians did not even consider the many questions that had to do with the ISO. But since the relationship between the ISO and SCs was the central issue of market implementation, the politicians left most design decisions to WEPEX.

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[11] The formal structure of WEPEX is described in the applications to FERC, e.g., "Joint Application of Pacific Gas & Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company for Authority to Sell Electric Energy at Market-Based Rates Using a Power Exchange," *FERC* ER96-1663, pp. 8-11; Appendix A.
[12] Tony Larson, quoted in O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 23.

Instead, the legislature focused on the creation of bipartisan support by handing out privileges to various stakeholders: public purpose programs (provisions for low-income customers, energy efficiency requirements, resource diversity requirements), the retail-price rate freeze and a 10 percent rate cut for end users during the transition period until stranded costs were recovered.[13] Such distributional decisions were important to generate support for restructuring. But they had little to do with implementation. Gary Ackerman, the head of the working group for scheduling coordinators, suggested: "I would say about 98 percent was the ISO and PX, and 2 percent was the top-level vision of AB 1890. Legislation never gets into detail."[14] The political processes sketched only the barest outlines of the markets, leaving most decisions to the WEPEX process.

The second reason for the autonomy of WEPEX was the shift in jurisdiction that occurred with the creation of wholesale markets. In contrast to the legislature, the CPUC kept closer tabs on the WEPEX process. The steering committee had to file all technical proposals with the commission, and the commissioners participated in the discussions. Nonetheless, this source of political oversight diminished over the course of 1995–96. Since the new markets would be regional entities, jurisdiction over questions of market design moved to FERC as soon as the utilities filed applications for a specific design.[15]

The three utilities who owned the transmission system had to apply to FERC for market-based rate authority in order to create the ISO and the PX. This gave FERC the authority to sanction all design decisions. Opened in 1996, the FERC proceedings quickly became the target of all work

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[13] Blumstein, Friedman, and Green, "The History of Electricity Restructuring in California," 12.
[14] Interview with Gary Ackerman, 11/17/17.
[15] The CPUC retained influence over anything that had to do with retail markets and the industry's property structure in California. This included generation divestiture, the CTC charge for the recovery of stranded costs, legal issues involved in unbundling distribution from transmission networks, retail service requirements and pricing, public purpose programs, and environmental provisions. "Decision 95-12-063 (December 20, 1995) as modified by D.96-01-009 (January 10, 1996)", Box 20, Folder 53a, *CPUC*, pp. 129/30 (short: Preferred Policy Decision).

at WEPEX.[16] Between 1996 and 1997, all working groups focused on the creation of a detailed proposal for the implementation of the new markets. They then translated this proposal into a tariff draft, and FERC decided whether the experiment would move ahead. The tariff contained all basic rules about the structure of the markets, the rules of conduct, the governance structure, and detailed information on how various functions would be performed (settlement, forward markets, grievance procedures, change of rules, etc.). Only after FERC approved the decisions could the groups move ahead and hire vendors to translate the tariffs into specifications for software, hardware, and organizational structures.[17] Thus, FERC assumed regulatory responsibility for the architecture of the new markets soon after the MOU entered the record.

With this shift, WEPEX began to operate almost completely autonomously because FERC made little use of its right to influence the proposals. The reason was the doctrine of cooperative federalism. When the CPUC first considered restructuring, Fessler had pointed to the problems a jurisdictional shift might pose. He proposed cooperative federalism as a solution. FERC would hold ultimate power to make decisions about the markets, but oversight and governance would primarily take place in California. FERC would therefore defer to local regulators and politicians.[18] As we have seen in the third chapter, the setup created problems as soon as the crisis pitted FERC's

[16] See filings in *FERC* ER96-1663.
[17] The application was split into two phases. The phase I filings gave a broad overview of the new structure and were submitted on April 20, 1996, several months before AB1890 created the legal foundation for restructuring in California. This highlights how influential WEPEX truly was: while the legislative process was ongoing, the utilities and other stakeholders had already negotiated details with FERC. The phase II filings then provided a more detailed outline of the market design, including activity rules, software specifications, organizational protocols, etc. The utilities submitted the phase II filings in March of 1997. "Preferred Policy Decision," pp. 129–30.
[18] The desire to retain some control over CAISO and PX was also the reason AB1890 created the Electricity Oversight Board (EOB), which had five members whose appointments were split between the governor and the legislature. The EOB was supposed to create rules for, and appoint members to, the CAISO/PX governing boards. It would also serve as a board of appeals for decisions made by the ISO board. Despite losing jurisdiction to FERC, so the hope was, these institutions would secure the influence of local government and regulators.

understanding against that of California's regulators and politicians. But before the cooperative federalism broke down, it motivated the commissioners to accept the WEPEX filings as submitted.

An example illustrates how lenient FERC treated the products of WEPEX. When the three utilities first filed their application with FERC, the technical staff in the Office of Economic Policy were extremely concerned about the proposed market structure. In addition, William Hogan had prepared an alternative filing for SDG&E, which proposed a design that was closer to the original PoolCo idea.[19] But neither of these last-minute attempts succeeded in preventing the hybrid structure of the new markets. The legislature, which was mainly aware of the MOU provisions, backed the application without reservation and thus put pressure on FERC through their ties to Congress. A consumer representative and CAISO board member remembers how the governor's office lobbied against modifications any modifications to the WEPEX proposal:

> [The governor] got the entire California congressional delegation—which was much more divided between Republicans and Democrats than it is today—to write a letter to FERC saying, "Don't mess with the California model. This is something that we've worked out. And it's California's plan. Please just approve it as filed." The feedback that I learned later is that there were real doubts, at least on the staff level, at FERC about what California was doing. But there was such a political blitz to say, "FERC approve this just the way it is," that ultimately, they did. And of course, the rest is history.[20]

The letter had the desired effect. FERC withdrew its objections and excised the SDG&E proposal from the record.[21] California could move on with its idiosyncratic market structure. The example shows that FERC was not a powerful force in the creation of the California markets in WEPEX. Yet, the legislature, which exercised pressure on FERC to accept the filings, was not acquainted with any of the details, and the CPUC had been cut out of the loop. With a disengaged legislature, a CPUC without formal regulatory authority, and a lenient federal regulator, the

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[19] Interview with William Hogan 12/11/2017.
[20] Interview with Andrew F., 01/25/2018
[21] Cramton, "Electricity Market Design: The Good, the Bad, and the Ugly," 1.

WEPEX steering committee assumed almost unchallenged power over the implementation of the new markets.[22] The WEPEX process turned general policy provisions into concrete blueprints that could be translated into requirements for software, hardware, and organizational structures.

An alternative view in the literature recognizes that WEPEX was an independent process but claims that power marketers dominated and rigged decisions in their favor. [23] This suggests, once again, that WEPEX should be understood in political terms.[24] Unlike the first claim, this argument has some merit. The WEPEX process was not a neutral or "technical" enterprise. This is just the flipside of the discussion in the last chapter: just as there is no "purely" political design process, there is also no "purely" technical design process. Many WEPEX decisions were obviously motivated by political concerns and fed back into the political processes surrounding

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[22] The political independence of WEPEX only increased over time. After completing a first "phase I" tariff filing that described the proposed market system in some detail, the last meeting of the steering committee took place in October 1996. At that point, the California assembly had passed AB1890 and the CPUC had allocated money to fund the new market organizations with up to $250 million in loan guarantees. Now it was time to bring the organizations to life as legal entities and implement the new system. Instead of disbanding the WEPEX process, the group largely reconstituted itself as a PX Trust Advisory Committee (TAC) and a CAISO TAC. These TACs took over the creation of the two organizations until PX and CAISO could assume legal existence in 1997. Though the TACs were smaller than WEPEX and they worked separately from each other to honor the separation provision of the law, these committees contained most of the old WEPEX members. The CPUC and the governor's office also brought in a new trustee who would coordinate the work of the advisory boards: S. David Freeman, who had run the Tennessee Valley Authority as well as the New York Power Authority and advised President Carter on Energy matters. The main reason for these structural changes was the need to increase the speed of decision-making. AB1890 had set the deadline for the start of the new markets to January 1, 1998. Freeman was there to both expedite and balance decision-making. Despite these organizational changes, WEPEX lived on in TAC. Many members do not even remember where on organizational entity ended and another began. The TACs created an even more detailed "phase II" filing for FERC, found the buildings for the PX and the ISO, and decided on the first vendor contracts. After the PX and CAISO assumed legal existence in 1997, most members of the TAC groups became employees of the new organizations or joined one of the two governing stakeholder boards. From there, they oversaw the last steps of turning the tariff into organizational reality, hardware, and software that fit specifications. For example, the designer Paul Gribik first worked for the ISO alliance that became the WEPEX process in 1995. Then, he moved over to Perot Systems, which coordinated the software integration of the different systems that the ISO would use. As an external contractor, he facilitated the link between the WEPEX/TAC teams that worked on the congestion management system and the coders at ABB's subcontractors who had been hired to develop the algorithms and computer codes for the software.

[23] This is part of the story that California's Select Committee was trying to tell, and it shows up in, for example, Stoft, "What Should a Power Marketer Want?"

[24] This argument is part of the story that power marketers built the loopholes they later exploited Beder, *Power Play: The Fight for Control of the World's Electricity*.

WEPEX. For example, a WEPEX team first conceived of the stakeholder boards for the PX and ISO. Since any substantial divergence of interest between stakeholders would paralyze the board, the decision made no sense from a market design point of view. During the crisis, this is exactly what happened. Power marketers, utilities, consumer advocates, and independent power producers sat on the ISO and PX boards. As soon as one side began to make a lot of money while the other side lost it, the board became paralyzed and unable to make decisive moves to end the crisis.

But the decision made political sense. It was a concession to those who feared an overly powerful ISO, which might turn into a new "uber utility" and destroy the benefits of restructuring.[25] A large stakeholder board ensured that everyone who mattered had a voice in the regulatory process.[26] Other decisions were less overtly political but had a political dimension because they impacted the revenues of stakeholders. For example, decisions about the structure of grievance processes or those for transmission updates had obviously political implications.[27]

Despite these political overtones, WEPEX did not simply yield to the powerful interests of the power marketers. The argument must be differentiated. Its most compelling version alleges power marketers influenced three specific restrictions that WEPEX imposed on the work of the PX, CAISO, and the Scheduling Coordinators. First, the ISO was not allowed to clear the market, but only resolve congestion. Second, scheduling coordinators could not submit bids outside their "preferred schedules." Third, the PX had to dispatch around known transmission constraints.

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[25] Interview with Andrew F. 01/25/2018.

[26] The CPUC therefore adopted the proposal without dissent. CPUC, D-06-08-038, August 2, 1996. The initial provision was for smaller boards then AB1890 eventually implemented. The provisions go back to WEPEX meetings in January and Feburary 1996, c.f. "WEPEX Steering Committee Meeting Minutes, February 20-21, 1996, San Diego California," ArchiveX Internet Archive, https://web.archive.org/web/20000817212105/http://www.energyonline.com/wepex/, capture from 11/09/1999, last accessed 12/11/2019.

[27] "WEPEX Steering Committee Minutes, January 29, 1996, San Diego California," ArchiveX Internet Archive, https://web.archive.org/web/20000817212105/http://www.energyonline.com/wepex/, capture from 11/09/1999, last accessed 12/11/2019.

Each of the three decisions put SCs—and thus power marketers—at an advantage relative to the PX. The PX was designed as a centralized exchange. Exchanges have to follow fixed sets of rules to determine market clearing prices. This has two advantages. First, power exchanges will create very transparent prices. Second, they are very efficient. Since the auction pools all offers and bids and computes the intersection between the aggregate supply and demand curves, it will find the most efficient market clearing price. SCs ran bilateral transactions, which were less transparent and less efficient. Accordingly, the PX was potentially able to offer cheaper energy to consumers than SCs. This would have been a hard advantage to beat.

The three restrictions undermine the advantages of the PX while boosting the gains from the SCs main advantage: flexibility.[28] Together, the restrictions ensure that the PX would never find the optimal dispatch for the market. They aim to isolate parts of the market from the PX. Since the PX never has all of the business, there are parts of the market that are excluded from it. These parts of the market play an important role for the optimal dispatch because they can lower prices or change power flows. The first restriction prevents the ISO from optimizing the schedules of the PX. The second restriction prevented the PX from optimizing across the market as a whole. It was only allowed to work with information that companies submitted directly to the PX. The third restriction forced the PX to optimize only around known congestion constraints (i.e., the zones) in its own schedules. This meant that redispatch would be required. Due to their flexibility, the SCs

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[28] This explanation discounts the claim that Enron built the design flaws to enable the games it later developed. The conspiracy theory presumes too much foresight on the part of the power marketers. It took them about a year to develop their schemes, and they depended on so many details in the protocols that it would have been impossible to orchestrate them all at the same time. Seen as an attempt to secure the profitability of SCs, the three features are consistent with a much more generic interest in inefficient marketplaces a power marketer may have. In other words, Enron did not have to plan its games in advance to prefer the rules that gave rise to them.

would eventually be able to organize such redispatch more flexibly than the PX. In sum, the three restrictions neutralized the advantages of the PX while strengthening the position of the SCs.

Not only are these provisions in the interest of the power marketers; there is archival and oral evidence that Enron lobbied for the three restrictions.[29] However, it is important to qualify this statement. While it is true that the three restrictions were the product of power marketers' influence, they do not indicate that all of WEPEX was dominated by them.

This becomes clear when we consider that the influence of power marketers on WEPEX was very *indirect*. Take for example the steering committee where Enron's influence was certainly most palpable. The committee provided the interface between WEPEX and the regulatory proceedings at FERC and the CPUC. As we have seen, the regulatory proceedings allowed stakeholders to exercise political pressure. Power marketers were free to attend meetings of the steering committee, and they did.[30] However, the steering committee *itself* was independent. As of 1996, the committee had fourteen members who made the final decision by majority vote. The members represented different interests. When the process moved from WEPEX to TAC, the different groups received fixed numbers of votes, representing the stakeholders equally. If proposals were approved, the decisions would go into the drafts for the tariff that the utilities would present to FERC. But despite representing a variety of interests, the power marketers did not have a *single* seat on this committee.[31]

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[29] Incidentally, the three restrictions also created the illegal arbitrage opportunities because it introduced inefficiencies into CAISO's market clearing process. This is the reason some authors have claimed that Enron created the loopholes it would later exploit. For an interview that documents Enron's influence, see the interview with Carmella G., 11/28/2017. For a similar argument in the literature, see Stoft, "California's I.S.O.: Why Not Clear the Market?"

[30] Power Marketers appearance in these meetings is noted at: "Joint Application of Pacific Gas & Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company for Authority to Sell Electric Energy at Market-Based Rates Using a Power Exchange," *FERC* ER96-1663, p.A-5

[31] The members of the committee who work for municipalities or power agencies are typically utility officials as well. In 1996, these were members: James Macias, Pacific Gas And Electric; Jan Smutny-Jones, Independent Energy Producers; William L. Reed, San Diego Gas And Electric, John Chandley, California Energy Commission;

Instead, utility officials and market designers with engineering backgrounds dominated the proceedings. Their outsized influence was so palpable that WEPEX had to justify their position to the CPUC. As they put it in a letter to Fessler dated January 1996, "The three IOUs are the parties responsible for the filings you have directed be made to the FERC by April 29 of this year. For this reason, it is essential that the three IOUs approve the policies and details that comprise these filings which they must jointly make."[32] Since the utilities would submit the applications and divest their assets in accordance with FERC, they maintained the right to decide on structural issues. Both archival and oral evidence suggests that they kept the pen firmly in hand when it came to writing the tariff. After all, they were the only "full" members of the WEPEX steering committee. Everyone else had "advisory" status.

But if the utilities dominated the WEPEX group, the power marketers cannot have been the decisive voice. Because the utilities' interests were often opposed to those of the power marketers, they sat on opposite sides of the markets. The utility executives also did not think that the power marketers had any particular advantage in understanding. For example, SCE's highly influential Vikram Budhraja pointed out that the power marketers had mostly expertise in the Natural Gas sector, which did not apply to the electricity system:

> The Enron viewpoint was not consistent with our thinking on how a power system operates. Gas, you have a lot of storage that is available, real-time operations don't mean the same thing [as] they do in electricity. We didn't think those things directly applied, but they influenced a lot of regulators and legislators.[33]

Vikram S. Budhraja, Southern California Edison; Barbara Barkovich, California Large Energy Consumers Association; Richard Ferreira, Sacramento Municipal Utility District; Elena Schmid, CPUC Division Of Ratepayer Advocates; Tom McGuiness (By Bruce Hamer) Los Angeles Department Of Water And Power; Jerry Jordan, California Municipal Utilities Association; Bill Carnahan, City Of Riverside, Michael Mcdonald, Northern California Power Agency; Ross A. Clark, Mock Resources; and Daniel Waters, Southern California Public Power Authority.

[32] "Letter from WEPEX Steering Committee to Dan Fessler, president of the CPUC, dated February 20, 1996," ArchiveX Internet Archive, https://web.archive.org/web/20000817212105/http://www.energyonline.com/wepex/, capture from 11/09/1999, last accessed 12/11/2019.

[33] Interview with Vikram Brudhraja, 02/02/18.

The skepticism is documented in the archival sources as well.[34] Dominated by the utilities, the WEPEX steering committee was thus bound to be critical of arguments provided by power marketers. But even if the steering committee was open to political maneuvers, the design work itself took place in relatively small teams. For each design question, the steering committee organized small teams that dealt with specific topic groups and were headed by project managers.

There was a governance team, which was supposed to figure out the best organizational structure for PX and ISO. Bidding, settlement, and billing teams sorted out how the market structures would operate and how physical dispatch could be integrated with markets. The transmission management team ("Transmission Protocols and Services") developed a solution to the pricing of transmission capacity. The Dispatch System Integration Team was responsible for questions regarding the systems CAISO's required to execute grid management, and the Regulatory Coordination and Filings team handled the interaction with CPUC and FERC. Debbi LeVine, who initially joined WEPEX as an engineer working for the Metropolitan Water District in Southern California but eventually moved to CAISO, remembers the work vividly:

> There must have been at least a dozen different teams. One would work on different cases of the market design. How are you going to handle ancillary services versus how are you going to handle congestion management versus how are you going to deal with bidding and that type of structure along with ISO? Most of those were in the PX teams, and I actually had staff when I was working at WD, I had people on both the PX teams and the ISO teams.[35]

The steering committee would meet every three weeks and assess the teams' results. But the teams would work continuously. Their size would vary and often overlap with working groups that the utilities organized internally.[36] For example, on January 29, the minutes state that "the

[34] See, for example, criticisms of Enron's position by SCE in "Reply Comments of SCE (U-338-E) on Commission Proposed Policy Decisions," Box 18, Folder 42a, *CPUC*, pp.3-4.
[35] Interview with Deb Le Vine, 11/29/2017.
[36] Interview with Carmella G., 11/28/2017.

DISI team was asked to evaluate other potential consultants to develop the specification for the telecommunications infrastructure. Team Leaders were delegated the authority to make the selection, but to use a disciplined and documented approach. Funding for the consultant will need to be approved by the steering committee."[37] PG&E and SCE selected a few market designers from their ranks to join the team and gave them the power to make decisions. At the next meeting of the steering committee, the team would present its results, the proposal would be discussed, and then approved or modified. All stakeholders had a chance to provide input to this decision. Debbie LeVine remembered the process like this:

> So, the decision-making process was first at the work groups level, and the work group would come up with, "Here's how we think that congestion management should be designed." Okay? They would put together a presentation and bring it to the steering committee. The steering committee would ask questions, hash it out, potentially send them back to the drawing board because concerns of one thing over another, and it was pretty much majority vote at that point.

The teams methodically assessed alternative proposals spelled out in the language of mathematical models, conducted empirical analyses based on the theoretical models, and then presented their recommendation to the steering committee. For example, Robert Wilson helped to create the rules for the PX spot market auctions. The basis for this work was an auction design by William Vickerey.[38] Regardless whether the members of the teams were primarily utility employees and industry experts or academics, the intellectual foundation of their work was theoretical blueprints and economic theory.

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[37] "WEPEX Steering Committee Minutes January 29, 1996, San Diego California," ArchiveX Internet Archive, https://web.archive.org/web/20000817212105/http://www.energyonline.com/wepex/, capture from 11/09/1999, last accessed 12/11/2019.

[38] "Activity Rules for the Power Exchange" and "Priority Pricing of Ancillary Services," Reports to the California PX and ISO Trusts for Power Industry Restructuring, March and May 1997 by Robert Wilson, (henceforth, Wilson Activity Rules for Power Exchange), ArchiveX Internet Archive, https://web.archive.org/web/20000817212118/http://www.energyonline.com/wepex/reports/reports2.html, capture from 02/04/1997, last accessed 04/11/2020.

This suggests that the argument about power marketers' influence on the design features is *incomplete*. Power marketers influenced mostly the political processes surrounding WEPEX. This suggests an alternative reading of the three restrictions that supported the interests of the power marketers: they bear out political decisions of the Blue Book proceedings. As outlined in the last chapter, the MOU introduced the equality and separation provisions that sketched the basic framework of the California system. The three WEPEX decisions can be seen as implications of these two provisions.

The first decision was to prevent the ISO from clearing the markets. This was meant to realize the equality provision. Any attempt to optimize across schedules submitted by scheduling coordinators would have put the positions in less efficient markets at a disadvantage and violated a presumption of equal treatment. The second restriction just follows from the first: since the ISO was not allowed to adjust across markets, the scheduling coordinators could not submit bids that exceeded their schedules. The third restriction served to implement a transmission pricing system that would obey both the separation and equality provision. To keep the function of the ISO away from the markets, the sale of transmission capacity should occur outside the ISO. However, the PX could not see the entire dispatch schedule because it was just one of several different scheduling coordinators. Accordingly, it could legitimately deal only with congestion that its preferred schedules would create.[39]

If the design only bears out the MOU and does not represent direct influence by the power marketers, one question remains open. If the teams operated on the basis of market design expertise and followed technical considerations, why did they create protocols that not only realized the inefficiencies implied by the MOU provisions but actually multiplied them?

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[39] See chapter 5 and also Stoft, "California's I.S.O.: Why Not Clear the Market?" 39.

In the last chapter, I showed that the MOU provisions actually rendered the methodology of market designers inapplicable to the global problem of economic dispatch. But the separation and equality provisions did not specify how exactly the market clearing process in the PX would work or how the PX should interact with the ISO. At the very least, the market designers could have tried to minimize the differences between the different market processes. If it was necessary for the ISO to represent the grid as a whole in its market operations, why did the PX not assume this representation as well? Conversely, if the PX followed least-cost dispatch on the basis of a two-sided auction, why did the ISO not organize its imbalance markets accordingly?

These questions point beyond the influence of power marketers. To answer them, we have to look at the design process and analyze the technical work on its own terms. In a first step, I will examine how engineers settled on the problematic division of labor and how this created problematic inconsistencies between the different submarkets. Then, I will show how the design work in the team for Transmission Management included decisions about the congestion management system and rules for SCs. Here, I reconstruct how blindspots in the blueprint for these markets derailed the team work.

9.3. Division of Labor in the WEPEX process

When the steering committee organized the division of labor between the different teams, they assumed that the construction of the markets could be modularized. Modularization means that different components of a larger system can be developed independently from each other. A given market would provide inputs for another, but the markets would otherwise operate autonomously. Explicit links between specific markets can be established by design, but these links simply establish input/output relations.[40]

Teams that worked on the implementation of the different markets of California's architecture therefore worked separately from each other. They would merely spell out what inputs and outputs of their market would look like so that the other teams could include those specs in their own work. When they finished their work, the teams submitted their proposals to the steering committee. The steering committee then held public debates to discuss how the different pieces of the system would work together.

Since these debates often involved dozens of people with separate interests, compromises were hard to come by. Several questions were left undecided until David S Freeman came in to run the smaller TAC process that created the organizational and technological infrastructure for the ISO and the PX. This meant that the actual integration of the different subsystems was not determined until late in 1997 when TAC took over and the nascent CAISO and PX began to build the specifications for the software that would realize the provisions of the WEPEX process. The utility officials decided other issues ad hoc. Either way, the division of labor meant that the teams worked in relative isolation and that the linkages between their work were not reflected in the decisions to adopt individual proposals.

Modularization had substantial implications for the design work. Whenever markets were supposed to interact with each other—as in the case of energy and transmission capacity markets—the teams had to find ways to resolve these interdependencies into simple input/output relations.

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[40] Modularization is a very powerful technological foundation for innovation and progress, precisely because it allows us to harness the power of hierarchies and parallel work processes in the development of complex products. Carliss Y. Baldwin and Kim B. Clark, *Design Rules: The Power of Modularity*, vol. 1 (Cambridge, MA: MIT Press, 2000).

For example, the institution of Schedule Adjustment Bids (SABs) organized the interrelation between energy and transmission capacity markets. Recall from chapter five that the ISO ran the congestion management system and the market process to allocate transmission capacity. But the PX and the SCs ran the energy markets. To bridge the organizational boundaries, traders in the PX would submit separate SABs. These would become inputs to CAISO's congestion management software. The ISO would not check these SABs but take them as simple inputs to compute an advisory redispatch schedule. Conversely, this schedule would become a mere input to the PX. Since the modularization forced the design teams to reduce the market interactions to simple input/output relations, the different markets had no way to check the logic underlying these inputs.

This became a problem whenever there were interdependencies between the markets that could not be reduced to this simple input/output logic. For example, when the designers created the SABs to organize the input/output relation between the energy markets and the ISO's congestion management system, they ignored that the SABs were meant to reflect the costs for the global redispatch of the system.

To make this problem a little bit clearer, it is important to remember the basic logic of the different markets. Together, all the different energy markets are supposed to produce the optimal dispatch, i.e., the best combination of generators to meet aggregate demand in the system. The congestion management system is supposed to ensure that the markets also obey the transmission capacity limits. In the next sections, I will discuss how the market designers tried to solve this problem. For now, it merely matters that the economic dispatch requires a solution that optimizes the relation between all generators relative to the transmission system. Accordingly, all markets are interdependent. In California, traders made sure the markets converged by arbitraging the price differences between all SC markets. Now, since all energy flows interact with each other, the best use of the transmission system depends on all inputs to the grid. This means that the transmission capacity markets are *also* interdependent, and that meant that the designers should have created room for arbitrage trades between different portfolios of SABs. Every time an SC submitted SABs, traders should have had an opportunity to arbitrage price differences between these bids and SABs of other SCs.

The ISO always develops the advisory redispatch relative to SCs individual portfolios. If there was no mechanism to balance the price differences between the SABs of these portfolios, the redispatches would be inefficient, i.e., the ISO would solve congestion in individual schedules that might be resolved more accurately in a global redispatch. Without arbitrage, there would be a nonrandom discrepancy between the market representation of congestion and the real congestion. The ISOs would resolve these inefficiencies in real time. In this intrazonal congestion management system, the costs would be socialized, and anyone with an infeasible schedule would be paid for the necessary adjustments. Accordingly, if traders could maintain these inefficiencies, they could be paid to relieve congestion that they had themselves created.

In sum, without a mechanism to arbitrage price differences between SABs in the portfolios of different SCs, there would be a mismatch between the fragmented market mechanism and the need for a global solution to the transmission congestion problem. This mismatch created room for games that created artificial mismatches and then got paid to resolve them. There should have been a system of rules in order to ensure that traders could arbitrage differences between SABs logged by different SCs. This would have given the market a chance to find the global ordering of opportunity costs for redispatch and allowed for an efficient allocation of scarce capacity.

However, to create protocols for arbitrage businesses across SCs' portfolios, teams working on the congestion management systems would have needed to cooperate with teams working on the protocols for SCs. Since this did not happen and since the logic of arbitrage protocols could not be reduced to simple input/output relations, the mechanism was never put into place. Since the teams did not cooperate directly with each other, they simply *noted* this problem without ever resolving it.

How this issue fell through the cracks of responsibility becomes apparent in the activity rules for the PX. These rules concern the question of how tenders can be submitted, when they can be submitted, and how they can be changed. In these rules, Robert Wilson explicitly noted the need for an arbitrage mechanism between SCs. But though the rules are designed to prevent gaming, they do not explain how the arbitrage business might work. The proposal merely states that "in the short-run the arbitrage can be done during congestion management after the ISO's advisory redis-patch by enabling a market for trading Inc/Dec options among the various scheduling coordinators."[41] Since the team was not responsible for this type of transaction, it had no information about the underlying mechanism and could not address the problem.

The transmission management team had no power to determine these rules either. The needed rules would have concerned the relationships between the SCs and not between the SCs and CAISO. Accordingly, the issue fell through the cracks of responsibility, and the functionality was not developed until the markets opened. In a filing to FERC in 1997, the WEPEX Steering committee voted to create a "bulletin board" mechanism that would facilitate such trades. But in the handbook for the PX from 1999, the author merely hints to a future software update that might allow such inter-SC arbitrage trades.[42]

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[41] "Wilson Activity Rules for Power Exchange," p.16.
[42] Daniel Kirshner, "Did Power Marketers Cripple the California Power Exchange? A Response to Steven Stoft," *The Electricity Journal* 10, no. 7 (1997). The handbook is at "California Electricity Market Primer, prepared for the CalPX Board of Governors (February 2000)", R400.010, Box 18, Folder 12, Electricity Oversight Board Subject Files, *CSA*.

Market designers with an economic background were aware of the problem that derived from the extreme division of labor. Robert Wilson, the prime architect of the PX's activity rules, publicly complained about the low degree of cooperation between the teams and warned that gaming would take place if the interrelations between the different markets were not going to be sorted out.[43]

However, the steering committee did not agree. The market designers on the steering committee had an engineering background.[44] Since they viewed the markets as simply a part of the larger electricity system, they viewed the markets with system functionality in mind. To the extent that the grid management required links between markets, they explicitly designed the links according to an input/output logic. This approach implicitly assumed that markets were closed systems and that traders would react only to the incentives that characterized one system at a time. The engineers did not approach the task by examining the incentives that traders faced in relation to the market system as a whole. Accordingly, they underestimated the need for market protocols that were globally consistent. This suggested that the division of labor could be modularized. The engineers faced tight deadlines, assumed that interconnections between markets were negligible, and came to the conclusion that potential interactions were not necessary for system operation and could be worked out once the system got off the ground. Accordingly, problematic inconsistencies between market protocols persisted until after the markets opened in 1998. The mistaken belief in modularization of market design work thus explains the inconsistent protocols between different parts of the market architecture.

[43] The complaints are referred to in Steven Stoft, "What Should a Power Marketer Want?" ibid., no. 5: 40.
[44] Market designers with (electrical) engineering background like Vikram Brudhraja at SCE, and Ziad Alaywan at PG&E dominated the Steering Committee because they represented the utilities.

However, it is just one part of the story. I will now move on from the division of labor and consider the work of the different market design teams itself. The next sections will explore why the teams created a congestion management system that was liable to a variety of games and the flawed rules for SCs. In the teams, designers tried to develop institutions that would realize the market mechanisms' theoretical blueprints described. I will explore how the design work made use of these blueprints. To this end, I will first reconstruct how market designers create these blueprints and how this gives rise to blindspots. To demonstrate this problem, I reconstruct the blueprint for the transmission capacity markets. Finally, I show how the designers used this blueprint, fell prey to its blindspots, and made decisions that created incentives for Enron's congestion games.

9.4. The Conceptual Work of Market Designers

Market designers seek to create institutional and organizational infrastructures that realize the market mechanism as described by a theoretical blueprint.[45] To understand this design work and under what conditions it fails or succeeds, it is first necessary to reconstruct the internal logic of the blueprints. I will show that the way market designers develop these blueprints is liable to blindspots. By tracing their impact on processes of market design work in WEPEX, we can then reconstruct why the designers failed to realize the blueprints as envisioned.

The *conceptual* goal of market design is to create the formal description of a mechanism that induces individuals to act in ways that mimic a perfectly competitive market.[46] This perfectly

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[45] The process is not linear, but involves a circular back and forth between model and institutional structures. The circularity derives from the fact that the theoretical models are practically underdetermined. Breslau, "Designing a Market-Like Entity: Economics in the Politics of Market Formation."
[46] Roth, "The Economist as Engineer: Game Theory, Experimentation, and Computation as Tools for Design Economics," 1341.

competitive market is a mechanism that links strategic interactions between individuals to a desired aggregate outcome. The most basic version of a perfectly competitive market is familiar from elementary microeconomics. Here, the desired interactional dynamic is simple. If rational buyers of a commodity compare offers until they find the best one, and if perfect competition between suppliers forces these suppliers to charge no more than their marginal costs, the process will tend toward an equilibrium in which supply equals demand. The classic vision of a Walrasian equilibrium is a theoretical endpoint at which all profitable trades have been made.[47]

The endpoint has desirable properties that are the goal of market design. In a short-run equilibrium, the allocation is allocatively efficient and Pareto optimal: no one can increase their utility by altering their behavior and no one can improve their position without making someone else worse off.[48] In the long run, companies will innovate to reduce their costs and stay ahead of increasing competition. As innovations diffuse through the industry, the total price paid by consumers and the total cost expended by producers will be minimized. Economists refer to this as "productive efficiency." At the same time, normal profits will be maximized—every firm in the market earns enough to cover their opportunity costs. This means that the total surplus is maximal, i.e., consumers' benefit plus sellers' normal profits. The short-run and long-run welfare benefits of perfectly competitive markets are what economists mean when they say that markets are efficient.[49]

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[47] The Walrasian equilibrium concerns the entire economy. In market design, the equilibrium of interest is usually Marshallian or "partial." This means that the mechanism only concerns one or a few goods since the formal descriptions of the mechanisms that lead to equilibrium are consistent with each other. Mas-Colell, Whinston, and Green, *Microeconomic Theory*, 1, 311-34. Market designers refer interchangeably to the two equilibria.
[48] Robert Pindyck et al., "Microeconomics 12th Edition," (Boston, MA: Pearson Education, Inc, 2012), 39.
[49] Mas-Colell, Whinston, and Green, *Microeconomic Theory*, 1, 311-43; Stoft, *Power System Economics*, 52-59. Since Marshall's first attempts to define welfare economics as a particular field of study, welfare means the material requisites of well-being. Alfred Marshall, *Principles of Economics*, 8th ed. (London, UK: Palgrave Macmillan, 2013 [1890]), 45-46.

The ideal of a perfectly competitive market is the *starting* point of economic design.[50] Less an assumed reality than a guiding ideal, the model provides a goal (the welfare benefits), a mechanism to get there (dynamic interactions between individuals) and a set of assumptions that need to be met to realize the mechanism (rational utility maximizers, perfect competition, perfect information, etc.). When designers approach a new industry or allocation problem, they begin by analyzing its characteristics with respect to this ideal. After differentiating the commodities to identify the number of potential markets, they analyze the industry structure and search for *challenges* that must be taken into consideration. These challenges appear as potential violations of the various assumptions of the perfectly competitive market. Empirical research guides this investigation.

Several subfields in economics analyze how nonideal conditions, such as imperfect competition, incomplete information, or bounded rationality, impact market processes and the resulting equilibria in specific industries. A battery of theoretical concepts and methodological tools aids the examination of such sources of "market failure." For example, a basic challenge would be information constraints: maybe buyers do not know who all the suppliers are, or maybe there are quality differences between products. A more complex constraint is product complementarity: the value of goods depends on how many other ones you already have. Other constraints derive from space and time: there may be transportation costs, or goods might spoil if they are not consumed before a certain time. Importantly, these empirical analyses are driven by the examination of cases that violate the explicit assumptions of a perfectly competitive market.[51]

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[50] Breslau, "What Do Market Designers Do When They Design Markets?"; Dani Rodrik, *Economics Rules: The Rights and Wrongs of the Dismal Science* (London, UK: Oxford University Press, 2015), 13.
[51] K. Puttaswamaiah and W. P. Hogan, *Growth of Economics in the Twentieth Century: Theories and Practices* (Enfield, NH: Isle Pub. Co., 2009).

After identifying sources of market failure, the designer considers how the challenges could be met through market design. Game theory, experiments, theoretical arguments, and empirical knowledge guide designers in specifying rule systems that augment market processes.[52] For example, if the problem is that sellers have an interest in hiding the true cost of their commodity ("private information"), an auction format can be devised that incentivizes market players to reveal their true cost (e.g., Vickery auction). In each case, the designers seek to conceive a system of rules in which a given problem can be resolved through processes of competitive trading.

The resulting blueprints are still theoretical: they develop a formal market mechanism that links a rule-structure to behavior that leads to an efficient equilibrium. The proposal specifies a set of assumptions that need to be realized when the mechanism is implemented. The assumptions need to be deemed feasible, i.e., it must be possible to realize them. Up to the point of implementation, economic design is therefore a *circular* process that moves back and forth between empirics (the practical context of design), the theoretical ideal (i.e., perfectly competitive markets) and the new mechanism. The circular movement is organized by an examination and specification of *assumptions*. Based on research about the ways the industry may obstruct these assumptions, designers develop institutional blueprints that can overcome these challenges. The solutions have their own sets of assumptions, which are supposed to guide the process of implementation—that is, because the assumptions specify how the social process needs to be altered to accommodate the mechanism.

Conceptually, assumptions are thus crucial in three ways: they mediate the circular movement between abstract ideal and empirical reality; they establish where economists look for

[52] Roth, "The Economist as Engineer: Game Theory, Experimentation, and Computation as Tools for Design Economics"; "What Have We Learned from Market Design?" *Innovations: Technology, Governance, Globalization* 3, no. 1 (2008); Stoft, *Power System Economics*, 74,82,93.

obstacles that their mechanisms need to solve; and they guide the subsequent implementation. The viability of economic designs therefore depends crucially on completeness and feasibility of the assumptions. Completeness means that the designs need to specify all assumptions that identify elements of the social process that would have to be changed for the mechanism to work. Feasibility means that it must be possible to manipulate the social process in such a way that the assumptions are met.

The crucial role of assumptions thus specifies conditions for the possibility of successful market design work: the assumptions of the model need to be complete and they need to be feasible. This requirement provides a vantage point for the analysis of technical market design work: by looking for blindspots, we might find reasons why a given market design cannot be realized as anticipated in processes of technical design work.

A blindspot refers to (a) an aspect of social reality that is in tension with the mechanism (i.e., an obstacle) and that is (b) *not* included in the design as an explicit assumption. Blindspots are those *implicit* assumptions that pose an empirical challenge to the theoretical mechanism. They refer to holes in the reasoning process that establishes new mechanisms. One reason why economic engineering might be liable to blindspots has to do with the mathematical tools that economists use to justify their mechanisms.

Market designers primarily draw on tools for the analysis of constrained extrema that originate from Newtonian mechanics as well as the various developments upon this basic concept, such as linear and dynamic programing techniques within the domain of control theory.[53] The discipline combines these tools with an axiomatic understanding of truth. This means that truth is

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[53] Amadae, *Rationalizing Capitalist Democracy: The Cold War Origins of Rational Choice Liberalism*, 220-23.

located on the level of mathematical entailment relations rather than, for example, experience.[54] This understanding of truth entails a very general procedure to establish the validity of a new mechanism. First, they define the obstacle the mechanism needs to resolve as an optimization problem under constraints, e.g., find the equilibrium with desired welfare condition, given that trade must follow certain conditions. Then, they develop the mechanism as a set of rules that characterize a trading process (e.g., the process has several steps, decisions exist under limitations, etc.).

The resulting trading process itself is described as a system of equations that captures the decision-making process of agents under the mechanism. The mechanism is defined as a mathematical model, a stylized representation of the world under the assumed framework of rules in which behavior takes the form of a mathematical function. The economists then analyze the resulting system of equations with the tools of multivariate calculus and optimization theory.[55]

They establish the validity of the mechanism by showing that the trading process converges on an equilibrium that fulfills the conditions of the optimization problem. This methodological approach explains why the market appears as an information processor that implements an algorithm.

Such mathematical modeling is liable to blindspots for two reasons. First, economists will only specify those assumptions if necessary or if it is required for the mathematical demonstration of the link between action and aggregate outcome. Many more assumptions can be stated, and

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[54] Roy E. Weintraub, *How Economics Became a Mathematical Science* (Durham: Duke University Press, 2002).
[55] Rodrik, *Economics Rules: The Rights and Wrongs of the Dismal Science*, 30. For example, see the topics covered in Kevin Wainwright and Alpha C. Chiang, *Fundamental Methods of Mathematical Economics* (Boston, MA: McGraw-Hill, 2005). The mathematical models for static or dynamic analysis are all either related to multivariate calculus (matrix algebra for systems of simultaneous equations, differential and integral calculus, differential equations, difference equations) or linear and dynamic programming.

economists often do. But on the level of conceptual argument, it is the rules of mathematical inference that determine what assumptions *need* to be specified.[56] For example, in the standard account of perfectly competitive markets, an explicitly stated assumption is that demand varies with quantity. This assumption is necessary because it determines the slope of the demand curve. However, the equally important assumptions that there are laws and free contracting are not necessarily stated because they have no correspondence in the mathematical framework. The methods stem from physics where they were not used to build institutions but to describe "pure mechanisms." Accordingly, there is a potential mismatch between the explicitly stated assumptions and what may be necessary for implementation. This can give rise to blindspots.

Even apart from contexts of application, it is possible to isolate at least three blindspots that affect economic models of market mechanisms generally. Indeed, these blindspots are embedded in the way mathematical modeling works. Mathematical models and their associated rules of reasoning rely on assumptions that are not usually stated because they do not introduce variation into the model. Instead, they are embedded in the structural *form* of the model.

By virtue of using a specific mathematical representation, the designers settle on hard claims about the ultimate nature of the world. For example, the linear model characteristic for much work in quantitative sociology assumes that there are fixed entities with varying attributes. The assumptions that characterize this implicit ontology are purely a function of the mathematical form, not of any substance presented with it.[57] They are blindspots in the medical sense of the

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[56] Which assumptions need to be stated does not follow a strict logic but is established pragmatically—i.e., you could always end up with infinite lists of assumptions. How many you end up having to include depends on rules of proof that are established by convention. This is the deeper lesson of the amusing conversation between Achilles and the Tortoise in Lewis Carrol's famous essay "What the Tortoise Said to Achilles," *Mind* 104, no. 416 (1895). For a more rigorous exposition of this point, c.f. W. V. O. Quine, "Truth by Convention," in *The Ways of Paradox and Other Essays*, ed. W. V. O. Quine (Cambridge, MA: Harvard University Press, 1976).
[57] Andrew Abbott, "Transcending General Linear Reality," *Sociological Theory* 6, no. 2 (1988): 38-40.

term. Here, a blindspot is an obscuration of the visual field. It results from the absence of photo-receptor cells on the optical disc where the optic nerve passes through. Even though the presence of the nerve creates a gap in the vision, it is also central for the functioning of our eye. The assumptions that are embedded into the form of mathematical models are similarly constitutive for the way they can represent the world. Economists' models carry within them at least three such constitutive blindspots.

First, by describing behavior in functional form, i.e., as either a complex decision function, a linear program, or a simple supply curve, the models rely on the assumption that individual behavior can be described by a *rule*. Definitionally, a mathematical function is a mapping of a set into another set. For the function f(x): x - > y, the set of elements x is mapped into the set y according to a fixed rule. Regardless how many variables are included and how probabilistic the framework, the principle behind the mapping is fixed. To the extent that agents in a market are described by such a function, it is assumed that their decision-making follows the rule. This means that mathematical models assume *uniformity* in the logic that animates individuals' behavior.

Second, the mechanism is assumed to be independent from external influences. To link the strategic interactions of players to a particular outcome in a system of simultaneous equations, there can be no interactions between players that are outside the scope of the model. If other or additional moves were possible, the equilibrium could shift, disappear, or be underdetermined. Accordingly, the rules of mathematical reasoning require that the market process described by the system of equations is a closed and exhaustive system.

Third and relatedly, any change in the market must conform to the structure that is anticipated by the model. Economists assume that all factors that determine activities in a market become variable in the long run. But to model long-run equilibria, what these factors are, and how they are related must be known. This is simply another consequence of the way systems of equations need to be solved to link individual behavior to aggregate outcomes. Any intermittent change to the structure of the interactional dynamic would destroy the model's link between behavior and outcome. Change must therefore be encapsulated by the logic expressed by the functional relations between the variables of the model. Economists usually assume incremental changes to cost based on changes in capital stock and other variables of interest.

All three assumptions are unrealistic and therefore point to features of the social process that might run up against the intended market mechanism. The assumption that individual decision-making has a uniform structure poses substantial obstacles to realization because our frame of reference is not usually fixed. We already act within a richly layered everyday lifeworld that transcends a present context of action. Any one context of action can be inflected by considerations that telescope out almost arbitrarily into other contexts and involvements.

For example, when you are playing a board game, you can decide on moves relative to the game or relative to the social relations between the players. And people can think about these relations in terms of a variety of time horizons and descriptions (e.g., contributing to a fun party v. respecting a long-standing friendship). Intentional action can therefore transcend the parameters of a current situation in ways that are hard to generalize, or as Alfred Schutz put it, the world within potential "reach" is extremely flexible and temporally variable.[58] That means that individuals may confront a decision (i.e., buy or not buy) in radically different ways. Even if the basic goal is to maximize utility relative to stable preferences, the considerations to fulfill this goal can vary drastically. What counts as utility maximizing can shift relative to the frame of reference. In short,

[58] Alfred Schutz and Thomas Luckmann, *The Structures of the Life-World*, 2 vols., vol. 1 (Evanston, IL: Northwestern University Press, 1973), 17.

different people may be operating against different time horizons, different dimensions of profit, etc.

Even more heroic is the assumption that the market is closed off from external influences. Not only are markets embedded in political, regulatory, and social structures on which they depend, markets are also typically interdependent in ways that are difficult to anticipate. The developments in an industry that supplies goods as inputs for another can impact the structural conditions in a third. In real life, it is rare to have spheres in which patterns of observable actions are truly independent from external influences (like an experiment or certain games).

For similar reasons, the assumption of predictable change is problematic. A perfect market is characterized by a pernicious, long-run dynamic: Economic profits decline as competition gets fiercer. Innovation allows companies to drive up profits until those innovations have diffused throughout the industry. But nothing suggests that companies will simply innovate improvement to existing products and do so in a way that mirrors the incremental changes required by the model. If the dynamic of perfect competition cut into their profits, companies will typically seek to change the logic of competition itself—they may come up with ways to change market rules, develop products that shift the landscape of demand, or disclose entirely different markets. Since the logic of long-run competition is hostile to the self-interest of players, they have all the reason to push against it and thus contradict the assumption of predictable change. The great, theoretical advantage of markets is that it is a hostile environment for players—it requires them to become inventive. In pitting players against each other, markets always pit them against the system itself as well.

However, the three assumptions are not *inherently* problematic. It may very well be possible to create institutional structures that realize and enforce them. It is important to dwell on this point for a moment. The argument here is not that the blueprints will always necessarily fail or that these assumptions are fundamentally problematic. The very point of economic engineering is to change the social process to conform to the assumptions of the model. Accordingly, the validity of these assumptions does not depend on how accurate they are. It depends on their *feasibility*. Precisely this is the issue with the three assumptions considered here. It *may* be possible to realize them. But their realization poses substantial obstacles that may derail the market mechanism if they are not recognized.

To appreciate these difficulties, it is instructive to move over to another market design experiment for a moment. Professors from the University of Chicago and the Harvard Business School developed a spot market for Feeding America in 2005. The market was designed to efficiently allocate donations to a network of food banks. It used a scrip currency that the system distributed relative to consumption to food banks on a daily level. The bidding process was entirely virtual, the beneficiaries of the market (those who would eat the food) were excluded from the market, and there was no way to profit. Neither could money be saved, nor could it be converted into dollars.[59] Accordingly, the logic of interaction was perfectly sealed off from other transactional systems. As a pure allocation mechanism without profit opportunities, it did not require room for innovative local behavior, and also avoided incentives that pitted individual food banks against the system.

In the case of these synthetic markets, the virtual environment does provide the opportunity to create perfectly closed systems of interaction and adaptation of behavior *can* be controlled. But the difficulties are supreme: market participants' options need to be reduced substantially, the allocation problem must be very simple and clear, and a scrip currency is required to seal the markets

[59] Prendergast, "The Allocation of Food to Food Banks."

off from external influences. The implicit assumptions *can* thus come with substantial control requirements for the markets. However, this does not have to be the case. It is imaginable that some market mechanisms work well even without explicit enforcement of the implicit assumptions. For example, a weekday market hardly ever has to enforce the uniformity assumption. The rules about buying and selling are evident by custom, and few people will have reason to circumvent the basic rules of interaction.

My point is that the assumptions are usually unrealistic and might therefore require explicit enforcement. But as long as these assumptions remain *implicit* and do not shape the implementation process, they might lead to design decisions that fail to realize the market mechanism as intended. Whether that is the case depends on the context of application and the other assumptions of the model. Accordingly, the implicit assumptions merely provide a useful vantage point for a sociological analysis. As for blindspots, the implicit assumptions mark features of the world that contradict the mechanism but are not explicitly considered. Not enforcing them might create operational problems for the mechanism. Accordingly, a sociological analysis should trace out whether the implementation of the model violates the implicit assumptions.

Though a sociological analysis should always deal with the specificities of a blueprint, the three implicit assumptions I have outlined should serve as a starting point. They mark a general condition for the possibility of successful market design. Designers must be able to evaluate the impact of the three implicit assumptions, and if they threaten to derail the market mechanism, they must be able to enforce these assumptions with suitable institutional structures. If this proves impossible, the design is infeasible and the market design must fail. Either way, we can now analyze the WEPEX process by asking whether the blindspots affected the design process and led to problematic decisions. In what follows, I am going to apply this analytical strategy to the creation of

California's congestion management system. The first step is to reconstruct the blueprint the designers were trying to realize.

9.5. The Blueprint for California's Congestion Management System

The central question of electricity market design is how much coordination markets can perform before the system operator has to take over. During the WEPEX proceedings, the transmission management team was trying to figure out whether decentralized markets could help with the allocation of transmission capacity.

Finding the economic dispatch is complicated by the presence of limited transmission capacity.[60] Transmission lines have limits that restrict the amount of power they can carry. These limits might block the cheapest generator from serving an area. Such "congestion" changes the economic dispatch because a more expensive generator at a different location must take over. Without reflecting transmission constraints, energy markets could not find the economic dispatch and therefore become inefficient—they would hide the cost of switching to the more expensive generator. At the very least, this would obscure where new transmission capacity or generation should be built. At its worst, it would create negative pricing incentives. It is thus desirable to include transmission constraints into the market.

However, the physical characteristics of energy make it difficult to incorporate these constraints. The availability of capacity does not merely depend on the static limits imposed by the individual transmission lines. Electric energy travels on all available paths. If the network has loops, simultaneous flows of energy interact with each other. Depending on the interaction, they

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[60] There is a variety of other issues that complicate the search for economic dispatch. Most important is the fact that generators have non-convex production costs. This violates the assumptions of equilibrium analysis. Stoft, *Power System Economics*, 18,23,258-61. See chapter 5 for details on the challenges of electricity market design.

can increase or decrease the available transmission capacity anywhere in the system. Transmission losses and "passive" energy flows further impact capacity. The aggregate patterns of energy flows in the system thus constantly influence the capacity of each individual line. This means that any adjustment of generation in response to capacity constraints creates new limitations elsewhere. Because of these interactions, the discovery of the economic dispatch constitutes a nonlinear optimization problem. How could a market account for such nonlinear dependencies? How could decentralized individuals who are only looking out for profitable trades find a global order of dispatch that optimizes both the usage of transmission capacity and the utilization of available generation if each side dynamically influences the other?

Economists at the Electric Power Research Institute in Palo Alto developed an answer to this question. Stephen Peck and Hung-Po Chao developed a general blueprint in conversation with their colleagues Shmuel Oren, Felix Wu, and William Hogan at Harvard as well as Robert Wilson at Stanford. Apart from references in the minutes of the steering committee, reports to the CPUC and FERC as well as interview recollections, the creation of the congestion management protocols is documented by scientific publications from this time. The relevant trade journals and think tanks put out research papers whose bibliographies and acknowledgement sections document the close relationship between industry experts who worked at WEPEX and academics who developed market design blueprints.

Table 1 contains the most important technical publications from this time, ordered by procedural context. The first section contains foundational works of electricity market design, the second work that accompanied the Blue Book proceedings. The third and fourth contain work that references the WEPEX proceedings and the progressively more refined protocols for the California system. They document a clear line from the work of the market designers to the work of the teams in WEPEX to the final structure of the system.

In particular, the papers by Chao and Peck from 1996 and 1997 spell out the blueprint that guided the WEPEX Transmission Management team. The blueprint works with the MOU requirements. It describes how transmission capacity could be allocated in a market setting with bilateral contracts and an independent market for transmission capacity rights.

Table 9-1 – Transmission Capacity Market Blueprint and Related Publications

Technical Publications for Theoretical Model of Market for Transmission Capacity	
Publications by Economists / Engineers	
Schweppe, F.C., Caramanis, M.C. Tabors, R.D. and Bohn, R.E. (1988) Spot Pricing of Electricity, Kluwer Academic Publishers: Norwell, MA. Caramanis, MC, Bohn, R.E., and Schweppe, F.C. (1982) "Optimal Spot Pricing: Practice and Theory," IEEE Transactions on Power Svstems, Volume PAS-101, NO. 9 Hogan. W. (1992) "Contract Networks for Electric Power Transmission." Journal of Regulatory Economics Vol. 4 (September): 211-242. Hogan, W. (1993) "Electric Transmission: A New Model for Old Principles." The Electricity Journal, 6(2), 18-20. Hogan, W. (1994) "Reshaping the Electricity Industry." presented at the Federal Energy Bar Conference: Turmoil for the Utilities (November 17) Washington D.C. Oren, S., S. Smith, R. Wilson and H. Chao. (1986) "Priority Service: Unbundling the Quality Attributes of Electric Power." Electric Power Research Institute. EA-4851, Palo Alto, California. Wu, F., P. Varaiya, P. Spiller and S. Oren. (1994) "Folk Theorems on Transmission Access: Proofs and Counter Examples." University of California: Program on Workable Energy Regulation (POWER).	Foundational theoretical texts that develop the idea of a contract network to represent power flows. Researchers associated with MIT, California, and Harvard.
Blumstein, C. and Bushnell, J (1994). "A Guide to the Blue Book: Issues in California's Electric Industry Restructuring and Reform." The Electricity Journal: 7(7): 18-29. Budhraja, V., Woolf F. (1994). "POOLCO: An Independent Power Pool Company for an Efficient Power Market." The Electricity Journal: 7(7) 42-47. Garber, D., W. W. Hogan, and L. Ruff. 1994. "An Efficient Electricity Market: Using a Pool to Support Real Competition." The Electricity Journal, 7(7) 48-60. Hogan, W. (1994) Efficient direct access: comments on the California Blue Book proposals. The Electricity Journal 7(7), 30-41. Joskow, P.L. (1996). "Restructuring to Promote Competition in Electricity: In General Regarding the Poolco vs. Bilateral Contracts Debate," presented at the AEA meetings, San Francisco, Oren, S.S., Spiller, P.T., Wu, F. (1995) – "Nodal Prices and Transmission Rights: A Critical Appraisal." The Electricity Journal, 8(3), 24-35 Oren, S. (1997). "Economic Inefficiency of Passive Transmission Rights in Congested Electricity Systems with Competitive Generation." The Energy Journal, 18(1): 63-84.	Discussion of Transmission Pricing Markets in the Context of the CPUC proceedings R-94-04-31. Mainly Nodal-Zonal debate.
Bushnell, J., Oren, S. (1997), "Transmission pricing in California's proposed electricity market". Utilities Policy 6(3), 237-244. Chao, H.P., Peck, S. (1996) "A Market Mechanism for Electric Power Transmission," Journal of Regulatory Economics, 10 (1), 25-60 Chao, H.P., Peck, S. (1997): "An Institutional Design for an Electricity Contract Market with Central Dispatch". The Energy Journal, 18(1), 85-110 Chao, H.P, Huntington, H.G. (1998) – Designing Competitive Electricity Markets, Kluwer Publishers, Boston. Borenstein, S. Bushnell, J, Stoft, S. (1997) – The Competitive Effects of Transmission Capacity in a Deregulated Electricity Industry, National Bureau of Economic Research Working Paper No. 6293. Singh, H., Hao, S., Papalexopoulos, A. D. (1997) "Power Auctions and Network Constraints," Proceedings of the 30th Distribution Factor Calculation HICSS-30, Wailea, Hawaii, January 7-10. Shangyou Hao ; A. Papalexopoulos (1997) "Reactive power pricing and management," IEEE Transactions on Power Systems 12(1). H. Singh ; S. Hao ; A. Papalexopoulos (1998): "Transmission congestion management in competitive electricity markets," IEEE Transactions on Power Systems 13(2) Wu, F.F., Varaiya P. (1995) "Coordinated Multilateral Trades for Electric Power Networks: Theory and Implementation", POWER Report PWP-03 1, University of California Energy Institute, June.	Theoretical Blueprint of the California Market for Transmission Constraints, follows the concept of the contract network developed by Hogan.
Walton,S., Tabors, R.D. (1996) – Zonal Transmission Pricing: Methodology and Preliminary Results from the WSCC. The Electricity Journal, 9 (9): 34-41. Gribik, P.R. "Transmission Congestion Management and Pricing in Forward Markets," Report to the WEPEX Congestion Management Subteam, September 1996 Gribik, P.R. Angelidis, G.A. Kovacs, R.R. (1999): "Transmission Access and Pricing with Multiple Separate Energy Forward Markets" IEEE Transactions on Power Systems, Vol. 14, No. 3, Harvey, S.M., Hogan W., Pope S. (1996). "Transmission Capacity Reservations Implemented Through a Spot Market with Transmission Congestion Contracts." Harvard University Oren, Shmuel S. (1997). "Economic Inefficiency of Passive Transmission Rights in Congested Electricity Systems with Competitive Generation." The Energy Journal, 18 (1): 63-84. Varaiya, P. (1997) Comparison of independent system operator structures. Symposium on Information Systems Requirements for a Deregulated Electric Power Industry. Utilities Policy 6, 2 Wilson, R. (1997) Bidding activity rules for the power exchange. Report to the California Trust for Power Industry Restructuring (March 14).	Technical Details about Implementation / Empirical Studies

Any market design needs to determine a working relationship between the putative markets and the system operator. Since the system operator uses command-and-control principles to manage the coordination of the grid in real time, the designers separated the markets in time. In California, a cascade of forward markets (mainly day- and hour-ahead) established progressively refined schedules for the delivery of energy at a future date. In real time, the system operator would then implement these forward schedules as closely as possible, adjusting them to the technical requirements of grid management. Given this structure, the congestion management markets also have to work as forward markets. From the perspective of economic theory, this introduces some additional difficulties into the definition of the market mechanism.

Forward markets are *financial* markets because they trade obligations that are contingent upon the realization of future states of the world. Since these future states are not certain and the obligations are purely financial, the proof that such markets have a socially optimal equilibrium requires more than the classic demonstration of markets' efficiency. In particular, the proof needs to show that forward markets contribute to the efficiency of the real-time markets to which they refer. Since equilibrium analysis is static, the easiest way to prove this is to collapse them into a singular complete market for so-called "state contingent commodities," i.e., commodities whose delivery is contingent upon a particular event occurring. This singular market can be analyzed with the standard tools of calculus and has an equilibrium with the welfare benefits of a Walrasian equilibrium.

To make the concatenation of the sequential markets possible, the economists assume that no new information is added. New information could create systematic tensions between trades in subsequent markets. If the traders in the real-time market had access to information that would allow them to correct previous decisions, their rationale would change between the two time points. In the concatenated market, this change would translate into inconsistency, i.e., irrational, trading decisions. The economists therefore introduce the assumption of "rational expectations." This assumption states that the forward markets correctly anticipate the prices that obtain in real time. In other words, to achieve a socially optimal equilibrium, the forward markets must anticipate the spot price accurately with only random errors.[61] At the price of an additional, explicit assumption, the designers thus found a way to connect energy markets to the work of the system operator.[62]

Against the baseline architecture of the markets, the designers could now consider how forward markets might price and allocate anticipated transmission usage. Again, the challenge was that the availability of transmission is not static but depends on the global configurations of inputs and outputs. The designers begin by offering a mathematical definition of the problem. The goal is to create a market that finds an economic dispatch of available generation capacity relative to available transmission capacity. This can be stated as an optimization problem:

$$\max_{0,q^s q^d} \sum_{i=1}^{n} [B_i(q_i^d, w^d) - C_i(q_i^s, w^s)]$$

where $B_i(q_i^d, w^d)$ is a benefit function for demand at node i and $C_i(q_i^s, w^s)$ is a supply function at node *i*.[63] These functions are defined by two variables: the quantity of demand q_i^d and the quantity of supply q_i^s at node *i* as well as the random variables w^d, w^s that represent locational idiosyncrasies. Stated in plain language, the optimization problem is to find the values for q_i^d and q_i^s that

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[61] Mas-Colell, Whinston, and Green, *Microeconomic Theory*, 1, 687-725.
[62] One important step for the implementation of this assumption is the two-settlement system as discussed in chapter 5. Other steps are more complicated and concern the "activity rules" for the different auctions.
[63] A benefit function is roughly the inverse of a demand function. It captures the marginal benefit that consumers derive from an additional MW of consumption regardless of other factors that might influence the ability to buy.

maximize benefit and minimize cost of generation. By itself, this problem would be simple. You could just solve it by plugging in different quantities until you approach a point where the derivatives of the two functions intersect, i.e., where the marginal benefits equal marginal costs. However, the optimization problem is subject to two constraints. They capture the presence of limited transmission capacity and bind the optimization process:

$$q_i = q_i^s - q_i^d = \sum_{j=1}^{n} \psi_{ij}(\theta_i - \theta_j), for i = 1, \dots, n$$

$$\psi_{ij}(\theta_i - \theta_j) \leq \bar{P}_{ij}, for i \leq i, j \leq n$$

The first constraint states that the quantity available at node i must be equal to the power flows (ψ_{ij}) on the paths between i and all other nodes j. The power flows are defined by the difference between the "voltage angles" of nodes i and j ($\theta_i and \theta_j$).[64] This constraint establishes that transactions of energy need to be equal to the physical power flows on the grid. The second constraint states that the power flow on line i,j must be smaller than the maximum power flow $\bar{P}_{ij}$ on that line. This is to say that any set of energy transmissions needs to obey the capacity limits of the transmission lines. Any combination of energy transmissions that the market finds to solve the optimization problem must also meet these constraints. The network as a whole can then be represented as a matrix that specifies the paths among all the nodes and the constraints on those nodes.

By stating the problem in this way, the designers conceptualize the market as an algorithm (linear program) that solves a combinatorial optimization problem. The problem is to find a combination of energy transfers between nodes that meets demand at lowest cost and obeys the

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[64] In A/C systems, voltage and current are represented in sinusoidal shape. The voltage angle is the phase difference between the voltage applied to the impedance of the line and the current driven through it. The difference between two locations captures how much power flow between them.

physical limitations of the system. The designers now consider the institutional structure for a market process that can fulfill the two constraints and solve the optimization problem. They propose a market mechanism that allocates tradable transmission rights. The rights entitle the bearer to use a certain amount of capacity on links in the grid. The definition of this mechanism has two steps.

The first step is to specify a system of transmission rights. The question is: how can you represent power flows on transmission links as property rights? Traditionally, contracts for the delivery of electricity specify a “contract path” for the entire quantity of energy. This is a single, direct path for the transportation of the quantity of energy that is sold. See figure 9-1 for an example. The generator at location 1 promises to sell 300 MW to consumer at location 3. The parties would specify that contract path as the shortest link 1 - 3. However, real energy flows take all available paths and are (roughly) inversely proportional to the impedances along the path of energy. Since link 1-2-3 is twice the length of link 1-3 and assuming equal impedances, *two* thirds of energy will flow on the shorter path (1-3) and the remaining third will take the other connection (1-2-3).

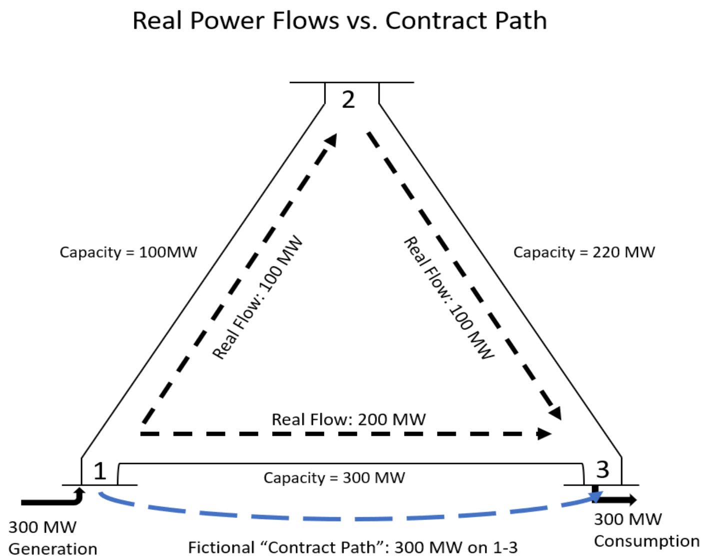

Figure 9-1 – Real Power Flows vs. Contract Path

To represent these power flows in the market, the designers create capacity rights for each directed link in the network, representing the maximum power flow. In the three-node example, this would yield six capacity rights. We get a system of property rights, where each link (i,j) has a fixed set of transmission capacity rights $(\bar{P})$ assigned to it: $\bar{P} = \left\{\bar{P}_{ij}\middle| 1 \le ij \le n\right\}$.

The second step presents the core of the proposal. The designers now specify a trading rule for the capacity rights. Crucially, this rule connects the market for transmission rights to an underlying market for pure energy. It specifies that any *energy* transaction between two locations requires a bundle of transmission rights.[65] These bundles can be described as sets of coefficients $\mathcal{B} = \{\beta_{ij}^{k} | 1 \le i, j, k \le n\}$ that represent a quantity of transmission capacity rights on links (i, j) that a trader needs to transfer a unit of *power* from node k to a node n. The simple yet ingenious idea is to specify β_{ij}^{k} in such a way that the bundles of rights represent the increase in real power

[65] Their model also deals with the pricing of transmission losses, which complicates the mathematical demonstration but leaves the basic principles unchanged. I will omit a discussion of this issue.

flow on links (i,j) due to injection of power at node k. In other words, the trading rule specifies a condition for transactions in the pure energy market; as a market participant, you need to buy or will receive transmission capacity rights that are consistent with the changes to the energy flows that a desired transaction would affect. You have to *buy* transmission rights if the transaction uses up available capacity, while you *receive* transmission rights if your transaction changes the power flows in such a way that capacity on a line becomes available.[66] With that move, both physical constraints of the optimization problem are represented in the market: no transaction is possible that does not conform to the existing power flows because they require transmission rights that reflect the changes in these flows (constraint 1). And no transaction can exceed the existing transmission capacity because the rights correspond to the real capacity of the lines (constraint 2).

The authors show how β_{ij}^{k} can be calculated as an expression of the quantity of energy inserted at node k and the current transmission capacity P_{ij}. Since individuals cannot calculate β_{ij}^{k}, the authors imagine a centralized bulletin board that states how many rights are needed or would be received for any particular transaction. The market operator would constantly update this bulletin board. The operator would use simulations to calculate the power flows at the current transaction structure and the marginal changes that new transactions would create. It would then translate these potential changes into bundles of rights that are either required or will be received.

In the last step, the transmission rights become tradeable in a perfectly competitive market. The market now features four types of possible activities: a participant can buy or sell transmission rights, and buy or sell energy if you have the requisite rights. Participants can have a variety of goals: to buy energy for their own consumption or profit from arbitrage trades in energy or capacity

[66] Counterflows cancel each other. This follows from the principle of superposition.

rights. Yet, all must engage in the same basic calculation: (1) find profitable price differences between energy at two locations; and (2) find the cheapest capacity rights that allow you to execute the transaction. The sellers of capacity rights use this calculation to determine what they should charge for the rights while the traders and consumers of energy use it to determine whose rights they should buy. All market participants are thus constantly comparing differences in price and demand levels between locations as well as shifting prices for capacity rights.

Those traders or consumers of energy who will benefit most from capacity will be able to pay most for the transmission rights. In a competitive market, the price of capacity rights will therefore tend towards the largest possible profit that can be realized in the underlying energy transaction. This optimizes the usage of scarce capacity. Since energy traders and consumers are looking to benefit from price differences between locations, the usage of generation is optimized. Certain energy transactions can increase the available capacity for subsequent transactions. This is reflected in positive capacity payments. Since this reduces the cost of transmission and opens new avenues for profitable energy transactions, all participants also search for combinations of energy transactions that maximize the available transmission capacity. Since each transaction leads to new calculations of transmission rights, the search behavior iteratively optimizes the available transmission capacity relative to the mix of inputs. This produces an economic dispatch order.

Formally, economists show that there exists a vector of prices and quantities at each node, as well as a vector of transmission rights for transactions between each set of nodes that fulfill the optimization problem. This establishes that the market mechanism is a valid solution to the optimization problem. The market works like a search algorithm that relies on humans and centralized computation alike. The computer provides information on the capacity requirements for energy transfers, and humans find profitable trades. The design relies on the following, explicitly stated assumptions: rational action (profit/saving maximization), perfect information, perfect competition, and rational expectations.

But the mechanism also involves the three implicit assumptions outlined before: uniform decision-making, system closure, and predictable change. First, a market participant is someone who makes decisions like a linear computer program, i.e., by repeatedly processing a fixed set of information in the same way. This information is: supply function, demand function at each node i, $i=1 \ldots n$, and all variables that are necessary to specify the market for transmission rights. Second, the model assumes that the energy and capacity markets are isolated from external influences. The market optimizes over the complete set of links and nodes to guarantee an optimal dispatch. All market action can be resolved in terms of this goal—there can be no actions outside the market that affect interactions inside the market. Third, change can only occur in relation to the variables included in the model. These would be changes to the supply/demand function at different nodes and as addition or subtraction of nodes and ties.

Since these three assumptions were implicit in the formal structure of the design, they did not feature during the process of implementation. They were blindspots. The next step is to show how the theoretical blueprint guided the design work at WEPEX and how the blindspots informed problematic design decisions.

9.6. Blindspots Affect the Transmission Management Team

A relatively small team was responsible for the design of California's congestion management system.[67] It brought the designers from the Electricity Research Institute together with

[67] I am ignoring the TAC phase of the process here. During this second phase, the design was implemented in software and hardware architectures of the CAISO and the PX. I will refer to some of this work in the next chapter.

engineers from SCE, PG&E, SDG&E, and Pacificorp as well as several outside consultants.[68] When the designers began to work on the capacity markets, they focused on the question of how they could realize the explicit assumptions of the blueprint discussed in the last section.[69]

Since the work was primarily concerned with spelling out the institutional structures that would realize the market mechanism, the group was dominated by market designers from the economists' camp. They viewed the market independently from the electricity system, i.e., as a structure that would incorporate external constraints set by the electricity system, but that should be evaluated on its own. Accordingly, they did not focus on the reliability requirements but on the creation of a market that would be true to the blueprint. When the team approached the task, they therefore worried primarily about meeting the explicit assumptions of the blueprint. The mechanism required rational action (profit/saving maximization), perfect information, perfect competition, and rational expectations. The team quickly recognized that these assumptions would be difficult to realize.

First, they considered the explicit assumption that market participants had to find the best trades. The quickly realized that even a rational actor might be overwhelmed by the complexity of the interactions between the markets for energy and transmission. Not only do traders have to calculate the price differences between locations and factor in the prices for the required

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[68] On the teams, engineers like Alex Papalexpopulus, Himanshu K. Singh, and Shangyou Hao from PG&E cooperated with market designers like Stephen Peck, Robert Wilson, Hung Po-Chao who had a more economic point of view. Together, they developed custom-tailored solutions for California's congestion management system. External consultants like Paul Gribik and Edward G. Cazalet helped. Robert Wilson, Vernon Smith, Charles Plott, Stephen Rassenti, and Steven R. Backerman created the rules for the Power Exchange spot auctions and tested the results of different auction formats in lab experiments. Wilson produced activity rules for the Power Exchange (in conjunction with a London-based law firm) and for the Ancillary Services Market in the ISO. C.f. Wilson Activity Rules for Power Exchange. Here is the summary of the experimental research: Steven R. Backerman, Stephen J. Rassenti, and Vernon L. Smith, "Efficiency and Income Shares in High-Demand Energy Networks: Who Receives the Congestion Rents When a Line Is Constrained?" *Pacific Economic Review* 5, no. 3 (2000).

[69] For the comparative analysis of different congestion management systems and the implementation in California, cf. also Singh, Harry; Hao, Shangyou; Papalexopoulos, Alex: "Transmission Congestion Management in Competitive Electricity Markets," *IEEE Transactions on Power Systems* 13(2), May 1998, 672-680.

transmission rights, they also need to figure out how to combine sequential transactions to find profitable trades. Since each energy transaction can impact the availability of transmission on all other links, this calculation becomes exponentially more difficult as the number of nodes increases.[70]

In a network with N nodes, any transaction between two nodes might require up to N^2 transmission rights (i.e., rights for all possible paths). Traders would have to consider these when determining whether a transaction is profitable. If they wanted to profit from several subsequent trades, they would have to figure out how the moves create new opportunities elsewhere in the system, and then consider N^2 prices for each of those potential trades, leading to an exponential increase in combinations.

The grid under the control of the California ISO had about 3,500 nodes, and the larger Western Interconnection had over 20,000 nodes. Even with a centralized bulletin board that lists all rights required for any given transaction, the possible dynamic combinations for trades quickly get into billions. Since these markets would take place on a day- and hour-ahead basis, traders would have about twenty-three hours to discover all profitable opportunities and push the system close to equilibrium. The sheer complexity of possible trades therefore posed a problem to the assumption of rational utility maximizers. It was not clear if real traders would be able to find and exploit all profitable trades.

Even if there were enough traders with sufficiently high cognitive capabilities, there would be another problem. For the market to be competitive, each location must have several competitors. But since California emerged from a set of vertically integrated monopolies, the total number of

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[70] "Official Transcript of Proceedings, Technical Conference, Thursday August 1, 1996, Volume 1," *FERC* ER96-1663, p.215 (short: WEPEX Vol. 1).

sellers in the Western Interconnection was at most around 230 between 1998 and 2001. Most supply nodes were served by individual generators. Accordingly, there would be no competition at these nodes, and prices might not reflect marginal cost. Lastly, it was not clear how all this information could be collected and dispersed among the traders. This rendered the assumption of perfect information problematic.[71]

How to deal with these problems was a central question during the WEPEX debates. The team converged on a solution whose technical rationale came from Tabor and Caramaris as well as Ellis & Cazalet. Both consulting firms had ties to MIT and California think tanks. Their solution was to structure the market around a simplified representation of the grid. The main argument for this approach was empirical. Based on an analysis of historical congestion patterns and simulations, researchers found that congestion was most likely going to be a negligible issue in California. Only a few transmission lines would likely be congested regularly. Accordingly, it did not seem necessary to allow trading on the network as a whole—a much simpler structure would capture all important sources of congestion. The system operator would then take care of the remaining congestion in real time. This would be a small amount of essentially random congestion whose cost could be socialized.[72]

Based on historical congestion patterns, the designers split California's grid into first two, then three zones and several scheduling points (NP15, SP15, and ZP26). The scheduling points represented the major switchyards where the California grid intersected with other areas of the Western Interconnection. With only twenty-eight locations to consider, the complexity of finding profitable trades would decrease significantly. Similarly, it would become easier to keep track of

[71] Ibid.
[72] Steven Walton and Richard D. Tabors, "Zonal Transmission Pricing: Methodology and Preliminary Results from the W.S.C.C.," *The Electricity Journal* 9, no. 9 (1996).

price, supply, and demand conditions in the system and publish them online in regular intervals. Lastly, since many different nodes would be bundled into trading hubs, generators at different physical locations would be competing at the virtual hubs.

Even in a market with less than a hundred active participants, the existence of only twenty-eight pricing locations guaranteed that the market would be competitive. A set of decentralized forward markets was then built on top of this simplified network, and the system operator managed the sale of transmission capacity rights largely according to the model. The use of SABs simplified the process further because buyers did not have to search for the best trade and negotiate trades of transmission rights. The ISO would simply take in all SABs and determine the opportunity cost for redispatch. In an adjustment round after the close of the day-ahead market, the traders could then agree to the recommended redispatch or pay the price of transmission capacity. This meant that the transaction costs for the search for suitable trades reduced to zero, and the problem of rational calculation became even easier.

This system implemented the logic of the original design and made sure that its underlying assumptions would be realized. With very few locations to consider, even moderately sophisticated traders would be able to find and exploit the range of profitable energy trades easily and quickly. By computing prices and collecting dispatch schedules, the system operator could easily publish the information about supply, demand, and prices centrally and thus realize the assumption of perfect information. This all but guaranteed that the forward markets would converge to an equilibrium. By combining different locations into individual zones, the generators in these zones would be facing the same demand and thus compete. This resolved the problem of imperfect competition.

But the system's convenience came at a price: the assumption of rational expectation required that the forward markets anticipated subsequent markets correctly—that is, the difference between the information represented in the forward market and the information in the real-time market had to be unsystematic. It had to be nothing but a random error to guess the spot price correctly. Of course, this is precisely what the designers were trying to ensure. They argued that the zones were defined in such a way that the predictable sources of congestion were taken care of. The information not represented in the forward market would effectively be random noise, and the assumption of rational expectations was justified. But this was a very strong requirement. For the system to work, there could be no *predictable* congestion outside the scope of the zones. The implementation thus relied on strong beliefs about what could and could not be known.

Now, the original blueprint also involved the three implicit assumptions that are embedded in the structural form of mathematical models. The design depended on the implicit assumptions of uniform decision-making, system closure, and predictable change. These constituted blindspots because the market designers did not explicitly try to enforce these assumptions with design decisions.

9.7. The Three Blindspots

I will now show how the three blindspots led to decisions that derailed the market mechanism and gave rise to the different congestion games. Since the blueprint described individual behavior in terms of linear functions, the design assumed that decision-making has a fixed, algorithmic structure. In and of itself, it is not impossible to enforce this assumption. Whether it can be realized is mainly a question of how much control one is able to impose on the market interactions.

For example, by channeling all transactions through a software interface that records, standardizes, and limits actors' choices, the designers can limit the kinds of calculations that actors can express. They can also enforce compliance with the theoretical model ex post. The electricity markets in the PJM Interconnection use both these principles. They enforce a standardized format for generators' bids and "correct" them if they exceed what is deemed the "competitive price." Either solution requires, first, a software interface that forces generators to separate their bids into different elements and make the costs transparent. Second, it requires a centralized entity that evaluates these bids relative to technical information about the generators, their operational history, and input costs. In PJM, where market designers could implement a fully centralized, security constrained dispatch, the control of all inputs by the system operator was a matter of course.

But the designers in California did not implement such controls because the uniformity assumption constituted a blindspot. There was no centralized oversight for the different scheduling coordinators. They conducted auctions or facilitated contracts. They did not they impose strong constraints on the kinds of bids that parties could submit, nor did they make retroactive changes to contracts. They simply submitted the results to the system operator. There was thus no guarantee that individual calculations would work like the optimization algorithm required by the theoretical model. As soon as traders had reason to divert from the logic assumed by the optimization algorithm, the link between profit-seeking behavior and equilibrium would break. This is precisely what happened in California.

As outlined in the previous section, the assumption of rational action, perfect information, and perfect competition required the designers to simplify the cognitive complexity of the trading process. The use of a simplified network representation put a strong condition on the fulfillment of the rational expectation assumption. The congestion patterns in the real-time market had to be nothing but random deviation from the congestion patterns captured by the zonal model of the forward markets. Unfortunately, the historical data the designers used to draw up the zones came from a time when no one made profits from congestion. Once the markets started, the congestion patterns began to change. There was now a potential difference between what *could* be known by traders in the forward markets, and what could be represented in these forward markets. Since no one enforced the consistency of traders' decisions with the rationality assumed by the theoretical model, they could begin to trade in ways that did not follow a logic of straightforward price competition and arbitrage. Instead, they figured out how to leverage their knowledge advantage against the system itself and introduced a different modality of action into the system.

This gave rise to the "dec game" discussed in chapter six.[73] In the forward market, traders in two separate companies would schedule a trade between two locations in the same zone. This trade would far exceed the capacity limits of the line that connected the two locations. But since the transaction took place within the same zone, the market for transmission capacity would not reflect this congestion. From the perspective of the simplified network model, it looked like the trade took place at the same location. Accordingly, the trade was accepted, scheduled, and submitted to the system operator. In real time, the system operator would now try to implement the schedules. Since it used the full network model, it recognized that the trade could not be executed. To deal with such real-time fluctuations, the system operator would buy "decrements" from the trader, i.e., pay the generator to decrease its output and relieve the congestion. The price for the decrement was established via adjustment bids that specified how much the lost opportunity was worth to the trader. Conveniently, the dec player had submitted very high adjustment bids and now reaped a

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[73] For a detailed examination of the strategies, c.f. chapter 6 and Lambert, *Energy Companies and Market Reform: How Deregulation Went Wrong*.

massive windfall for *not* delivering energy—energy that they could not have delivered in the first place. Since the system operator only had a couple of minutes to resolve the problem before dispatch, this game put strain on the reliability of the grid.

The game capitalized on the simplified information structure that the designers had embedded in the forward market. Based on the historical data, the intrazonal congestion patterns would indeed be hard to predict. But of course, traders could easily determine the capacity on transmission lines in zones and then *create* congestion through strategic trading. The profits from this game depended on the fact that the forward markets were supposed to be the best approximation of the real-time market. Accordingly, the real market treated all diversions from the forward market as unpredictable diversions from good faith agreements and compensated traders for it. As soon as traders figured out how they could get paid for their ability to predict or create congestion, they derailed the market mechanism (and system reliability), broke the precarious connection of mutual improvement between the two markets, and made a massive profit.

This reveals a fatal flaw: since no one *enforced* the uniform rationality implicitly assumed by the model, the traders were free to switch to a logic of action that did not compare price differences between locations but went against the system itself. This was possible because of the compromises necessary to realize the explicit assumptions of the model. The implementation of the California model was therefore at odds with itself. The zonal structure in combination with the intrazonal relief payments created incentives to act in ways that were inconsistent with the desired market mechanism. But since a more complex representation of the grid in the market was impossible in a decentralized market system, the WEPEX team would have had to create a more stringent oversight regime. It would have been necessary to detect and prevent trades that did not conform to the logic of the market mechanism.

For market designers with an economic outlook, the blindspot of uniform decision-making had a specific implication. It led them to underestimate the various ways in which the difference between the physical reality of the grid and its representation in the markets could distort the incentives that sustained the market mechanism. When making design decisions, they were preoccupied with the concerns of equilibrium analysis. This type of analysis reasons backward from a desired allocation to a set of incentives that can configure a market process that leads to this allocation. From the perspective of the rules that organized interactions in the zonal market, there was a clear path from individual behavior to an optimal approximation to the dispatch problem. Had the economists considered the many ways the real structure of energy flows might derail the logic of the incentive structure they might have noted the assumption of uniform decision-making and realized that it was precarious.

For the same reason, the blindspot led the team to specify very lax rules for the scheduling coordinators. The blueprint for the transmission capacity markets required that all energy trades had to include the purchase of rights for the transmission capacity being used by the transaction. Since the rights have no independent value, their price will converge on the marginal cost for the generator that derives the most value from using it. In California, the SABs represented the bids for transmission capacity rights. In order to enforce the assumption that the SABs reflected opportunity costs, the California system should have implemented a way to monitor the SABs. The monitor would have had to evaluate if the bids reflected the real costs a trader would incur if they had to buy their energy elsewhere. This would have curbed the worst excesses of congestion games because it would have revealed attempts to profit from the rules for intrazonal congestion management. In other words, if a company submits very high adjustment bids for energy that has little purchase value, this action indicates an attempt to profit through the congestion management system rather than an attempt to profit from the energy transaction itself.

But the WEPEX team did not write the rules that forced SCs to ensure the integrity of the SABs they submitted. It was very easy for a company to become a scheduling coordinator. To apply, any company merely had to prove that it could fulfill the hardware and software requirements to interface with the ISO, that it had a legal right to represent its clients, and that it had the necessary credit rating to act as an intermediary.[74] The motivation behind these lax rules was to ease entry into the market for SCs. Even though the construct of the SC was a central innovation of the WEPEX process and is one of the main referents in the ISO tariff, not much attention was spent on the rules governing the SCs.[75]

The implicit assumption of unitary decision-making came with the ontological belief that actors are unitary entities—a producer is a producer, a consumer is a consumer, and a broker is a broker. Accordingly, WEPEX teams did not ensure that the SCs were neutral entities. The implicit assumption of uniform decision-making meant that the activities of the SC were presumed separated from the activities of buyers and sellers. But of course, companies can subdivide into different corporate structures and then play both sides of the market. As an SC, a company could assume a brokerage role that was conceptualized as neutral "market making." It could then use the lax rules to transmit fraudulent schedules to the ISO. Many sellers acted as SCs who handled no one's business but their own. In sum, the failure to explicitly enforce the assumption of uniform decision-making led to market features that created incentives and opportunities for congestion games that allowed them to profit from violating this assumption.

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[74] *San Diego Gas & Electric*, "CAISO Scheduling Coordinator Application Protocol, FERC Electric Tariff First Replacement Vol. No. II, Exhibit No. MID-18, October 13, 2000," *FERC* EL00-95.
[75] Interview with Gary Ackerman 11/17/2017.

The second potential blindspot was the assumption of system closure—the market process must be independent from other domains of action. In the last section, I have already shown how this assumption affected the division of labor at WEPEX. Now, I consider how it affected the implementation of the congestion management system. The assumption required that all existing links of the network were reflected in the system of transmission rights. Since all power flows in the network interact, only a system of rights that captures all possible interactions can actually translate the search for an economic dispatch into a market process. If it turns out that the transmission rights do not capture all power flows, the trading rule will not lead to an equilibrium. This is because transmissions outside the market can impact transmission capacity inside the market and thus derail the correspondence between rights and flows.

This crucial requirement was not met because California's part of the grid was tied into the larger Western Interconnection. In addition, there were several municipalities (such as the Los Angeles Department for Water Resources) that had retained exclusive control over their part of the grid. California's market for transmission rights was therefore not complete. Nothing prevented traders from linking trades outside the system operator's jurisdiction to activities in California's markets. They could use external trades to influence the internal market logic and thus violate the closure assumption.

This was the essence of Enron's "Death Star" game. The game would begin when traders could confidently predict congestion somewhere in the California network. For example, they were often able to tell when the main line that connected northern and southern California was congested. They would then schedule a counterflow into the opposite direction, which would generate capacity payments for relieving congestion. At the northern delivery point, they would then move the power outside of California, e.g., to Oregon or Washington. From there, they would send the power back south and then to the initial scheduling point in California. The complete schedule was therefore circular. Since counterflows cancel each other, such circular schedules do not actually lead to power flows—they simply cancel out. But the incomplete market for transmission rights did not reflect this fact. It only reflected half of the complete schedule, so the company could reap payments for providing transmission capacity when they produced no energy at all.

The independence criterion thus points to another basic problem with the market design: the system within which the profit maximization takes place must be closed and exhaustive. A successful implementation would have either required control over the entire network or strict import/export limitations. In California, this implicit assumption was violated by a simple empirical fact that rendered its realization impossible—California simply did not have jurisdiction over the whole Western Interconnection. Dominated by economists, the WEPEX team treated the grid as an external fact that had to be represented in the market. After they decided to use a zonal structure and simply defer the task of resolving the residual congestion to the ISO, they no longer considered the problem of the real power flows beyond the model. Economic activity referred to the fictional flows between the zones, not the real physical flows on the complex network. Accordingly, there was no independent analysis to determine if the real flows could be used to create illusionary congestion patterns in California. Once again, the team decided on a set of institutional rules that violated the physical representation of the grid, but did not put safeguards into place to detect and curb behavior that would play on these misrepresentations and deviate from the required market mechanism.

Lastly, the market mechanism also relied on the assumption that market change followed the logic anticipated by the functional relations of the model. Long-term changes would have had to enter the market exclusively in terms of new transmission links, new generating capacity, new competitors, and cost reductions that would change existing supply curves. Change as envisioned by the model thus has a very definitive character that is limited to the productive elements of the industry. Since the assumption was implicit, the designers did not create institutions that limited changes to market activities. This was problematic because the blueprint introduced a tension between the short-run and long-run dynamics of the markets.

There were two modalities through which sellers could make money. They could sell electricity if they had generation assets, or they could act as intermediaries and derive profits from financial speculation such as arbitrage trades or bets on future price developments. This type of speculation was a crucial part of the market algorithm as it aided the mutual adjustment of transmission capacity and generation. It was important for the short-term efficiency of the market. But it was devastating to the long-term efficiency: arbitrageurs had incentives to *retain* productive inefficiencies because they were the source of their profits. For them, innovation is activity that increases the avenues for short-term speculative profits. As Thorsten Veblen already observed in *The Theory of Business Enterprise* (1904), expanding financial revenues often contradicts the logic of profitable production because it leads to innovations on the balance sheet that undermine long-term planning.[76] Given the presence of arbitrage traders in the market, the implicit assumption of incremental change to productive facilities would have required a stricter oversight regime to determine if innovations that contradicted the market mechanism were positive and should be retained or negative and should be curbed.

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[76] Thorstein Veblen, *The Theory of Business Enterprise* (Chicago, IL: Charles Scribner & Sons, 2016 [1904]), 20.

But not only did the implementation forgo restrictions on the kinds of changes companies could introduce to the markets, the designers also did everything in their power to increase companies' ability to innovate freely. They decentralized transactions as far as possible and put very few restrictions on traders' choices. They argued that strong limitations on the range of choices available to traders would *inhibit* the long-term equilibrium of the markets. Underlying this argument was a fundamental premise of economic theory: that competition fosters innovation that leads to efficiency gains in the long run. Since only individuals know their local contexts and have the information to solve their local problems, innovation cannot be anticipated by centralized planning. It is a question of individual ingenuity in the face of highly contextual problems. Such "creative destruction" is defined by its ability to disrupt established patterns of change.[77] The only way to get long-run efficiency in markets is thus to guarantee the individual freedom that is necessary to unleash the creative capacity that leads to new inventions. This is what the designers tried to do by decentralizing the markets as far as possible. It thus seems like the assumption of predictable change ran up against a more fundamental premise of economic theory: that markets require freedom.

9.8. Conclusion

In this chapter, I have argued that the problematic congestion management system, the rules for the scheduling coordinators, and the protocols for the interaction between the SCs and CAISO go back to a distinctly technical design work. This technical work was guided by blueprints that contained blindspots. Blindspots are implicit assumptions that must be enforced to realize the

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[77] Schumpeter, *Capitalism, Socialism and Democracy*, 82-85.

mechanism, but that are not explicitly stated. I have shown that these blindspots affected the two types of market designers differently.

The engineers on the steering committee underestimated the need to consider the interdependencies of markets from the perspective of incentives. They decided to divide the work between teams in such a way that the teams responsible for different submarkets would not coordinate closely with each other. This introduced discrepancies into the operation between the ISO and the SCs. Here, the fragmentation of market design expertise first appeared as a problem. Economists like Wilson and Stoft were aware of the need to determine the interactions between the different market settings, but did not prevail against the engineers. Since both sides used the same mathematical and conceptual language, the engineers did not recognize the fundamental difference between their perspectives. They treated the interrelations between different markets as a minor problem that could be sorted out once the markets started to operate. Accordingly, the fragmentation of expertise prevented a solution to the problem.

In the next part of the chapter, I analyzed how the Transmission Management Team approached the task of implementing the blueprint for the capacity markets. I showed how they designed institutional structures in order to realize the explicit assumptions of the blueprint. They did, however, fail to realize the implicit assumptions that were embedded in the structural form of the mathematical models used in the blueprint. As economists, the blindspots affected them differently than the engineers. They viewed the markets as independent structures and analyzed them from the perspective of incentives. However, their perspective was static: they reasoned backwards from the equilibrium to a set of incentives that would create the mechanism they desired. This led them to ignore, on the one hand, many of the operational details of grid management, and secondly, the different ways the market process can be derailed from the path toward equilibrium.

Since the assumption of uniform decision-making was implicit, the team did not design oversight structures to curb trades that exploited the discrepancy between physical reality and its representation in the grid. This also explains the ease with which companies could become scheduling coordinators. The designer did not consider the possibility that the companies would abuse this neutral position to act on their own interests. Considering the grid management as external to the markets, the designers also failed to put safeguards into place to ensure that trades in the larger Western Interconnection would not impact the California markets. Lastly, they did not consider the various ways traders might find incentives to innovate beyond what could be represented by variables in the model.

In particular, this last point shows that we are dealing with a crisis of expertise. Engineers had a tendency to think about the markets as a dynamic system that could continuously deviate from the path to equilibrium. This perspective would have probably identified several ways in which the markets could derail in the presence of unusual operational conditions. Similarly, the economists could probably have taught the engineers that market players always act in all markets at the same time and do not behave in terms that are consistent with the mechanism if there is some incentive *somewhere* not do so. In a word, the engineers appreciated how a closed, complex system can veer off course in the process of moving from one state to the next.

In contrast, economists were better able to understand the ways people optimize across different systems and seek to "game" the system to avoid the horror of true competition. If the two groups of market design experts had not used the same mathematical and conceptual tools, these differences would have become more obvious quicker. But as it was, true engagement with each other was avoided, partly due to the division of labor at WEPEX. In that sense, then, the problematic decisions of the WEPEX process have to be understood as the consequence of a fragmented expertise that was affected by the blindspots embedded in the formal models.

Yet, the technical work at WEPEX also tells us about problems that affected both camps equally. Particularly the need to create room for innovation brings us to a basic tension that we have already encountered in chapter four. It seems that the design of economic machines is stuck between two equally undesirable extremes. One extreme is market designs that give freedom and flexibility to market participants. This freedom is necessary to unleash the creative force of competition and push markets towards long-run equilibria. To unleash the creative energy of the market, economic machines should therefore "tolerate" a variety of different behaviors. The equilibrium needs to be an emergent consequence of the decentralized interactions between free individuals. In the fourth chapter, we have seen that the promise of decentralized decisions is one of the main reasons market design may be able to succeed where other forms of centralized planning fail.

But the tolerance for individual decision-making poses a problem to the enterprise of market design. The designers need to show how the equilibrium comes about and what its characteristics are. The more expansive the set of possible actions in the market, the more difficult the anticipation of their permutations in the theoretical model. But in order to guarantee the link between strategic behavior and aggregate allocation outcomes, the designers must be able to anticipate all configurations of behavior. Economist engineers do not simply need to figure out a set of rules that organizes an interactive logic; they also need to show that *all* possible moves combine in such a way that they end up at a desired equilibrium distribution. The more possible moves, the more intractable this task becomes.

The first two blindspots capture the resulting problems. The larger the range of possible behaviors, the more difficult it is to determine and guarantee all assumptions that must be met for the market to reach equilibrium. Similarly, the more individuals are able to act in relation to different contexts and temporal horizons, the harder it becomes to enforce the independence of the market mechanism.

This consideration reveals one of the conditions under which market designs necessarily fail. A market mechanism that makes no constraints on individuals' actions would guarantee the freedom necessary to reach the long-run equilibrium, but it would lose the ability to define and engineer the behavior that would get us there.

However, the opposite extreme is equally undesirable. If the designers gave up on innovation and created rigid institutions that minimized individual choices, they could enforce the mechanistic rationality that would guarantee the aggregate outcome of their designs. It would become easier to specify the market mechanisms, list the required assumptions, and enforce them in the organizational implementations of the mechanism. Since the range of possible behavior would diminish, the market operator could potentially enforce the mechanisms' independence as well. Accordingly, market designs that aim to minimize individual freedom and that can sufficiently anticipate all possible permutations of activity will operate as advertised. But the designer would sacrifice the ability of individuals to innovate and thus reduce the markets' tendency to produce and accommodate changes. As soon as external shocks produced structural changes to the market that had not been anticipated, the market mechanisms would become inefficient.

While it is thus certainly possible to create the desired equilibria by simply restricting individual freedom to a small set of options that designers' mathematical framework can model, this would severely impact the long-run efficiency of these constructs. In fact, the long-run efficiency would depend on the foresight of the centralized agency that defined the mechanisms. At that point, it becomes questionable why markets would be better suited to organize an industry than classic forms of regulation.

It thus seems like economic engineering as a technical form of expertise is caught in a paradoxical tension. In order to guarantee the link between competitive market interactions and equilibrium outcomes, the designs may have to sacrifice a core assumption that guaranteed this link in the first place: individual freedom. This paradox is rooted deep in the imaginary that orients market design. Economics—like much of sociology—is based on the vision of society as a machine that operates according to causal laws. The mathematical form of market "mechanisms" envisions the strategic interactions in the market akin to cogs and wheels that are interacting in a causal process to create some aggregate outcome. Building an economic machine means to turn individuals into these predictable cogs whose behavior can be linked to desired outcomes. Crucially, this involves moves to restrict the intentionality of individuals in such a way that it becomes akin to the causal mechanism of their framework.

However, the very justification of markets is based on the liberal idea of individual freedom. In that sense, then, the paradox of economic engineering follows from the desire to link a substantive vision of the creative force of individual intentionality to a causal image of the world as machine. The economist engineer wants to both believe in the emergent wisdom of Smith's invisible hand and be the creator that anticipates its every move.

It is important to note that this philosophical conundrum plays out in a fundamental tension in the temporal logic of markets. Beneath the surface of mathematical consistency, the vision for the short run is settled on top of a different philosophical paradigm than that of the long run. One is static, one is dynamic. One is Neoclassic, the other is Austrian. It is this logic that will occupy me in the last chapter of this dissertation, which will investigate the creation of the oversight structure.

10. The Problems of Oversight

10.1. Introduction

The last piece of the puzzle is the creation of California's control structure. Between 1995 and 1998, regulators tried to determine what their role in the new markets should be. They would no longer act as arbiters of rate cases and utilities' investment decisions. Instead, their new role as guardians of the markets was more distant and abstract. They would have to observe the market through new oversight structures and ensure that it worked as desired.

By the time the markets opened in 1998, they had put into place a new infrastructure of monitoring and reporting standards. But despite the lengthy efforts to get ready for the world of market competition, the regime was flawed. The problems extended into all parts of the control structure. Not only did parts of the wholesale market go unmonitored, but the units at the PX and the CAISO markets started with poorly defined goals and limited analytical tools. They practically had no jurisdictional power to mitigate problematic behavior. All tariff changes and punitive actions had to be approved by FERC, which relied on participatory, administrative processes that moved very slowly.

FERC itself—despite lengthy restructuring under the "FERC first" program—had not developed processes to monitor the new markets in-house.[1] When the agency first began to follow up on the allegations of abusive seller behavior in California, they found that their existing data was inadequate to even investigate the problems. They had only collected quarterly transaction reports from the companies. These revealed none of the market dynamics that drove the crisis. As a prominent market designer put it, in a system where you only have the word of those you monitor, you simply have to "believe what you believe. If a teacher at school says, 'Well, I'm sick today. I

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[1] See the last part of chapter six for an extensive discussion of the different flaws.

cannot come to school,’ nobody knows if you are sick. But you don't go to school, so nobody can prove it. The fact is that depending whose narrative you're following, you can see this both ways.”[2]

At the height of the price spikes in 2000, many FERC employees, who were supposed to develop analytical reports about the crisis, proved unfamiliar with the basic principles animating the new markets. With few exceptions, most employees had no expertise in analyzing the datasets that arrived from the market monitoring units in California, nor could they evaluate the content of the reports. This was not just the perception of external investigators but a widespread opinion within the agency.[3] In the aftermath of the California crisis, the General Accounting Office concluded: “Despite its long-standing awareness of the need for a new regulatory approach, FERC has struggled to define the specific strategies, information, processes, and activities that it will use to regulate and oversee competitive energy markets.”[4]

In this chapter, I will investigate the genesis of the flawed control structure. Its design can be divided into two stages. During the first stage in 1995 and 1996, regulators at FERC, the CPUC, and the CEC debated the basic architecture of the oversight regime. They established the basic responsibilities of the monitoring units in California as well as FERC’s role for the oversight of the new markets.

Though the Blue Book proceedings dealt with some of these questions, both CPUC and CEC ultimately took a backseat in the design process.[5] FERC was responsible for wholesale

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[2] Interview with Armin P., 01/25/2018.
[3] GAO, *Concerted Action Needed*, 32.
[4] Ibid, 33.
[5] The CPUC assumed responsibility for the local distribution and transmission networks as well as the retail markets. The distribution system would continue to be regulated according to performance-based ratemaking. The retail markets, as I have outlined, were deregulated, but the rate freeze in combination with the bond-funded 10 percent reduction meant that the markets never became competitive. The CEC retained control over the licensing of new generation facilities. Blumstein and Bushnell, "A Guide to the Blue Book: Issues in California's Electric Industry Restructuring and Reform," 27-28.

markets, so the decisive debates took place in technical conferences at the agency's offices in Washington.[6] After the basic architecture had been put into place, the second stage of development began. Between 1997 and 2000, the monitoring units at CAISO and PX hired economists and engineers to fill the market monitoring function. These employees then developed analytical capabilities to collect and process information.

The first part of the chapter focuses on the regulatory process that established the basic outlines of the oversight regime. I will seek to explain why the regulators settled for a highly fragmented oversight structure with slow and limited information exchange, limited enforcement power, and poorly defined goals. This architecture set the control system up for failure. Once economists and engineers started to develop the monitoring units in California's ISO and PX, there was little they could do to salvage the situation.

Even though the monitors quickly developed substantial analytical capabilities to discover problematic behavior, they could not observe the market as a whole, and they could not intervene quickly or by themselves. This proved fatal during the crisis. Shortly after the markets opened in 1998, the monitors in California recognized that their basic metric for market power was flawed. Wrestling with these problems, they developed the Residual Supplier Index (RSI) and discovered widespread market power potentials in their markets—two years prior to the crisis. But they did not have the authority to do anything about these problems by themselves. They had to go to FERC. When they tried to convince FERC to switch their approach and intervene, the agency did not react. It was not until the crisis became a national disaster, in January of 2001, that FERC changed its analytical approach. Even though the monitors in California found evidence of problematic

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[6] FERC, Annual Performance Report For Fiscal Year 1999," (Washington, DC: FERC, 2000), accessible under: http://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=10003552, last accessed 04/20/2020.

behavior two years prior to the crisis, there was nothing they could do. Working in a flawed architecture of control with few enforcement capabilities and slow information exchange, the insights of the local monitoring mattered little. To explain the flawed oversight structure, we thus have to focus on the decisions about its broad architecture.

As I approach the regulatory debates in 1995–96 to investigate the reasons for these flaws, a puzzle emerges. Market designers were almost completely silent on the issue of appropriate oversight. Even though they participated in the debates and were aware that market processes could be gamed or derailed during ordinary operations, they were reluctant to specify criteria for the appropriate oversight structure.

In a first step, I am going to explore this puzzle and show that engineers and economists both underestimated the control requirements for the new markets. Each side suffered from blindspots that obscured the relatively high requirements for control embedded in the blueprints for the complex market structure. Ironically, the economists and engineers could probably have resolved their respective epistemic problems. Each side held the key to the blindspots of the other side, but they did not engage deeply enough with each other's point of view to solve the problems.

To the engineers, ongoing oversight was important because they recognized that the markets were dynamical systems that could easily derail from the path to equilibrium. But they conceived of the problem of market failure in mechanical terms—control structures had to ensure correct inputs for grid operation and detect human error. Since they did not think in terms of malevolent intentions, they did not worry about the larger architecture of control and were content to shape local oversight units. Accordingly, they built the information architecture at CAISO/PX to detect if schedules would violate operational requirements, not to detect if they were the product of manipulation to drive up prices.

Conversely, economists were aware of the problems that derive from games and market interdependencies. Yet, they thought these issues could be resolved ex ante through institutional design. This suggested that market oversight would be a mere scaffolding to get the markets going. They assumed this scaffolding could later be disassembled once the markets operated according to the blueprints. They, too, did not weigh in heavily when the regulators debated the oversight structure.

In a second step, I then show how regulators made the decisions about the basic architecture of oversight. In their decisions, they relied on regulatory dogma that was beholden to a problematic imagining of the markets as "places." Based on analogies to other industries, the regulators misunderstood how quickly and dramatically electricity markets could derail from their intended course. They focused almost entirely on market power, understood as a structural feature of the industry as a whole. This suggested that after the fact, hands-off regulation might suffice. They were led to believe that the market mechanism would operate according to plan most of the time and that problems would emerge slowly and on the level of the industry structure. This prompted them to put a slow and fragmented architecture into place that could only intervene slowly and ex post.

In sum, then, the silence of market designers constitutes the third crisis of market design expertise. Based on blindspots inherent in the fragmented expertise of market design, they did not recognize the tremendous importance of fast, real-time, and aggressive market oversight in the fluid, interdependent world of electricity markets they had wrought.

At this point, the analysis of California's market design process is complete. I conclude that the failure of California's markets goes back to a crisis of *expertise*. Market designers faced a variety of problems that prevented them from building the markets they had conceptualized. They did not have the jurisdiction to take control over issues that concerned the applicability of their methodology. They were also internally divided. Engineers and economists were afflicted by blindspots that prevented them from implementing the blueprints for the designs they had anticipated. They put into place precarious structures that were always in danger of derailing and then failed to put checks and balances into place. The failure of the design experiment in California is thus a failure of expertise.

So far, the argument about the problems of expertise has tacitly assumed that the designers could have realized the intellectual project if the conditions of work had been better. But this does not have to be the case. As this dissertation is coming to an end, it is perhaps the most crucial, open question. Under what condition does the project itself become incongruous? How do we distinguish between feasible market design projects and those that are self-contradictory and infeasible?

These questions are related to the control requirements of market designs. Control structures are the flipside of market mechanisms. If a market mechanism does not operate as intended, a control structure must constrain the mechanism back into order. The feasibility of market design thus *ultimately* hinges on the requirements for the control structure.

Successful control requires that the oversight regime *collect* the necessary information, *process* it accurately, and then *intervene* to push the market process back on the path to the desired equilibrium. If a market design blueprint makes any of the three functions impossible, the intellectual project is logically infeasible. If it makes any of these functions exceedingly *difficult,* it is practically infeasible. The California case offers examples of both problems.

First, I show that the blueprint for California's transmission management system was *logically* infeasible. Effective control of the market mechanism would have required knowledge that the market mechanism was supposed to produce in the first place. Since the market was affected by the game, it did not produce this information.

Second, I argue that the combination of interdependent, decentralized markets with substantial room for innovation made effective oversight *practically* infeasible because it required an adaptive oversight regime that could revise the assumptions of its guiding heuristics. Such adaptation is an inherently local process that requires groups of experts who work closely with raw system data to challenge their background assumptions about the market, and there is a limit to the market complexity the regulators can handle. A complex market with many interdependent market settings would require a division of labor. This division of labor would be liable to assumptions about the market, which would soon become incorrect. To make this argument, I reconstruct what was necessary for California's market monitors to discover a flaw in their oversight regime and update their guiding metric, while FERC failed to do so. This prepares the ground for concluding thoughts about the limits of successful market design. I will now begin by examining the regulatory processes that animated the creation of the problematic control structure.

10.2. The Silence of the Market Designers

As with so many of the design processes, the deliberations about the oversight regime for California's new markets began in 1995. Initially, regulators debated the issues in the context of the Blue Book proceedings, but the topic quickly migrated to FERC's technical conferences and proceedings. During these deliberations, the market designers were oddly silent on the issue of oversight. Though they had much to say about nearly all other aspects of the markets, they rarely ventured opinions when it came to the architecture of the control structure. This is puzzling because their blueprints could not be realized without an adequate control structure.

The need for a control structure did not just derive from mistakes made during the political and technical design processes—in that case, we might simply chalk up their silence to the poor decisions in other contexts. No, the basic need for a centralized and capable oversight structure was endemic to the design project itself. It followed from the problematic temporal structure of California's markets—the last structural flaw. This flaw had nothing to do with any particular blueprint or design decision. It followed from the basic way competitive markets operate.

Basically, the problem was that competitive markets only price the capacity that is being used at some distinct hour of operation. As soon as the system comes to a point where it could generate revenues to recompense the last bit of idle capacity, market power emerges. This destabilizes the system and subverts markets' incentive structure. Accordingly, the markets face a paradox: To ward off market power, there needs to be an excess of idle capacity; but the market only prices this capacity when market power has already arisen. So, how could the market create the idle capacity that prevents it from derailing? The signal for the creation of new capacity to ward off market power necessarily comes too late.[7] Due to its orientation to discrete moments of future system operations, the very institution of competitive markets thus moves into conflict with the investment structure required for the reliable operation of electricity systems.

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[7] More robust forward markets also do not solve this problem. Buyers of electricity would use such markets to hedge against the price risk in spot markets. They would certainly base their purchases on estimates of future demand growth, which would, in turn, create revenues for investments in new generation capacity. However, if the estimates were exaggerated and the forward markets would incentivize the creation of excess capacity, the buyers of energy would effectively pay for energy they do not need. This would lead to losses they would try to avoid by shifting to the spot markets. Forward markets thus produce excess capacity only because of bad predictions and punish those responsible for it. These kinds of problems were becoming clear around the time California designed its markets. Adam B Jaffe and Frank A Felder, "Should Electricity Markets Have a Capacity Requirement? If So, How Should It Be Priced?" *The Electricity Journal* 9, no. 10 (1996).

Since this problem is embedded in the temporal structure of markets, there is no real market solution to the problem. The demand for excess capacity needs to be created by regulatory fiat.[8] Either the regulators need to measure and enforce the “correct” marginal cost for all generators at all times, or they need to monitor the use of the system and control the expansion of the system directly.[9] Since the problem is endemic to the market design project, the designers should have presented blueprints for the oversight structure. But they did not. Even though they participated in the regulatory proceedings and contributed to other decisions, market designers left the design of the basic control architecture to regulators and utility company lawyers.[10] Why were they silent?

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[8] One option is to impose price caps on energy markets that can curb the exercise of market power but are high enough to reflect the enormous entry costs for new generation. Economists usually propose to set the limit at the Value of Lost Load (VOLL), which is the marginal consumer surplus associated with a unit increase in electricity supplied to rationed consumers. In other words, it is set to the opportunity cost of those consumers who would have to be cut off if the capacity did not exist. Increasing the reserve margins substantially or adding capacity payments to the energy markets are based on a similar logic. David P. Brown, "The Effect of Subsidized Entry on Capacity Auctions and the Long-Run Resource Adequacy of Electricity Markets," *Energy Economics* 70 (2018); Farhad Billimoria and Rahmatallah Poudineh, "Market Design for Resource Adequacy: A Reliability Insurance Overlay on Energy-Only Electricity Markets," *Utilities Policy* 60 (2019). To solve the “missing money problem,” market designers might also build separate capacity markets that price long-term investments in new generation assets separately from pure energy markets. Though capacity markets use auctions, they, too, rely on an administrative process to develop the demand curve for different time horizons. This is one of the reasons Breslau arrives at the conclusion that market design is really a form of politics—the construction of the demand curve uses the concepts and ideas from economics but is really an administrative negotiation based on political interests. PJM’s designers do not even refer to the capacity market as a market, but as a “market-like entity.” Breslau, "Designing a Market-Like Entity: Economics in the Politics of Market Formation." Resource adequacy is a complicated and multifaceted issue and exceeds the question of how to get the “missing money” for the necessary excess capacity. Some of the other dimensions are covered by James Bushnell, "Electricity Resource Adequacy: Matching Policies and Goals," *The Electricity Journal* 18, no. 8 (2005).

[9] Ironically, it was precisely the benefits of market-based investment that originally provided the main argument for the restructuring of the electricity industry. The designers hoped that they would create a more efficient infrastructure over the long run by shifting the burden of investment risk from consumers to competitive companies. They overlooked that the integrity of reliable operation is a public good that cannot be guaranteed by the market.

[10] The discussions are predominantly located in FERC docket ER96-1663. For my analysis, I used commission orders and inquiries as well as the transcripts of different “technical conferences.” However, the discussion of appropriate rules and standards for market oversight has a longer trajectory and can be traced back to the 1980s and late 1970s. It developed in proceedings that dealt with situations where utilities traded with each other on the margin as well as in the relationships between utilities and QFs. Table 2-1 contains a listing of the most relevant dockets for the development of standards for market oversight. For the evolution of the market power standards, see also Udi Helman, "Market Power Monitoring and Mitigation in the U.S. Wholesale Power Markets," *Energy* 31, no. 6 (2006).

This question is dramatized by a particularly puzzling moment at the Blue Book proceedings before the CPUC early in 1995. In these proceedings, a market designer testified as an expert witness on issues of market oversight and structure. Shortly after his testimony, Michaels published an article in the *The Electricity Journal* that anticipated the problematic temporal logic of the markets and criticized the designers' lack of attention to this problem. With remarkable foresight he writes,

> Numerous specialists are laboring to squeeze every possible inefficiency out of the short-term energy exchanges before they begin to operate, but hardly anyone is thinking about future investments in the capital that will produce and move this energy […]. If the sunk costs of a plant of any size (as distinguished from its fixed costs) are high enough, investments will be inefficiently timed unless there is a market for capacity commitments.[11]

To solve the problem of long-term investments, he suggests, the regulators should introduce capacity side payments.[12] This would involve regulatory judgment about the value of these side payments—and thus ongoing oversight of the markets—to determine where specific investments are necessary. Michaels thus appears as an expert who was well aware of the need for regulatory intervention into substantial decisions in the market process.

Yet, in his presentation to the CPUC, Michaels does not argue for the creation of an oversight structure. Instead, he proposes the opposite. He begins with a joke: "Electricity was once an industry that was so simple, you could actually regulate it." After the laughter subsides, he explains that the development of market processes made the industry too complex to be regulated. "When you get a lot of opportunities, when you get a lot of potential buyers, a lot of potential sellers, regulation can at best follow behind. It either becomes redundant or it becomes pernicious"[13]

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[11] Robert J. Michaels, "Mw Gamble: The Missing Market for Capacity," *The Electricity Journal* 10, no. 10 (1997): 62.
[12] For an explanation, c.f. Hogan, "On an "Energy Only" Electricity Market Design for Resource Adequacy."
[13] "Hearing before the California Public Utility Commission June 15, 1994, Los Angeles, Reporter's Transcript Vol. 2, pp. 299-596," Box 69, *CPUC*, pp.343f.

Restructuring is the solution to this problem; the creation of market mechanisms will allow regulators to reduce their oversight substantially. While his article suggests that electricity markets are structurally unable to self-regulate, his statements before the CPUC suggest that they do precisely this. Michaels' statements seem to be in direct contradiction with each other. But they are not an isolated example.

Over and over, market designers who argue for specific regulatory interventions in one moment in the next turn around and argue against an expansion of regulatory structures. Even William Hogan vacillated on this issue. In his presentations, he argued for a pure energy market with caps at the VOLL level. But though the imposition of price caps required substantial regulatory intervention, he talked about this proposal as if it excluded regulatory interference. As if discussing a self-regulating process, he writes: "A bid price pool […] induces economic dispatch of the entire system. It also offers the right marginal incentives to build, to maintain, to run, and to close plants."[14] Why would market designers advocate regulatory interventions while preaching regulatory abstinence?

To be sure, the historical moment had something to do with the general lack of concern. The now commonplace insight that "freer markets, mean more rules" had not penetrated the imagination of politicians, industry participants, and designers.[15] The early 1990s were a moment of unfettered and rejuvenated belief in the "stark utopia" of the self-regulating market.[16] When the CPUC negotiated the Blue Book and FERC began to ponder the outlines of what would be Order 888, the opposition between markets and regulation was common sense. Inefficient regulation

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[14] Don Garber, Willian W. Hogan, and Larry Ruff, "An Efficient Electricity Market: Using a Pool to Support Real Competition," *The Electricity Journal* 7, no. 7 (1994): 48.
[15] Steven K. Vogel, *Freer Markets, More Rules: Regulatory Reform in Advanced Industrial Countries* (Ithaca, NY: Cornell University Press, 1996).
[16] Polanyi, *The Great Transformation - the Political and Economic Origins of Our Time*.

stood opposed to efficient markets and one side had to replace the other. For example, between 1993 and 2001, FERC reduced its employees from 1488 to 1196 and thus shrunk the already small regulatory agency by almost 20 percent.[17] The general expectation was that the markets would reduce the requirements for regulation.

But while free-market ideology can explain many of the follies committed in the act of "deregulating" complex industries, the electricity industry is a special case. Market designers rarely spoke of "deregulation." They usually referred to their work as "restructuring" because they recognized that electricity markets are highly synthetic structures. The whole project of market design *starts* with the insight that market mechanisms can be derailed by a variety of omnipresent market failures. These failures need to be resolved through institutional design, which is itself a form of regulation—market designers were unlikely to believe in the idea that markets work on their own accord. In my interviews, market designers stated quite often that the vision of a market without regulation was a convenient fiction, but not anyone's true belief. The same contention can be found in numerous articles written by the economists who participated in the creation of California's markets.[18] Why, then, did even those who recognized the problem with the temporal logic of electricity markets speak out against the need for extensive regulatory frameworks? The answer lies in the fragmentation of market design expertise. I will consider the two camps in turn.

As outlined in chapter seven, designers with a background in economics primarily thought about the new markets in terms of incentive design.[19] Accordingly, they tried to address issues of

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[17] GAO – *Concerted Action Needed,* 14.
[18] C.f. Paul L. Joskow, "Restructuring, Competition and Regulatory Reform in the Us Electricity Sector," *The Journal of Economic Perspectives* 11, no. 3 (1997); Matthew W. White, Paul L. Joskow, and Jerry Hausman, "Power Struggles: Explaining Deregulatory Reforms in Electricity Markets," *Brookings Papers on Economic Activity. Microeconomics* 1996 (1996).
[19] This follows from the close connection between game theory and market design. C.f., Roth and Wilson, "How Market Design Emerged from Game Theory: A Mutual Interview."

gaming and manipulation not through oversight, but through the institutions that would govern the rules of market interactions. For example, I talked to one economist who frequently raised the issue of gaming during the regulatory debates before FERC. Prior to his work in California, he had been in the UK and Norway, where electricity markets had already been introduced.[20] In the UK, he observed massive attempts to game the market and was worried that the same would happen in California. Interestingly, he talks about the issue entirely in terms of market structure, not in terms of market oversight. Consider the following quote:

> So, I'm bouncing around in UK, in Norway, Denmark, Sweden, Russia, Ukraine, Poland, and people are asking me, "How do we create a competitive electric market?" I try to pull a set of experts over and create these forums. Meanwhile, like I said, I'm talking to some of my friends at National Grid [in the UK]. And they're showing me Swinden, [where they have] two floors of computer docks [working to] game the market every day. And I'm like, "Whoa. Wait a minute. How can they do that?" [and they say:] “Well, you create a few loops [in the network], then you could do this and that.” And then I start seeing what they're doing in the United States, and I'm living in California and I'm going, "Uh oh. Why won't that happen here?" And I'm talking to the Norwegians and the Swedes and they're going, "Oh, well no, *we're* not going to create loops, we don't do that, we stick to pure economic theory. You want the dumbest market possible, the most straightforward transparent market possible, we don't want any loops and holes and other things that allow that iterative gaming to occur." And I'm saying, "Well, the contrast in these two views is absolutely startling."[21]

The quote indicates the economists’ point of view quite well. The difference between the UK and Norway is conceived in terms of the market structure alone. He thinks that the complexity of markets is the problem and needs to be reduced via institutional design. This was exactly the idea the market designers had in 1995–96. They thought that market design could take care of the various problems ex ante. The analytical tools of equilibrium analysis helped them to reason

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[20] For evidence on economists’ considerations of gaming during the regulatory conversation, see for example the statements by Eric Woychik during the FERC proceedings: *Pacific Gas & Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company*, “Official Transcript of Proceedings, Thursday September 13, 1996, Washington D.C.,” Vol. 3, (short: WEPEX Vol. 3), FERC ER96-1663, pp. 129-135.
[21] Interview with Eric Woychik, 02/03/2018.

backwards from a desirable allocation outcome to a set of rational behaviors. Then, they developed blueprints for institutions that would enforce the incentives for this rational behavior and assumed that the market would converge on the desired equilibrium. This way of reasoning draws a single trajectory from individual behavior to an optimal outcome.

Depending on the mathematical framework, the economists also demonstrated the robustness of the behavioral trajectory toward equilibrium. But they did not systematically consider the possibility of deviation from the path charted by the institutional framework. The synthetic markets thus appear as a kind of wind-up toy—a more sophisticated version of the self-regulating market Polanyi criticized a century ago. If you design the rules right, the toy will march where it is needed after it is wound up.[22] Oversight becomes a subsidiary function, mostly meant to ensure that errors of implementation can be corrected.

This way of looking at the design process is in evidence during several technical conferences at FERC's offices in Washington in 1996. During these conferences, the utilities presented their ideas for the new market structure and discussed open issues with commissioners and FERC staff. The proposal included the creation of internal market monitoring units. When commenting on these provisions, the economists suggested that the program might be limited to three years. Initially, the idea was to stop monitoring after one year.[23] The reason they proposed the limited time frame was that the monitoring regime was initially meant as nothing but a scaffolding to check the implementation. It was supposed to collect information about the market and evaluate

[22] C.f. for example the discussion in Cramton, "Electricity Market Design: The Good, the Bad, and the Ugly."
[23] C.f. Testimonies by Jim Macias and Paul Joskow in *Pacific Gas & Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company*, "Official Transcript of Proceedings, Thursday August 1,1996, Washington D.C.," Vol. 1, (short: WEPEX Vol. 1), FERC Docket ER96-1663.

whether it operated as intended by the designers. Joskow, for example, describes the monitoring system like this:

> Finally, because of the many novel features because of the proposed structure and other elements of the California restructuring program as well as the inevitable uncertainties associated with diagnosing market power, the applicants have recommend a three-year monitoring program be put in place to collect data that can be used by interested parties and this Commission […][24]

The monitoring units collect information and evaluate if the market process works as it should. If not, the rules can be adjusted. After the time is up, the commission can evaluate whether additional changes are necessary or if everything works according to plan.[25] The monitoring units may then be disbanded. Once the market process flows as needed, oversight can recede into the background and only enter the markets in case anomalous events begin to occur.

While market design has thus thrown off the belief that markets are *naturally* self-regulating entities, they still believe that markets that follow their blueprints will be self-regulatory structures. In contrast, market designers with an engineering background did not share the faith in the possibility of creating preestablished harmony between markets and electricity system. They were well aware that systems can always deviate from the path that the designer has divined. And indeed, a few market designers with an engineering background recognized the myopia of their colleagues with economic backgrounds very clearly.

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[24] Ibid, 154.

[25] Later, in testimony to FERC after the crisis, Joskow and other market designers argue for much more extensive market oversight. In this respect, the creation of California's markets was a learning experience. Today, the oversight of electricity markets is comprehensive and takes place in real time. For the learning process in California during the crisis, see Wolak, "Lessons from International Experience with Electricity Market Monitoring."; AF Rahimi and Anjali Y Sheffrin, "Effective Market Monitoring in Deregulated Electricity Markets," *IEEE Transactions on Power systems* 18, no. 2 (2003). For the development of monitoring generally, see José A. García and James D. Reitzes, "International Perspectives on Electricity Market Monitoring and Market Power Mitigation," *Review of Network Economics* 6, no. 3 (2007). I will discuss this further in the second section of this chapter.

Perhaps the most interesting case is that of George Backus and Paul Gribick, members of WEPEX and TAC who became embroiled in controversy during the litigation of the California crisis. In 2002, staff members of California's Senate Select Committee to Investigate Price Manipulation in the Western Energy Markets found a suspicious document that had been distributed by Perot Systems. CAISO had hired Perot Systems to integrate computer systems from several different vendors. These computer systems handled different parts of CAISO's operations and needed to be integrated into one software environment. Since communication between the CAISO and PX software was a major issue during the startup of the markets, Perot had also done some consulting for the PX.[26] Accordingly, the company had intimate knowledge of the computational infrastructure linking markets with the electricity system.

While going through filings to the committee, the staff of the California investigation found a 44-page power point presentation from Perot Systems in one of the many boxes that the energy merchant Reliant had transmitted to the committee. To their surprise, the document outlined in detail how the California markets worked in theory and how they could be gamed in practice. The document (dated 1998) showed how trades could take advantage of various shortcomings, foreshadowing some of the same tricks that Enron and other companies would later use to bring the system to its knees.[27]

Quickly, it became clear what had happened. Unsure whether their services were going to be retained by the ISO in 1997, Perot Systems had turned around and tried to market their intimate

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[26] C.f., "Statement of Terry Winter, president of the California Independent System Operator," in: "California's Electricity Market: The Case of Perot Systems," (henceforth, The Case of Perot Systems), Congress, House of Representatives, Committee on Government Reform, 107th Congress, 2nd Session, July 22, 2002, pp. 26-30.
[27] "Perot Systems Presentation," LP402:335, Box 17, Folder 1, Sheila J. Kuehl Papers, Sen. Select Committee to Investigate Price Manipulation of the Wholesale Energy Market, *CSA*.

understanding of the new market system to some of the biggest prospective players in the industry. The power point was part of a training module they were hoping to sell to these companies.

After several hearings, Senator Dunn and his team concluded that Perot System had used its intricate knowledge of the ISO's operations to run a "crime school." This school was designed to teach power marketers how they could bleed out California.[28] These revelations made headlines and heightened the public anger against "power marketers from Texas."

However, it later turned out that none of the energy companies had decided to hire the services of Perot Systems, choosing instead to develop their games in-house. After a brief and largely unsuccessful foray into this market, Perot Systems stopped marketing their services to outsiders because the ISO had decided to retain them until market opening in 1998. Nonetheless, the findings of the Select Committee prompted the House of Representatives to set up a federal hearing. During the hearing, two of the employees who had designed the "crime school" testified. They were Dr. George Backus, a safety engineer, and Dr. Paul Gribick, an electricity engineer. Both of them were adherents to the basic design logic of electricity markets as conceived in the Harvard/MIT nexus.

Neither of the two men were particularly intimidated by the hearing. To the contrary, they seemed happy to receive a platform to express their opinions. After a few minutes, Backus revealed with a tangible amount of glee that he had by no means taught only power marketers how to play destructive games. Instead, he had given a nearly identical presentation to many stakeholders and regulators prior to restructuring—but they had not listened to him.

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[28] Joseph Dunn (2002), "Perot Systems: Pied Piper of Gaming or Innocent Entrepreneur?" in "The Case of Perot Systems," pp. 11-20.

Before working on energy policy issues, Backus had been a nuclear safety design engineer. In his work, he used simulation tools originally designed for the Apollo Space program to aid the construction of safety standards for nuclear facilities. Starting in the 1980s, he transferred these simulation models to forecast the impact of deregulation on the energy sector. Based on the experience in the UK and the first plans that matured in California, he ran a simulation and found that players would quickly figure out ways to take advantage of the market structure, in particular through the exercise of market power. He presented his findings to the WSCC and the CEC, offering his services to the CPUC, the ISO and the PX in 1996. In 1997, he was then "giving presentations continuously, probably to hundreds of organizations, almost all identical."[29] In these presentations, he pointed out that the optimistic plans for restructuring were almost certain to fail. In the hearings before Congress, Backus submitted a statement that summarized the basic point he had tried to make in 1996 and 1997.

"Any system that changes over time, such as markets," he said, "must have a control system. In a market, the control system is the market rules. Any system that changes over time is in disequilibrium. [But] all economic analyses used for deregulation relied on equilibrium approaches." After allowing that equilibrium analyses *may* be helpful in understanding the dynamics in mature markets, he points out that they are absolutely useless when developing a new market system.

> The conventional, optimal equilibrium tools of regulated utilities and economists are not only poorly suited for such analyses, they mislead policy makers into a false sense of comfort. They tell what the best of all possible worlds should look like. They provide no help in how to get to that world. The control system must be flexible and allow the system to self-correct under all possible conditions. A complicated control system will often be wrought with contradictory responses that create catastrophic interactions.[30]

[29] "The Case of Perot Systems," p.172.
[30] Ibid, p.120.

To understand market dynamics and build adequate control structures, he argued, economists should not merely rely on equilibrium analysis but use *simulations* that could evaluate how the system "will self-correct or fail safe under the most adverse conditions."[31] His point was not merely that the dynamic process of deregulation could quickly throw up adverse conditions, but that due to the many ways the system can move away from the precepts of the theory, the regulatory and political framework has to be part of the market design.

At the core, the problem is that the standard equilibrium models obscure the need for dynamic adjustments to the market process. Since economists envision a straight line from initial conditions to final outcome, they do not include a plan for a control structure that can monitor, control, and adjust to the development of the market structure. This explains the seemingly inconsistent position of economists: the static framework makes it possible to discover a variety of imperfections that might be resolved in one way or another. But it does not allow the designers to plan a system that can discover such imperfections during the operation of the market and adjust to it. Accordingly, while targeted interferences are part of the framework, the structure necessary to enforce them is not.[32]

When Backus was unable to convince regulators, politicians, or fellow market designers of his point of view, he turned around and offered the information to the power marketers. During his testimony, there is a palpable sense of self-satisfaction when he adds that it "was quite nice to do so, because as time is marching on, 100 percent of the forecasts that I had produced, as to where

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[31] Ibid, p.121.

[32] Another way to put the same point is to see that designers' blueprints that are based on optimization theory are forward looking. They anticipate certain problems, predict their impact, and suggest solutions. Such predictions are, however, incomplete because the system's environment is constantly evolving (in this case, demand, technology, etc.). This necessitates not just homeostatic (e.g., markets for reserve requirements), but also feedback methods that can adjust the system to fluctuations that had not been previously considered. These are well-known principles of industrial design. Simon Herbert A., *The Sciences of the Artificial*, 3rd ed. (Cambridge, MA: MIT Press, 1996 [1969]), 149.

the problems would be, what would occur next, were actually occurring exactly in the sequence and timing that I had predicted."[33] Backus's argument captures the perspective of a safety engineer on synthetic markets. But if engineers were aware of the problems, why did the market designers with engineering background not put a more extensive oversight structure into place?

Just like Backus, the designers with engineering backgrounds were attuned to the need for ongoing oversight in complex systems. The markets appear as a dynamic component of the larger electricity system, which must be kept under constant oversight. But unlike Backus, the engineers in California did not consider the markets in terms of malevolent intention. They thought people would do what a generator would do—submit marginal cost bids. This meant that they subscribed to a mechanical understanding of market failure and did not recognize the *kind* of control that the new markets would require.

I have shown that the origins of electricity market design lie in the homeostatic control framework, which was conceived to think about the interaction between machines in the electricity system. In this imagination, actors always behave as specified by the rules of the mechanism. This view is in evidence at various points during the regulatory deliberations before FERC. Revealing their lack of suspicion about sellers' intentions, engineers repeatedly suggested that the monitoring program would not need strong powers of mitigation because it would primarily work as a vehicle for stakeholder deliberations about the market rules.[34] At other times, they suggested that sellers of electricity should just file quarterly reports about their generation costs to the ISO (or FERC). This would enable the ISO to determine fixed costs and compile benchmarks of competitive prices. This suggestion only makes sense under the assumption that generators would freely submit

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[33] Ibid.
[34] Ibid, p. 79.

adequate data about generation costs without further scrutiny. The litigation of the California crisis shows that the opposite was the case.

This leads to a mechanical understanding of market failure. Perhaps generators might send a mistaken input, or the dynamic combination of inputs may push the market off course. But this perspective does not consider the possibility that some traders would do anything to find flaws in the system and exploit them. Accordingly, the engineers did not think that FERC would have much to do. As one of the designers put it, “and if all goes well, basically the report [to FERC] would say that the system is working well. So, in that case, I do not see it being potentially reams of data [for FERC to handle].”[35]

We can observe this philosophy at work in the information architecture of California’s markets, which was put into place by engineers. Figure 10-1 displays the flows of information in the markets.[36] The center of the figure describes CAISO’s information system. All bids enter the scheduling infrastructure on the left side of the diagram. From there, they are passed onto the Energy Management System and the Scheduling Applications. As the figure indicates, there is no independent step where CAISO evaluates the genesis of the schedules on the level of the SCs or the PX. The architecture is set up to determine whether the market results in the form of schedules can be used to balance the system or not. The ISO can overlook its internal markets, but it does not have direct access to the market processes at the SCs.

[35] Ibid, p. 100.
[36] I discuss this structure in detail in chapter 6.

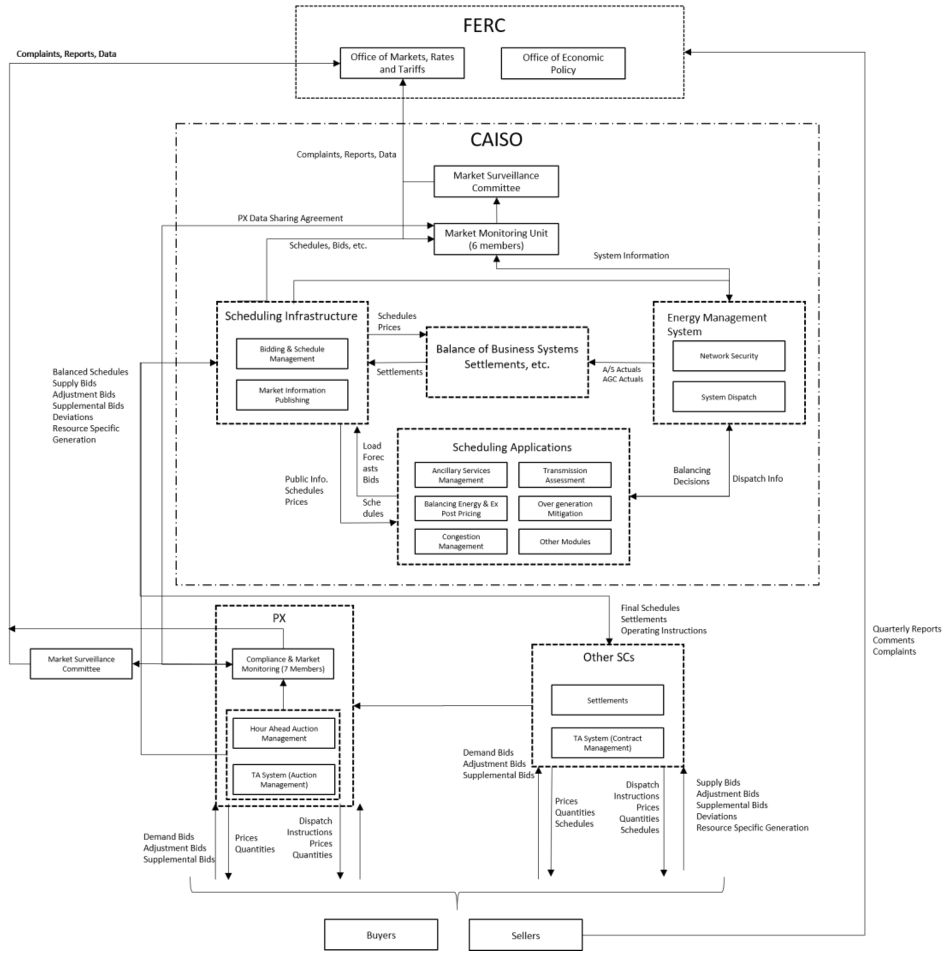

Figure 10-1 – Architecture of Information Flows

The structure of information flows shows that the designers did not worry about the interplay between incentives and that they focused on ensuring correct inputs for reliable grid management.[37]

[37] One of my interviewees tried to illustrate the engineers' lack of attention to this issue with an example. It concerns an episode of market redesign, several years after the California crisis. More and more sellers in the markets were offering renewable energy. These energy sources (wind and solar) are not as reliable as other sources because their output fluctuates with the weather. Normally, these resources are backed up by fossil generators with lower intermittency. But these generators had high ramping rates. Accordingly, there would sometimes be a gap in the supply stack. Renewable energy may fail to materialize but fossil generation cannot come online fast enough to back up the renewable energy. To solve this problem, the markets have to attract *flexible* generation that could be substituted to fill the gap. The engineers now developed market design proposals that "are made to deal with this reliability problem." They proposed to create a new product for flexible capacity and then require everyone to buy a certain amount of it. For reasons that had to do with the timing of the markets and the ramp rates of the generators, they decided to sell these products in the day-ahead markets to be available in real time. But this poses a problem: flexible generators whose capacity would be sold in the day-ahead market also served as a resource adequacy product in the

In sum, the engineers thought about the markets as mechanical systems that were part of the larger electricity system. They conceptualized market failure in terms of human error and problems immanent to the rules of a given market. Accordingly, they thought control could be modularized and focused on how to ensure the output's compatibility with reliable grid management. [38] This explains why they neglected issues of oversight and control during the FERC and CPUC proceedings in 1995 and 1996. Decentralized oversight on the basis of technical requirements seemed sufficient. This could be developed locally.[39]

The engineers thus underestimated precisely those elements of market design that the economists had focused on. It does not lack a certain irony that engineers and economists held the missing pieces for each other's puzzles. If they had recognized the differences and collaborated more directly, they might have discovered the control requirements that derived from the structure of California's markets. They had a chance to collaborate during WEPEX and in the regulatory contexts. Why did they miss this opportunity to learn from each other?

Though the early regulatory proceedings do not contain much evidence of confrontations between market designers from opposing camps, my interviewees sometimes mentioned difficulties that economists had when they tried to understand engineers and vice versa.[40] Though it is only possible to speculate, economists' point of view provides an indication for the possible

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ancillary markets. In other words, the sellers would be able to sell their capacity twice. The engineers had not considered this because the problem derived from the dynamic interplay between different products in different markets. It only becomes visible if you consider the incentives a generator faces when they decide to sell their product.

[38] This is very tangible in an exchange between PG&E's Joe Pace and Richard O'Neill. They discuss what should be monitored and what not. When O'Neill points to the many different bidding protocols and how they obscure the composition of market prices, Pace is surprised at the suggestion that this information might not easily be available from generators. Ibid, 34-35.

[39] There was also a pervasive sense that oversight structures should be the result of regulatory and partisan efforts. Paul Joskow had a good point, when he noted: "We felt that people would say you can't design your own monitoring system." *Pacific Gas & Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company*, "Official Transcript of Proceedings, Thursday September 12, 1996, Washington D.C.," Vol. 2, (short: WEPEX Vol. 2), *FERC* ER96-1663, 80.

[40] Interview with Steven Stoft 11/12/2018; interview with Carmella G., 11/28/2017.

reasoning behind these difficulties. When I discussed the socialist calculation debate, I noted that many market designer— and indeed many economists in the tradition of information economics—have endorsed Hayek's views. This is rather odd given that Hayek opposed the use of formal modelling *on principle*. Nonetheless, generations of economists who joyfully express their thoughts through mathematical models have endorsed Hayek's views on the use of information in society.[41]

I think that this contradiction can be traced to a difference between the verbal and the mathematical meaning of the concepts that economists use. Market designers frequently justified the use of markets by drawing from the toolbox of Austrian economics. They do not primarily praise markets' superior incentive structures. Instead, they argue that human institutions cannot emulate the information processing powers of the market.[42]

For Hayek, this argument is fundamentally tied to the limits of knowledge: precisely because markets are inherently *unknowable* entities, they cannot be emulated by human institutions. They can be disassembled into discrete parts that operate according to known principles. But their emergent properties remain beyond prediction. As Hayek put it so poignantly: "The dispersion and imperfection of all knowledge are two basic facts from which the social sciences have to start."[43] The imperfection of all knowledge applies to *all* humans, regardless of whether they are market actors, regulators, or market designers. *This* is the reason the market is a superior coordination

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[41] On the surface, economists' endorsement might also be attributed to the misinterpretation of Hayek's views in the mainstream reading of the socialist calculation debate. This reading provided an agenda for market designers and thus turns Hayek into a founding father of the intellectual project—the endorsement would then be ritualistic rather than substantial. However, even people like Vernon Smith, who has clearly engaged with Hayek's original writings, endorse his views. This suggests a more charitable interpretation. Smith, *Rationality in Economics: Constructivist and Ecological Forms*.
[42] The quote by Prof. Michaels in the second section can be read in this way. He suggests that regulation is impossible when a certain level of complexity has been reached.
[43] Friedrich A. Hayek, *The Counter-Revolution Science: Studies on the Abuse of Reason* (Glencoe, IL: Free Press, 1952), 50.

device—precisely because it cannot be comprehended in its details, it must be deferred to.[44] In their verbal statements, economists loved to draw on these ideas to push for the use of synthetic markets.

However, in their *mathematical* statements, the economists do exactly what Hayek proclaimed impossible: they show how the basic interactions in the markets lead to an emergent order. The market becomes knowable because it *is* like the model. It is an algorithm that processes decentralized information according to a set of rules. Of course, market design would be impossible without this knowledge; since markets do not actually work as Hayek proposed, they need to be known.

There is thus a contradiction between verbal and mathematical statements about synthetic markets. Ambiguities in the concepts such as “information,” “competition,” “equilibrium,” and “coordination” hide these contradictions. For example, if left undefined in its relation to information and equilibrium, “competition” can be both a force that triggers creative destruction as well as a mathematical principle embedded in the relations between buyers and sellers.

As outlined, market design took place in the domain of control theory, linear and dynamic programing, and the occasional game theoretical models. Yet the disagreements and contradictions are located on the conceptual level where economists and engineers differed in their basic imagination of the markets. Since the connection between the two levels remained blurry and ambiguous, there was perhaps no room to clarify the differences between economists and engineers. The different “literatures” of market design dealt with the ambiguities of their guiding conceptual

[44] Gamble, "Hayek on Knowledge, Economics, and Society," 111.

distinctions differently, but since much of this happened implicitly and without explicit reflection on the mathematical tools, there was perhaps no room to nail down exact the differences.[45]

Regardless of the deeper reason for the lack of cooperation may be, we have to conclude that market designers underestimated the requirements for the oversight structure. They did not have blueprints for the kind of control structure that would correspond to the market mechanisms they proposed. They thought about oversight as a subsidiary concern, something that did not have to occur on an ongoing basis from a centralized position. Accordingly, the market designers never proposed clear frameworks of oversight. But if there was no clear blueprint for the control structure, how did the regulators make the basic decisions about California's control structure?

10.3. Regulatory Design Work at FERC

The first reason why regulators created a weak and fragmented oversight structure was that they did not have a strong legal mandate to do so. The powers FERC had received from congress were adequate for the era of regulated monopolies but not for the world of competitive markets. Most of its authority derived from the Federal Power Act of 1935 (FPA).[46] The agency had to reinterpret the act substantially in order to derive a mandate for the regulation of electricity markets. Under sections 205 and 206, FERC had the authority to review whether new or existing electricity rates were "just and reasonable." Since the markets would now produce these rates, FERC concluded that rates were "just and reasonable" if the markets operated as advertised by

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[45] This is a rather general phenomenon in the "space between literatures." Andrew Abbott, "Seven Types of Ambiguity," in *Time Matters: On Theory and Method*, ed. Andrew Abbott (Chicago: University of Chicago Press, 2001), 95.

[46] Some important changes were made in the EPA Act of 1992, which was designed to make smaller utilities competitive with larger utilities. It created FERC's legal mandate to open transmission lines to competition. It *also* lifted restrictions on holding companies that had prevented the kinds of games that the three big utilities played in California's markets. Jeffrey D. Watkiss and Douglas W. Smith, "The Energy Policy Act of 1992-a Watershed for Competition in the Wholesale Power Market," *Yale Journal on Regulation* 10 (1993).

economic theory. Economic theory dictates that markets work when they are competitive. Accordingly, FERC determined that it had the right to assess the competitiveness of wholesale electricity markets. But while it now had the legislative tools to create an oversight structure that would be able to determine the competitiveness of the new markets, the FPA did not give much power to penalize and mitigate behavior that undermined the competitiveness.

If FERC found an existing rate to be unjust or unreasonable, they could set a new rate and order a refund. However, such refunds could only be ordered for the period following the refund "effective" date. The earliest this date can be is sixty days after a complaint was filed with FERC or after a notice of a Commission-initiated investigation was issued. Outside this period, FERC was powerless.[47] It did not have general authority to levy monetary penalties for violations of the "just and reasonableness" standard. Its hardest weapon was the ability to revoke market-based rates and thus exclude companies from the new markets. Since this would often reduce the competitiveness of the markets further, it was not a very powerful tool. In lieu of coercive and punitive measures, FERC tried to negotiate disputes with input from stakeholders and find mutually agreeable solutions after long and careful rounds of deliberation. This situation limited FERC's ability to define an effective oversight structure. The GOA concluded after the crisis: "In today's competitive energy markets, the lack of adequate refund and penalty authorities may be a significant handicap to FERC's ability to fulfill its regulatory mandate."[48]

But by itself this handicap is not enough to explain the flaws in California's oversight structure. It had a sufficient legal mandate to specify information flows, order a centralized

[47] GAO, *Concerted Action Needed*, 48.
[48] Ibid, 49.

monitoring regime, and set up its own structures to monitor the markets on an ongoing basis.[49] PJM's example proves that a more successful oversight structure would have been possible under FERC's legal mandate. During the first year of operation in 1998, PJM ran its markets experimentally. It did not allow generators to bid freely, but forced them to bid at marginal costs. The market monitoring unit (MMU) used this trial run to establish a hypothetical baseline for the operation of a perfectly competitive market. Once the market started, the MMU compared incoming bids with the data from the experimental period to have a benchmark for abusive tactics. Just as in California, the MMU was not allowed to impose drastic remedial measures on companies.[50] But with more precise allegations against companies that exercised market power, it was able to use the enforcement structures that FERC did offer more effectively than California.[51]

To explain why FERC sanctioned a fragmented, slow, and toothless oversight structure in California, we thus have to look at the regulatory proceedings where the regulators made these decisions. During these debates, the regulators focused almost entirely on the issue of market power, which was the overriding concern for any question that had to do with regulation. A few examples indicate the importance of this issue. *Every* reply comment to the Blue Book contained a section on market power. The utilities' applications for the creation of CAISO and PX had to be

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[49] After the California crisis, they established an Office of Market Oversight, which quickly developed live-monitoring and mitigation procedures, even though the legal landscape had not yet changed. The Energy Policy Act of 2005 substantial extended FERC's mandate to observe the markets and interfere with deviant behavior.
[50] The gradual introduction of market-based pricing is explained here: Market Monitoring Unit, *PJM Interconnection State of the Market Report 2001*, (Philadelphia: PJM Interconnection, L.L.C, 2002), available under: http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2001/200206-pjmmmusom-2001.pdf, last accessed 04/17/2020. The market power problems were discussed here: "Investigation of Bulk Power Markets, Northeast Region November, 1, 2000," *FERC* EL-00-98-000, p. I-46.
[51] Interview with Armin P., 01/25/2018.

accompanied by independent market power analyses. Finally, during its technical conference, FERC dedicated the panel on market oversight to the issue of market power.[52]

The focus on market power made sense from a legal perspective. Since market power affects the competitiveness of markets, it clearly constitutes a violation of FERC's "just and reasonableness" standard.[53] But the focus on market power was also justified by the history of the industry. Since California's three utilities had enjoyed monopoly status in their service territories and had the most to lose from restructuring, they were considered the enemy. As monopolies, they had absolute market power.

Regulators were worried that the utilities would try to block the entry of new competitors by making their use of the transmission system difficult (vertical market power), or would try to drive up the prices in the spot markets (horizontal market power). In a policy statement, the CPUC commissioners link market power and utility behavior explicitly: "An allied step will be to monitor the evolving market for the presence of excessive concentration of ownership of these generation units and devising appropriate prophylactic and remedial strategies."[54]

FERC clearly had the same concerns. In its market power study submitted to FERC, PG&E proposed that the California monitoring regimes appease FERC's fears about PG&E's potential market power. They wrote:

> In order to further allay concerns about the potential exercise of market power, PG&E proposes the following monitoring program. […] PG&E recommends that the monitoring program be run by a compliance division of the PX, similar to the compliance divisions that exist within the stock exchanges, as well as the New York Mercantile Exchange. […] The Compliance Division would establish guidelines to identify market anomalies that may

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[52] The panel on market power took place in the afternoon during the first technical conference before FERC, c.f. FERC, "WEPEX Vol. 1." The market power analyses can be found in docket ER96-1663. E.g., *Pacific Gas & Electric Co, San Diego Gas & Electric Co., and Southern California Edison Co.* "Market Power Analysis of Pacific Gas & Electric in Support of Joint Application, July 19, 1996," *FERC* ER96-1663.
[53] Helman, "Market Power Monitoring and Mitigation in the U.S. Wholesale Power Markets," 878.
[54] CPUC, "Preferred Policy Decision," p.5

be indicative of market power abuse and then apply the guidelines when monitoring PX transactions.[55]

The regulatory proceedings were thus keyed to develop oversight structures that would be able to detect market power. In electricity markets, market power can emerge from one second to the other. It depends on the competition over residual demand. If a generator is necessary to serve demand at a given moment, it has market power. Due to the way energy flows can segment the market and the fluctuation of demand from hour to hour, market power is highly *fluid* and depends on the patterns of transactions in the market as a whole. Accordingly, the control structure would have to be able to evaluate all transactions in the market relative to the demand in the system from moment to moment.

However, as we have seen, FERC decided against requirements for a centralized, real-time oversight structure. They allowed for the creation of real-time market monitoring in California, but did not specify how it should be done and did not require the unit to have access to all market data. At the level of FERC, no ongoing, real-time oversight took place, and the agency collected data only in mediated form. Sellers sent quarterly reports about transactions to the agency, and the market monitoring units submitted annual reports. Attempts to verify (or even just analyze) the filings did not take place during the first years of operation. Everything else was sorted out through a variety of formal proceedings with stakeholder input.

When the regulators made these decisions, the wholesale markets did not exist yet. There was very little experience with electricity deregulation anywhere, and the blueprints for the California markets were unique. Paul Joskow, who participated in the debates at FERC and the CPUC, explained the considerations about the regulatory structure like this: "Our analysis and almost any

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[55] *Pacific Gas & Electric Co, San Diego Gas & Electric Co., and Southern California Edison Co.* "Market Power Analysis of Pacific Gas & Electric in Support of Joint Application, July 19, 1996," *FERC* ER96-1663, p. 24.

other analysis is based on two things, historical data and projections about the future based on what we know about how markets work today."[56]

Since historical data stemmed from a regulated industry structure and since the market designers did not have much to say about the issue, the decisive form of knowledge was "how markets work today." In other words, the regulators and stakeholders tried to apply knowledge from *other* areas to the nascent electricity markets, in particular natural gas markets, trucking, and telecommunications. These parallels were drawn explicitly. For example, the Blue Book draws parallels to the deregulation of adjacent industries at various junctures to justify the move toward competition.[57]

Absent a formal modeling framework, these analogies suggested a guiding *imaginary physical marketplace* when speaking of the new markets. The regulatory discourses reveal that regulators envisioned the markets in analogy to market squares where customers move among the booths of sellers to negotiate contracts about the delivery of products. For example, they talk frequently in spatial and material terms about the markets as when they refer to the need of "price signals being sent into the marketplace."[58] Three basic beliefs sustained the imaginary physical marketplace.

The first belief was that nearly anything relevant to the sale and purchase of energy could be negotiated between individual parties. Just like buyers and sellers in a weekday market can agree on price and delivery conditions of a good, so can buyers and sellers in an electricity market. As an interviewee working at CAISO put it in retrospect: "There was a notion that if there was a willing buyer and a willing seller, there would also be a way for them to come together and do a

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[56] FERC, "WEPEX Vol. 1," p. 185.
[57] E.g., "Order Instituting Rulemaking and Order Instituting Investigation," Box 10, Folder 1, *CPUC*, p. 9-10.
[58] FERC, "WEPEX Vol. 2," 136.

transaction."[59] The market consists of a set of interactions between decentralized individuals. These interactions determine the aggregate patterns of energy flows.

The second belief was the idea that markets take place in "geographic locations" that are temporally stable. A weekly market has a visible, spatial boundary. People need to come to the marketplace, set up their business, and then wait for customers. If they want to leave, they need to pack up and travel away. Guided by this fundamental belief, the regulators defined the electricity market for certain "geographic areas." Buyers and sellers who were connected through transmission lines were in one area and would be potential transaction partners. This spatial imagination is visible in a quote by an economic expert who explains that congestion of electricity lines can cut suppliers off from each other. Even though the market size changes, the different "geographic areas" can still be defined: "There are three different geographic markets that we identified that are relevant when different combinations of transmission constraints are binding."[60] So the experts assumed that the markets were fundamentally geographic locations and that these locations were reasonably stable—even if congestion might occasionally change their size.

The third fundamental belief followed directly from the first two: since physical markets do not have entities that coordinate the decentralized decisions of individuals, the central system operator must be a mere location for market activities or, if viewed from outside the market, an "air-traffic controller" who executes the schedules provided by the marketplace. One stakeholder expressed this belief even more explicitly in a hearing before FERC: "We do not want the ISO to be engaged in competitive market making functions; economic dispatch is a function that bilateral

[59] Interview with Barbara Barkovich, 08/21/2018.
[60] FERC, "WEPEX Vol. 1," 155.

contracts will perform themselves and power exchange should perform on its own."[61] Table 10-1 lists quotes that illustrate the presence of these three beliefs.

Table 10-1 – FERC's Three Beliefs about Markets

Cosmology of the market as decentralized location	**Examples from Transcripts and Formal Filings (1996-1998) and FERC (1998-2001)**
The market is a stable, geographic location that determines on which paths energy will flow	"How do we attract more generation in strategic locations in the marketplace?" "I find I could think of market size as being as small as San Diego or as large as the whole West, and unless I know what the right market area is to look at as a first step, the market share numbers for the HHI indices to follow don't have a lot of meaning unless I have the geographic market to try to correct in." "People in a marketplace will price congestion. They will price higher across constrained paths than across unconstrained paths." "The analysis examined three years of data on transmission data and constraints as well as data on energy trading patterns in the WSCC to define three relevant geographic markets"
The market consists of decentralized buyers and sellers who develop efficient schedules	"The California markets are designed to let the generation providers themselves determine their own schedules." "This new [market] process relies on iterative market clearing and arbitrage by market participants among the various energy and ancillary service markets." "[the market] replaces inefficient, regulated pricing of generation with […] good old fashioned supplier-customer bartering on prices" "[the market design] abolishes ineffective, centralized planning and new generation, and replaces it with an open market structure that will lead to greater efficiencies." "these filings propose a market structure that promotes unbundled sales of electric energy by a multiplicity of sellers to retail distributors and end-users at rates set by competitive markets"
The system operator merely executes schedules	"The fact is, the vast majority of stakeholders, including both buyers and sellers, concluded that the ISO's operating function should be kept separate from the power exchange's market functions". "I think that the compromise that was reached and sort of hard-fought in California over the separation of the power exchange and the ISO was based on the need to keep any kind of market-making function separate from the transmission operation function." "I think the ISO should have, as I think all the participants in the debate have acknowledged, the access to the resources they need to maintain system balance and physical reliability, but they don't need to be running a market."

The imaginary physical marketplaces was not simply a function of regulatory discourse. Perhaps more importantly, it was engrained in legal doctrines and organizational routines belonging to the existing regulatory framework. Unlike the market institutions, the provisions for the control structure were grafted on top of an existing regulatory structure that had evolved since the beginning of the century. This regulatory framework had developed a view of markets that was independent of market designers' expertise. It went back to the gradual emergence of wholesale markets in transactions between utilities who moved energy between service territories.

[61] FERC, "WEPEX Vol. 1," 163.

Central to FERC's approach to rate cases that dealt with such transactions was the doctrine of the "contract path." Administrative law judges used this methodology to assess whether bilateral agreements about the delivery of energy were legitimate. It had been spelled out in various orders and rules since the 1980s.[62] Relying on the same analogy, it stated that the path of energy flows could be determined in advance and specified in contracts. This made it possible for parties to negotiate transmission prices and factor them into proposed rates. As a legal doctrine, the concept of "contract paths" came with a methodology to assess whether transmission prices had been calculated correctly and supported arguments in central regulatory decisions.

The doctrine was based on the same beliefs just outlined: since it is about contracts, the market appears as a decentralized set of individual decisions. Since the market is a real "place," transmission of energy occurs along stable pathways in a geographic market area, and all aspects of the transaction and its delivery can be specified in the contract. Accordingly, the system operator is a subsidiary entity that merely executes schedules.

The institutional setup in California also resonated with the three beliefs, most prominently, the separation of the CAISO and PX into two separate organizations. While we have seen that the MOU was the consequence of interest politics, it was made up by the regulatory imagination. It suggested that two institutions should be separate because they performed separate functions: the regulators considered grid management to be independent of market activities. As a CAISO representative pointed out, combining the two functions would potentially obstruct the efficiency of the markets: "The operational role of the ISO [is] to be separate from the commercial role of the

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[62] C.f. See *Indiana Michigan Power Company*, 64 FERC 61,184, 1993; and "Order 888" 75 FERC 61,080. Hogan, "Electricity Market Restructuring: Reforms of Reforms."

power exchange. [This] is an issue of integrity of the market. It is perceived by those of us who will be participating in that market that separation is important."[63]

The background imagination of the market thus helps to explain why the CPUC commissioners ultimately endorsed the MOU when they were confronted with pressure from the governor's office. Either way, the three beliefs were deeply embedded in regulatory discourse, institutional rules, and legal dogma. They were foundational for the regulatory approach to energy markets during the negotiations before the CPUC and FERC.

The conception of the market as a place informed the debates about the appropriate control structure for the new markets. As I said, the design of the control structure and the correct regulatory framework were closely tied to the issue of market power. But the idea of the market as a place suggested a problematic understanding of market power. Both FERC and the state regulators decided to apply the so-called "Hub-and-Spoke test" to assess market power.[64]

This test was inspired by antitrust procedures from the Department of Justice and relied on concentration measures, in particular the Hirschman Herfindahl Index (HHI).[65] The HHI computes the sum of the squared market shares of all the suppliers in the market, multiplied by 10,000.[66] This provides a measure of how many competitors of similar size are facing each other in a market. The larger the index, the less competitors of similar size compete. The less suppliers compete, the

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[63] "WEEPX Vol. 1," p. 171.

[64] Diverging from the strict definition of economists, FERC defines market power as a situation "when the seller can significantly influence price in the market by withholding service and excluding competitors for a significant period of time." "Order Noting Intervention, Accepting in Part and Denying in Part Request for Waivers, Conditionally Accepting Rate Schedule, August, 1989," *FERC* ER98-401.

[65] Borenstein, Bushnell, and Knittel, "Market Power in Electricity Markets: Beyond Concentration Measures," 66; Seth Blumsack, Dmitri Perekhodtsev, and Lester B Lave, "Market Power in Deregulated Wholesale Electricity Markets: Issues in Measurement and the Cost of Mitigation," *The Electricity Journal* 15, no. 9 (2002): 12-14.

[66] The convention is to multiply the resulting sum by 10,000. Thus, for example, a market with 4 equal sized producers would yield a HHI of 4 * 0.252 * 10,000 = 2,500.

more market power an individual company has.[67] Concentration measures like the HHI are structural measures because they tie market power to shares in the ownership of generation assets. Such metrics do not change quickly and can be evaluated in longer time intervals.

The three basic beliefs that characterize the conception of the market as a place render the underlying idea of market power plausible. The assumption of spatio-temporal stability made it possible to apply a structural test like the Hub-and-Spoke in the first place. In order to see market power as a structural market feature that can be evaluated in advance of market activity, the market needs to have a stable structure in the first place. Physical market's size may fluctuate over longer periods of time, but a market square is not going to grow or shrink drastically from minute to minute. The first belief thus provided the assumption that made it possible to apply structural measures like the Hub-and-Spoke test.

The other two beliefs sustained the logic of concentration measures at the heart of the Hub-and-Spoke test. Concentration measures view the number of suppliers as the most important factor for market power. The idea behind this concern is simple: Given that competition requires multiple suppliers, market power emerges when there is only one supplier or few enough to collude. In that case, customers do not have alternative suppliers to go to and will be forced to pay the price the monopolist asks.

The simple logic is familiar from everyday life and basic economics. To apply this logic to electricity markets, you need to assume that the markets are a set of decentralized decisions between buyers and sellers and that the system operator simply executes these decisions. These two

[67] If the applicant controlled more than 20 percent of the market shares, which corresponds to an HHI of 2000, it was considered to have market power. It also measures the ratio of "uncommitted" capacity, where the load obligations of both the applicant and other firms are subtracted from installed capacity. James Bushnell, "Looking for Trouble: Competition Policy in the U.S. Electricity Industry," in *Electricity Deregulation: Choices and Challenges*, ed. James M. Griffin and Steven L. Puller (Chicago: University of Chicago Press, 2005), 13.

beliefs mean that one can understand the “market” by merely looking at the interactions between buyers and sellers in the forward markets, excluding what the system operator is doing.

In the forward markets, there are indeed many different buyers and sellers who come together with scheduling coordinators to strike deals about the delivery of electricity. Since the markets are forward looking, there is some price-responsiveness: buyers can decide to buy less if the prices go up, and sellers can decide to increase supply if prices go up. Imports and exports from adjacent control areas can offset shortfalls because the increasing price would make it worthwhile to increase the supply “in” the market.

Thus, from the point of view of this imagined scenario, the logic of the concentration measures applies seamlessly. As a FERC analyst put it in an interview: “If you have a homogeneous market that’s all one product, the only question you have is how many producers does it take before you stop having oligopolistic pricing. […] The only thing is that electric power markets are more geographically and temporally differentiated than a typical market like for copper or pizza, or something.”[68]

The conception of decentralized marketplaces made it reasonable to choose the Hub-and-Spoke test for an assessment of market power: though not perfect, it could be adjusted to the conditions in the electricity system. Accordingly, the regulators did not simply overlook obvious information that should have suggested a different market power analysis or choose the test on the basis of political considerations that ignored economic realities.[69] Instead, they chose a metric that fit their understanding of market power.

[68] Interview with James Turnur, 01/12/2018.

[69] The secondary literature has occasionally suggested that these were the reasons the Hub-and-Spoke test was chosen. C.f. Walsh, *The $10 Billion Jolt: California's Energy Crisis: Cowardice, Greed, Stupidity and the Death of Deregulation*, 43-61; Beder, *Power Play: The Fight for Control of the World's Electricity*; Bushnell, "Looking for Trouble: Competition Policy in the U.S. Electricity Industry." But these explanations ignore that the flaws of the

The excessive concern with market concentration explains why the monitoring structure was set up in such a way that it would not be able to detect market power and why it was not particularly attuned to the operation of the market: the regulators did not think it necessary to develop strong, ongoing control over the market because they viewed the problems as mostly structural in nature. They did not mandate monitoring units for all scheduling coordinators because the only market participants powerful enough to manipulate the prices were the utilities that would be forced to buy from the PX. They did not give substantial enforcement capacities to CAISO or PX because they assumed that structural issues could be solved through the regular process of iterative regulatory filings before FERC.

Compliance mechanisms that could act quickly were directed to deal with grievances between members and dysfunctionalities of the market that might inhibit fair competition. The shape of the control structure that FERC grafted on to the existing regulatory framework can thus be understood as an outgrowth of an imagining of the new market that was deeply embedded in the legal dogma that had been shaped during the previous era of the "utility consensus."

The legal conception of the market as a "place" and the corresponding understanding of market power also explain why the regulators trusted the market with investment decisions. As we have seen, the decision to get rid of regulatory planning processes sustained the problematic temporal dynamic at the heart of the California markets. The markets would have required continual regulatory oversight to guarantee the presence of excess capacity. But to understand this requirement, it is first necessary to understand the dynamic nature of market power. The excess capacity required to keep market power at bay is only remunerated by the markets when market power is

Hub-and-Spoke test were far from obvious between 1996 and 1998. Even stakeholders who suffered from the exercise of market power advocated for it during the regulatory proceedings. See the testimonies of PG&E's economists in the afternoon sessions of the first technical conference in FERC, "WEPEX Vol. 1."

already present. Accordingly, the markets cannot solve the problem. To understand this control requirement, regulators have to first understand that market power emerges relative to the residual demand in the system. It was precisely this piece of the puzzle that was missing during the deliberation about long-term investments.

If market power is simply a structural issue that hinges on supplier concentration, there is no need to worry about the temporal structure of the markets. They will be competitive as long as the ownership over generators is sufficiently distributed. Given that California was experiencing a glut of excess capacity, that Qualifying Facilities had proven the efficiency of small natural gas turbines, and the belief that "price signals of the spot markets" would clearly indicate where new investments were needed, it seemed pointless to hold on to the "byzantine" and "arcane" process of integrated resource planning that hinged on the CEC's biennial resource planning projections. No one recognized that the moment the incentive for the creation of new capacity emerged, it would be too late to start the process of building new plants because the system would be in free fall.

In sum, the imagining of the market as a place dominated the regulatory proceedings that gave rise to a new framework for the control of California's energy markets. It suggested minimal guardrails based on the assumption that the worst problems would be structural—a concentration of ownership. This meant that no centralized, ongoing oversight was necessary, and that FERC could take a lenient approach to oversight: occasional reviews of the reports from monitoring units and quarterly filings about the existing transmission would be enough to observe the glacial shifts in ownership concentration. And so it was decreed.

When the economists and engineers began to create procedures for market oversight at CAISO and PX in 1997, they were locked into a structure with untransparent SCs, very vague oversight goals, and few powers of mitigation. When they wanted help from FERC, they had to go through long and arduous processes in which guilty parties could contest all allegations. FERC had no regular way to verify the claims independently. Though it could set up staff investigations, usually the solutions would be found by working out compromises between competing positions. In the face of markets that continuously produced opportunities for behavior that derailed the market, these oversight structures were woefully incomplete.

This concludes the analysis of the market design process. We have seen how political, technical, and regulatory design work gave rise to problematic decisions. In each case, we found that we were dealing with problems of *expertise*. In political discourse, the designers had trouble establishing jurisdiction over design issues that were crucial for the success of market design. In technical contexts, they were afflicted by blindspots embedded in their theoretical blueprints. The impact of these blindspots were exacerbated by the fragmentation of designers' perspective into economic and engineering camps. It led to a problematic division of labor in the design process and problematic decisions within the design teams. The resulting market structure offered various opportunities for games and market processes that were poorly aligned with the goals of grid management. In this chapter, we have then seen that the fragmentation of design expertise led the experts to underestimate the requirements for the control structure. Regulatory decisions filled the void. These decisions were based on a flawed conception of markets as "places" and led to a control architecture that made effective control impossible.

All of this suggests that the failure of California's market design was a failure of expertise. And yet, one crucial question remains open. Would the market designers have been able to succeed if their market design practices and their epistemological orientation had not presented them with the problems discussed in the second part of the dissertation? Was the design project they pursued in California in principle *feasible*?

10.4. The Feasibility of California's Blueprints: Control and Adaptation

The blueprints for California's markets contained blindspots. Blindspots are implicit assumptions that must be enforced for the market mechanism to work as advertised, but are not explicitly reflected in the blueprint. I have focused on three assumptions that were embedded in the structural form of the blueprints for transmission capacity markets: uniform decision-making, system closure, and incremental change. In the analysis, I have shown that the designers did not try to enforce these assumptions and ultimately made decisions that allowed market participants to violate them.

So far, the argument has established that the design process failed because the designers were *unaware* of the implicit assumptions. But a deeper question is whether they *could* have enforced these assumptions if they had become aware of the requirement. Were the blueprints *feasible* or would it have been impossible to implement them even under perfect conditions for market design work?

With this question, we are moving to a different level of analysis. We are no longer asking about the conditions of design work, but about the plausibility of the design project itself. After all, it is only possible to diagnose a crisis of expertise if the market designers *could* have succeeded. Further, a sociology of economic engineering will ultimately need to develop an independent stance on the question of the conditions under which market design should be attempted and when it should not. The analysis has brought us to a point where we can begin to sketch an answer, albeit a preliminary one.

This question about the feasibility of designers' blueprints is intimately related to issues of oversight and control. Control structures are the flipside of market mechanisms. If a market creates room for behavior that violates the desired market mechanism, a control structure might be able to eliminate the problematic behavior. Due to the possibility of ongoing control, a blueprint can be *feasible* even if its assumptions cannot be inscribed into the rules and software interfaces that establish the basic logic of market action. The feasibility of a market design thus hinges on the compatibility between the requirements for the realization of the market mechanism and the requirements for the control structure.

The crucial question is at what point the market mechanism requires, but does not allow for, effective oversight. Control requires at the least that the oversight regime can collect all necessary information to discover deviant behavior, that it can process the information on the basis of a valid model of the market mechanism, and that it has the power to interfere in the market process to correct deviations. A given market design project is *infeasible* if the characteristics of the market mechanism either make it impossible or overly difficult to fulfill these control requirements. In what follows, I will argue that the blueprints for California's markets were both logically and practically infeasible.

10.4.1. The Blueprints Were Logically Infeasible

A blueprint becomes logically infeasible if it creates control requirements that cannot be met. I will illustrate this problem by considering, again, the blueprint for transmission capacity discussed in chapter 10. I showed the designers ignored the need to enforce the uniform decision-making assumption. This made it possible for traders to act on the basis of information that was not represented in the simplified network structure, which in turn, derailed the market mechanism.

Now, the crucial question is: Could the market designers have enforced the assumption if they had been aware of it?

Again, the problem was that traders could use information not represented in the market to game the congestion management system. They would essentially make trades that did not reflect the calculative rationality required by the blueprint. Instead, they aimed to trade in ways that would generate artificial congestion. They would then get paid to relieve this congestion by not producing energy that they had never intended to produce in the first place. Since the trades did not follow the rationale of the model, they did not contribute to the search for optimal dispatch and put the market at odds with the requirements of the allocation problem.

To prevent this game and enforce the correct logic of decision-making, the monitor would have needed to detect situations where traders acted on information other than those represented in the simplified network structure—i.e., information about intrazonal congestion or power flows outside California. For each trade, the monitor would have needed to decide if the transaction reflected an attempt to create an artificial transaction or a legitimate attempt to buy or sell energy or benefit from price differences between locations. The question is whether a monitor could have made this determination given the structure of the blueprint.

For some transactions, the answer is yes. In fact, it would have been quite simple. Several instances of congestion games could be discovered because they violated expectations about actors' basic behavior. The blueprint assumes that traders seek to make profitable transactions of energy under conditions of strong competition. If, in pursuing a congestion game, a trader registered a transaction that violated the absolute transmission limits on a line by a large amount, traded at an absurd price, or traded at a clear loss, monitors would be able to discover the deviation easily. The behavior would stand out in obvious ways against the local standard of rational behavior.

Software could be coded to flag such deviations from past or average behavior. In these cases, the trader behavior violated clear, local standards of behavior and was thus not ambiguous.[70]

However, most transactions that created artificial congestion did not violate the local logic of rational behavior—they were ambiguous. They could be read as either a transaction that created a profit or as a transaction that created artificial congestion. This ambiguity derived from the non-linear interactions between power flows. Since power flows interact with each other and can even cancel each other out, there can be sequences of transactions that produce artificial congestion even if they are locally rational. Conversely, there are sequences of transactions that first create and then resolve congestion, but push the system closer to equilibrium.

For example, if a line is at the capacity limit, a transaction in the opposite direction can free up additional capacity. A trade on that extra capacity now becomes possible. What would have constituted a violation of the capacity limit at one point turns into a feasible transaction in the next. This means that the validity of a single transaction can only be evaluated *relative* to its position in a system of transactions that lead to the optimal dispatch.

But in a decentralized system like that of California, the bilateral trades on a simplified network were supposed to produce the optimal combination of transactions. If the market was affected by a game, it did not produce this information and the controller would not be able to construct the counterfactual that is necessary to evaluate the transaction.

Accordingly, the blueprint was logically infeasible. As a decentralized search algorithm, the implicit assumption could not be enforced. The requirements for the blueprint's explicit

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[70] This is how CAISO and PX discovered games early on. Traders scheduled to send thousands of MW/h through a 500 KW line called at Silver Peak; at other times they submitted tiny bids to sell ancillary services for absurd dollar values (e.g. one MW/h for 9999$). These were obviously meant to test whether there were internal limits in the bidding software, not to make trades that were rational in relation to the market as defined by the blueprint.

assumptions (simplified network structure) were inconsistent with the *requirements* for the implicit assumption of uniform decision-making (centralized oversight of information used to make trades). The problem was one of *insufficient information*. Due to the high interdependency of transactions that would produce the optimal dispatch, there was no *local* standard of behavior that could have given the game away. The monitors would have needed to know what the market was first supposed to produce; since they did not have the information, detecting the game in all cases was impossible.

Note that there is a certain irony here. If it *had* been possible to compute the ideal solution to the dispatch problem in order to evaluate the transaction, the market would have been pointless.[71] Either way, we can conclude that the blueprint for the California market was infeasible because it required a control structure that would have to act on information that was not available. But this was only one very specific way in which the blueprints for California's markets were infeasible. There was a second, more general problem with the basic architecture of California's markets.

10.4.2. The Blueprints Were Practically Infeasible

I will now consider why the blueprints for California's market were practically infeasible. The blueprints for California's markets emphasized the freedom to innovate. This requirement was directly related to the underlying allocation problem. The operation of an electricity system is a very demanding task. The many interacting parts, the dangers of dependence on fossil fuels, and the hazards to the environment all mean that the industry is in a constant process of technological

[71] Hence, most modern markets use a centralized mechanism to compute locational marginal prices at each node and then simply tie them to the energy transactions—there is no independent market for transmission capacity.

transformation. The development of renewable energy technologies over the last fifty years illustrates the dynamic nature of the industry. Accordingly, the blueprints for electricity markets have to give market participants substantial flexibility to make local decisions about how to produce, how to consume, and what to trade. Yet the blueprints for the California markets also envisioned a set of ten to twelve highly interdependent markets with different geographical and temporal reach. The markets for these products were highly interdependent. Further, the logic of competitive markets was fundamentally at odds with some reliability requirements in California.

Even without the many decisions that exacerbated the mismatches between market mechanism and allocation problems, the combination of market complexity and adaptability created very high control requirements. The intellectual project effectively envisioned a world where market participants were free to act and innovate as they wanted. But in this world, they would also act in ways that were consistent with the highly specific requirements of optimal dispatch. Since any market produces incentives to profit by circumventing rules, only a highly coercive control structure could have reconciled the competing requirements. Specifically, this control structure would have needed to *adapt* to changes in the market.

Such adaptation has two requirements. Monitors need to discover changes in the market logic. Then, they need to decide whether to constrain the anomalous behavior or to allow it and change the market rules. However, both of those requirements are difficult to meet in complex market environments. Detecting anomalous behavior becomes difficult if the market mechanisms can evolve to contradict the blueprint. Suddenly, the heuristics that guide regulators' approach to the market no longer fit the market. This means that signals of anomalous behavior may not reach the regulator. The only way to respond is to challenge the background assumptions of the heuristics used to collect and screen the market data. This, however, is inherently work that has to take place in small teams and runs up against the static information flows in large bureaucracies.

To illustrate this problem, I will reconstruct how California monitors managed to adapt their oversight regime and why they failed to convince FERC to do the same. The market monitors at both FERC and in California started with a flawed metric of market power. Soon after the markets opened in 1998, monitors at CAISO and PX discovered these flaws and developed an alternative metric. In what follows, I will show what was necessary to detect the problem in the first place. Here, the issue is that monitors use heuristic models to filter the market data. These heuristics are based on imagining how the markets work. If the evolution of the market violates these expectations, the heuristics may fail to reveal problematic behavior. Since there was no clear signal of deviant behavior that could have alerted the regulators to the need for change, the discovery required regulators to expose themselves to unfiltered market data. In a second step, I show how monitors at CAISO and PX managed to develop the new metric—the so-called Residual Supplier Index (RSI)—and why FERC failed to adapt this measure despite repeated warnings from California. FERC failed to adapt because the regulators did not have to struggle with data in the way Californians did.

The highly local process of adapting the background assumptions of the analytical heuristics and the way large bureaucracies prevent such adaptations illustrate how market design becomes practically infeasible. If an allocation problem requires both an adaptive and a complex market process with many interdependencies, the control requirements escalate. This brings some of the basic problems of centralized planning back into the picture. I will now analyze the process of adaptation in California to illustrate these problems.

10.4.3. California Recognizes Flaws in the Imagination of the Market

A member of CAISOs internal market monitoring remembered that the shift from the Hub-and-Spoke to the Residual Supplier Index (RSI) occurred in 1998. "I came to that understanding that the traditional market power indices just were measuring the wrong thing in power markets, probably one year into the operation of the market."[72] This discovery occurred while the market monitors were working on operational problems in ancillary service markets.[73]

CAISO used ancillary markets to purchase electricity services for contingency purposes. The market for replacement reserves was designed to procure a small amount of standby capacity to balance the difference between scheduled demand and the ISO forecast one hour in advance. This market was neither very large nor supposed to be particularly volatile. Yet in May of 1998, the operators in CAISO's control room suddenly observed large price spikes during times when there was almost *no* demand ($5,000 on July 9; $9.999 on July 13).[74]

Confusingly, when there was high demand, the markets cleared with reasonable prices. Similarly, the relation between the prices for different ancillary services did not make sense. Lower quality services gained higher prices than higher quality services. Alarmed by these developments, the governing stakeholder board of CAISO imposed price caps on the market (i.e., a fixed ceiling for the price) and asked the monitoring teams to find out what was happening.[75]

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[72] Interview with Anelise S., 12/13/2017. The archival documents also begin to mention the RSI toward the end of 1998.
[73] Much of the material for this section stems from two archival sources. Either it is drawn from the FERC dockets that chronicle the back and forth in the redesign of the ancillary markets (particularly ER98-2843) or the internal business documents at the CAISO. The FERC docket started when CAISO asked for emergency help because the ancillary markets displayed vast price spikes after several power marketers had received the right to sell ancillary services at market rates. The material from CAISO chronicles the work on the ancillary markets that leads to the FERC filings. Most of the other material stems from the internal documents of the market monitoring units. C.f. table 2-1 for a detailed list of sources about market monitoring in this archive.
[74] There were corresponding investigations of anomalous behavior at the Power Exchange. E.g., "Enron Silver Peak Investigation—Investigation Timeline, January 2000," George Sladoje Private Archive of Compliance Filings.
[75] C.f., "Emergency Motion to Stay, Notice of Action Taken, Request for Rehearing, and Motion for Clarification of the California Independent System Operator Corporation," FERC ER98-2843, Jul 13, 1998.

Initially, the operational problems seemed like a routine issue that could be explained within the prevailing idea of markets as "places." FERC interpreted the problems along these lines. After very brief consideration, the commissioners approved the price caps and moved on. In their explanation, they focused on the fact that some generators were selling energy at regulated rates rather than market prices, which suggested that there was not enough competition. Accordingly, it was possible to read the problem as a consequence of scarce supply. Since the problems seemed minor and the startup of the markets had created many other issues, they quickly moved on.[76]

However, the market monitors at CAISO/PX did not adopt the routine explanation. Instead, they launched a long and careful investigation that lasted over a year. As an economist in the unit put it, "The ancillary services markets occupied most of my attention for the rest of my time in the ISO."[77] Two factors were crucial for their ability to discover the systematic error in the course of this investigation. First, an organizational context that motivated them to investigate the operational issues deeply, and second, the need to reconstruct their analytical categories from raw system data. I will discuss these factors in turn.[78]

California's market design was as unique as it was radical. It was conceived as a revolutionary vision of what electricity markets could be, an early version of Silicon Valley's idea of "disruptive technology." The proximity to the culture of Silicon Valley was explicit: the official who ran the HR department in 1998 had previously worked with start-up technology firms in Silicon Valley. One of CAISO's founding members explained the search for employees like this:

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[76] "Order Denying Motions for Stay, Authorizing the ISO to Take Interim Action, Requiring Market Monitoring Reports, and Providing Opportunity to Comment, July 17, 1998" *FERC* ER98-2843.
[77] Interview with Jan S., 01/23/2018.
[78] This first issue is consistent with Karl Weick's observations about the requirements for "high reliability organizations." He isolates several dispositional traits that are helpful, such as being attuned to failure, a culture of vigilance, etc. Karl E. Weick and Kathleen M. Sutcliffe, *Managing the Unexpected: Sustained Performance in a Complex World* (New York: John Wiley & Sons, 2015).

"We need somebody who really wants to do this because it's cool, 'cause I can make this work, this is the new stuff, this is where I want to be."[79]

The founding members at CAISO and PX were looking for people who were highly motivated and excited to try something new. In addition, the timeline for the development of the new organizations was tight. As an engineer put it: "We had a little over a year to go from monopoly utilities based on service areas to some type of a market with an independent transmission operator."[80] This meant that the employees had to work very hard in a context where few problems had been worked out; they signed up for 60–80 hours weeks in a high-stress environment. The ambition of the project, its startup character, and the intense working environment attracted employees that identified closely with the fundamental vision of "reliability through markets" and were invested in its success.

In the interest of getting the best of the best, the ISO and the PX either hired employees who had worked in electricity systems their entire life or outsiders who were enthusiastic about markets. While the former tended to be engineers and operators who were close to the age of retirement, the latter tended to be analysts and economists who were just beginning their careers. As one of the founding members of CAISO stated, there were not many staff members "who had both types of expertise."[81] Most members of the monitoring units came to the ISO and the PX without a detailed understanding of how electricity systems worked. The internal unit at CAISO had only five full employees. All of them were trained as economists. An electrical engineer served the group in an advisory function.

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[79] O'Donnell, *Soul of the Grid: A Cultural Biography of the California Independent System Operator*, 50.
[80] Interview with Deb Le Vine 11/29/2017.
[81] Interview with Ziad Alaywan, 08/31/2018.

The PX's market monitoring group employed seven people with a more diverse background (economists, traders, lawyers, and system administrators) but none of them had previous experience in the utility industry. Accordingly, they did not have strong intuitions about the details of how the ISO used ancillary services, or how generators made choices about when and how to provide such services.

The two independent surveillance committees were staffed with academic economists at CAISO and with academics from other fields at PX. They, too, had no experience with grid management. A story by a CAISO economist illustrates this point forcefully: "A couple of days before I was supposed to come in [for my first day at work], I got a call, saying, would you go down to have a meeting in the market surveillance committee in Oakland because there has been a crisis in the ancillary service markets, [to] which, my question was: what are ancillary services?"[82]

Conversely, the engineers did not have much experience with markets because they were used to the world of regulated utilities. An engineer described it like this: "The operator mentality for all utilities back in the 90s was command-and-control, and so trying to get operators to rethink things as a market and obtaining reliability through markets was a challenge."[83] Accordingly, engineers and economists tended to be demographically apart and had disparate sets of expertise. The difference in age, expertise, and outlook created barriers to the cooperation between the two sides and insulated their respective knowledge from each other.

These differences were exacerbated by the problems I have already observed for the two types of market designers. Seemingly conversing in the same formal language, the two groups were not fully aware of the conceptual differences in their basic approach to the new markets.

[82] Interview with Jan S., 01/23/2018.
[83] Interview with Kimberly M., 11/21/2017.

Since these differences were crucial to understanding the oversight requirements and since they worked largely separate from each other, both sides had strong expectations about the efficacy of market mechanisms. Both thought that the logic of markets would assert itself without much regulatory activity. One of the employees who got hired at this time told me that the culture was described to her in the following manner: "If your mindset is that you want to continue command-and-control, then this is probably not the right place for you."[84]

The idea was to create the minimal set of rules to allow the wisdom of the market to assert itself and produce efficient dispatch schedules. Perhaps nothing illustrates this mentality better than the market monitors' initial confusion about their jobs. When one of the new monitors first came to the ISO, she did not know what she should be doing. Trained to think about these markets as analogous to natural gas and trucking industries, she thought they were guided by "Adam Smith's invisible hand." To gain some orientation, she even "tried to visit a couple of other industries that had market monitoring and tried to figure out, well, what is it that they call the exercise of market power."[85] There was, accordingly, a strong perception that market mechanisms should produce efficient dispatch schedules without regulatory interference.

Coming to the problems with the ancillary markets with this expectation, it was highly counterintuitive to the market monitoring units that lower quality services could obtain higher prices than higher quality services or that prices would increase during time of lower demand. This seemed simply wrong. As one economist stated, "The amount of each ancillary service demanded by the ISO does not depend on market prices, and these demands are not procured in a rational

[84] Interview with Deb LeVine, 11/29/2017.
[85] Interview with Anelise S., 12/13/2017.

manner."[86] It seemed like market participants were behaving *irrationally*. This, however, was deeply vexing to the monitors because they identified with the organization and its mission to achieve "reliability through markets." The irrational pricing patterns violated this principle because it required the ISO to impose price caps on the market. This created a strong motivation to figure out what really caused the operational problems. Though the available heuristics offered a standard interpretation of the troubling signal, its occurrence violated the expectations and therefore required deeper investigation.

Since the problems occurred early in 1998 when the markets had just opened, there were no established routines for dealing with this challenge yet. A corollary of the strong belief that markets were self-regulating, the market monitoring function at CAISO and PX had not been well specified. As a member of CAISO's unit put it, market monitoring "was sort of an afterthought" during the design of the markets.[87] The existing cosmology suggested that market power was a structural issue that could be measured in advance with the Hub-and-Spoke test. FERC had required a market monitoring function in the tariff, but the designers of the system assumed that the divestiture of utilities' generation assets had taken care of market power problems.

In addition, none of the other electricity systems had market monitoring units, according to the aforementioned CAISO monitor. "The first month that I was on the job, I couldn't find quote 'a market monitoring unit'—none of the ISOs had them because they were all from tight power pools."[88] Accordingly, the economists had no specific routines for dealing with problems that were

[86] "Report on Redesign of Markets for Ancillary Services and Real-Time Energy, prepared by the Market Surveillance Committee of the California ISO, March 25, 1999," *FERC* ER98-2843, p. 3.
[87] Interview with Anelise S., 12/13/2017.
[88] Ibid.

specific to electricity systems. Absent detailed routines for dealing with operational problems, the monitors wanted to start with standard econometric methods.[89]

A typical "markup study" as well as more sophisticated game-theoretical analyses of oligopoly behavior required them to analyze buyer and seller behavior relative to information about production costs and existing demand. This analysis would have allowed them to know if the problem was scarcity and lack of competition or something else. But the market monitoring teams at CAISO and PX did not have customized tools to conduct the analysis of the market data yet.

To address the ancillary market crisis, they needed to create the tools to make the market observable. They had to collect data that would allow them to observe supply and demand curves, to disaggregate them into bidding behavior, and to compare them against the production costs of generators under transmission constraints. This turned out to be much more difficult than anticipated: "One of our biggest challenges at the startup was understanding how the market systems themselves produced the data because there was so much of it", according to one CAISO monitor, who pointed out that "a tremendous amount of effort goes into just setting up the database and the analytic tools to drill into that database…."[90]

The problem was that the database simply did not create data that was legible to the monitors. Some of the software was not working yet, and parts of the database were empty—areas outside CAISO's control zone could not submit bids yet. The operations department was continuously tweaking the database structure in order to improve on operational problems. In addition, the coordination between the scheduling coordinators and the ISO involved several,

[89] Interview with Lawrence Conn, 11/20/2017.
[90] Interview with Theo C., 11/27/2017.

interdependent interactions. The different parties therefore adjusted bidding schedules relative to decisions in the markets and system requirements.[91]

Lastly, there was a rapid development of workarounds in other departments who worked with the database. The Norwegian company that provided the software for the new markets was slow in adopting functionalities for the substantially different setup in California. Employees who faced tight deadlines began to use shortcuts to “put out fires” as one economist put it.[92] They started separate spreadsheets for calculations of settlement data and set up additional databases to accommodate changes in data formats and solve compatibility issues. This made the interaction between PX and CAISO difficult and multiplied the technical problems of extracting data. Accordingly, it was not possible to simply request price/quantity pairs for suppliers and customers and aggregate them into supply and demand curves.

When they requested data for their analysis via queries to the Oracle database, they received data that was highly unstructured, littered with confusing, technical information, and had substantial gaps. In other words, the monitors had to contend with raw system data. This data reflected how software recorded information that was needed to operate the markets as well as the electricity system. It did not reflect the cosmology of decentralized market places that oriented the monitors’ analytical approach.

In order to apply their methods, the monitors tried to create datasets from this raw system data and impose the quantitative categories of econometric methods. This represented an attempt to resolve the inherent ambiguity of data into stable categories.[93] But the attempts failed. As soon as they abstracted from the system data, the quantitative relations between these categories did not

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[91] Ibid.
[92] Interview with Lawrence Conn, 11/20/2017.
[93] Abbott, "Seven Types of Ambiguity," 68-9.

make sense. Also, much of the potentially relevant data remained outside the scope of their analysis. This suggested that the analytical categories misrepresented the data and made visible the inherent ambiguity underlying the categories they tried to apply to it.

In the face of this ambiguity, the monitors were unable to even specify hypotheses about what was happening. The raw system data resisted their attempts to apply their analytical framework, and since the analytical framework was informed by their basic understanding of energy markets, it threw that basic understanding into doubt. Accordingly, they realized they were suffering from some fundamental misperception.[94]

In sum, two factors proved decisive for detecting the mismatch between the cognitive model of the market and its actual operation. First, the monitors were highly motivated to address even minor operational problems because they contradicted explicit expectations that they identified with. Second, when they tried to develop an explanation, they confronted raw system data whose structure did not conform to the categories of their cosmology. When they tried to reconstruct their analytical framework from this data, they recognized the limitations of that framework. This made the problems with their understanding of the market visible.

From this, we can already infer one of the ways in which adaptive market mechanisms can overwhelm oversight structures. If the dynamic complexity of the market is too great to allow the granular analysis of transactions on the basis of raw system data, regulators may become unable to note shifts in the market process. It is important to note that this is already how complex market environments (such as financial markets for credit derivatives) operate. Since companies always

[94] This argument is based on the internal debates of the market monitoring units at the PX and the ISO. The minutes from these meetings can be found in "ISO Market Surveillance Committee Meeting Files, 1998-2000," R400.006-R400.007, Box 12 & 13, *CSA*. I supplemented the sources with material from the interviews with the members of the market surveillance committee and the market monitoring unit.

have an incentive to avoid competition by circumventing regulation, investment banks constantly look for ways to create products that are ambiguous to regulators and then fall through the cracks of the oversight regime. These strategies benefit from the fact that regulators use very limited indicators of deviant behavior. If a product does not match these evaluative heuristics, it does not register as problematic. The signal is filtered out before it arrives at the level of regulatory attention.[95] The next question is how the regulators in California resolved the problem after they became aware of it.

10.4.4. California Develops a New Heuristic

Shortly after they had been asked to investigate the operational problems in May of 1998, the monitors found themselves unable to develop explanatory hypotheses and evaluate them. Their analytical framework did not fit the data, and the data itself was complex and confusing.[96] Institutionally, there was not much guidance. The startup culture of the ISO simply suggested that one should figure out the expertise necessary to fix the problem.

In light of these problems, the group entered a space of reflexive suspension. Even though they faced tight deadlines and other tasks, they recognized that they had to take a step back. They needed to understand how the system *produced* data before they could begin to determine what was happening in the ancillary markets. To this end, they established an independent working

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[95] Russell J. Funk and Daniel Hirschman, "Derivatives and Deregulation Financial Innovation and the Demise of Glass–Steagall," *Administrative Science Quarterly* 59, no. 4 (2014); Donald MacKenzie, "The Credit Crisis as a Problem in the Sociology of Knowledge," *American Journal of Sociology* 116, no. 6 (2011).
[96] As can be inferred from Paul Joskow's "Intervenor Comments, N. 6" in "Market Surveillance Committee Meeting, Radisson Hotel at Berkeley Marina, El Dorado Room, September 18, 1998," R400.006-R400.007, Box 12, Folder 1, *CSA*.

group. It brought together two economists, two electrical engineers, a lawyer, and three administrators with expertise in data management.[97]

In what follows, I am going to first analyze how the working group managed to enter a meta-reflexive discourse that enabled them to revise their basic understanding of the markets. In the second step, I show how this discourse led them to progressively revise the core beliefs of the old cosmology. This led to a new understanding of the markets and revealed the nature of market power in energy markets to the market monitors.

The working group could bring in experts from other parts of the organizations. They worked in concert with the market surveillance committee, monitoring staff at the PX, the operations department, and input from other stakeholders. In the past, cooperation between economists in the monitoring group and engineers in the operations department had been difficult. They tended to blame each other for problems and avoided engaging too deeply with each other's perspective. The problem was exacerbated by the difference in age and expertise: the economists were young and tended to come from outside the utility industry, while most engineers were older and had largely spent their careers in the regulated industry. Instead of cooperating with each other, they preferred to divide tasks and stick to their area of expertise.

When the market monitors realized that they had to revise their understanding of electricity systems to address the problems, the members of the working group overcame their opposition to engineers. Both economists and engineers perceived the problem in the ancillary markets and wanted to solve it. The problem also irritated similar expectations even though they arose from different backgrounds. While the economists had strong expectations about flawless market performance because they did not understand the constraints of the electricity systems, the engineers

[97] Interview with Jan S., 01/23/2018.

had similar expectations because they did not understand how these constraints would impact market performance.

To the engineers, the markets were just another source of inputs for their task of managing the grid reliably. In the past, generators had logged their marginal costs and provided resources to maintain reliability. Their understanding of markets suggested that the same should happen in a competitive environment. Though the engineers thought about the problem mechanistically as an "input/output" issue rather than in terms of flawed competition, both groups thus dealt with the same problem.

When the economists in the working group decided that they needed to revise their fundamental view of electricity markets to understand how the markets produced data, the shared problem allowed them to establish a meta-reflexive discussion with the engineers in the operations department. The shared perception of the problem allowed them to draw out and discuss the differences in their understanding of how electricity systems and markets worked. Quickly, the members of the working group realized that the two perspectives had to "be married to each other," as one manager put it. An engineer described the unfolding interactions with the monitoring group like this:

> I used to go to the market monitoring folks and would basically have long debates with them about what causes the problem and what we are going to do about it. And it's very challenging, because you have group of people […] who are very smart, but […] they have never really run an electric grid before. […] So, here I am pulling my hairs and I say: "that is not how it works," and they say "well, that is how it *should* work." And I say "I don't know what it should. It just doesn't work that way." And they say "well, explain why it doesn't work that way." So, I would explain it to them.[98]

This quote illustrates two processes: on the one hand, it highlights the strong, conflicting expectations on both sides ("that is not how it works" versus "that is how it should work"). On the

[98] Interview with Ziad Alaywan, 08/31/2018.

other side, it shows how the economists' inability to understand why the markets were not working the way they *should* be working created a readiness to actually learn how the system worked. The problem of having to make sense of counter-intuitive market data forced them into interaction. The fact that they faced the same problem sustained the exchange. An economist described the experience with the ancillary markets like this:

> G.R.: Did you work mostly with other economists on these problems or did you have input from other professionals as well?
>
> F.W.: […] I guess the short answer to your question is: you wanted to learn what was going on. And the big thing is, at least my view: if doesn't make sense then you keep asking questions and you keep looking at the data, go dig in deeper, until you can start to make sense of what is going on. And that means you talk to engineers, you talk to market participants, you name it.[99]

This interaction would be so basic as to involve little numeric examples, hashed out on pen and paper to illustrate basic elements of system functionality (to the economists) and games of strategic interaction (to the engineers). The process of slowly integrating the expertise about the technical features of electricity systems with the expertise of how markets worked threw larger and larger parts of the guiding cosmology into question, creating space for exchanges between economists and engineers and led to the revision of the three fundamental beliefs that characterized the cosmology. It was a meta-reflexive exercise in which a particular piece of data would lead the experts to take a step back from the problem at hand. They would explain their reasons for thinking about the data in a particular way and then evaluate these background assumptions in conversations with the other side.

The conversations first changed the perspective on the role of the system operator (ISO). When the monitors tried to reconstruct bidding behavior from the system data with the help of the

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[99] Interview with Frank Wolak, 03/16/2018.

engineers, they noticed that the demand for ancillary services was not composed of various bids from different, price-responsive customers. Instead, the ISO decided what to buy on customers' behalf, and it did differently than market participants, i.e., occasionally it bought low quality services at a higher price than available higher quality services would have cost. This was one of the factors that drove the abnormal price patterns.

To understand why the ISO structured its demand curve like this, the team talked to staff in the operations department and found out that "the ISO operators will adhere to rigid procedures when acquiring ancillary services."[100] The ISO simply had requirements for each type of service. It would buy exactly as much as required regardless of the price or of considerations about the kinds of incentives this would create for generators who offered these services. This challenged the view that the ISO was merely an "air-traffic controller." Rather, it became obvious that the ISO acted as a de facto buyer who is not driven by concerns about cost, but reliability of the system.

In addition, once the working group began to disentangle the behavior of sellers from the data, the regulators recognized that the bidding patterns correlated with this reliability requirement. The sellers submitted schedules that systematically tested the boundaries of what the system operator was willing to do. For example, the reason the price was set to $9.999 on July 13 was that traders were testing the boundaries of the system. They thought the software would not be able to handle more than four digits and wanted to see if the ISO would be willing to buy at the maximum possible price. Once the team realized that the ISO was actively buying from the markets and that its reliability standards drove sellers' behavior, they began to view market activity as dependent

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[100] "Preliminary Report on the Operation of the Ancillary Services Markets of the California Independent System Operator (ISO), prepared by the Market Surveillance Committee of the California ISO, August 19, 1998," *FERC* ER98-2843.

on the ISO's task of maintaining reliability. This insight transformed all three beliefs that characterized the old imaging of markets as places.

First, it supplanted the view of markets as locations where decentralized buyers and sellers meet. Since the ISO acted as the ultimate buyer who would do whatever was needed to "keep the lights on," it made more sense to see market dynamics as oriented around this task. The markets thus began to appear as a mechanism that generated inputs for the task of managing the grid. The first annual report for the ISO created by the market surveillance unit stated this sentiment explicitly: "The underlying approach adopted in restructuring California's electric industry was to replace centralized optimization, based on iterative numerical algorithms, with a process of coordinated decentralized optimization."[101] In other words, markets are seen not as independent locations, but as a mechanism of "decentralized optimization" that the ISO uses to organize the efficient dispatch of generation to match demand.

This change also affected the perception of the system operator's role. Since it "operated the markets" in line with its operating requirements, the ISO was no longer seen as an "air-traffic controller" who executed schedules provided by the markets. Instead, it appeared as the designer of the market. Accordingly, the market activities are then dependent on what the system operator does rather than the other way around, as this quote reveals: "The market structure adopted in each case is, to a large extent, characterized by the scope of activities and authority delegated to […] the system operator."[102]

Since the management of the grid occurs in very short time frames (i.e., second by second), the vision of the market as a piece in the larger mechanism of the electricity system implied a

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[101] CAISO, "Market Surveillance Report 1999," 6.1.
[102] Ibid, 2.2.

different spatio-temporal imagination. Seen from the perspective of system operation, supply and demand conditions in the system change all the time and relative to the way energy flows on the transmission system. Since the relations between buyers and sellers are the economic representation of these conditions, they can change anytime as well. Accordingly, markets are no longer stable locations, but constantly fluctuating relations between buyers and sellers.

In the annual report for 1998, the head of the market monitoring unit states that "the electric power market is composed of 8,760 hourly markets in a year, exhibiting vastly different demand and supply conditions even within the same geographic area."[103] The quote reveals that markets are no longer considered locations. They are tied to geographic locations but exist independently. They are defined by continuously shifting relations between supply and demand in varying geographic areas.

In sum, the market monitors changed the original imaging of markets as (1) temporally stable locations where (2) decentralized buyers and sellers came together to create schedules that (3) the ISO merely implemented. They now believed that markets were (1) flexible relations between buyers and sellers that (2) served as a mechanism for a centralized system operator who (3) designed and operated the markets in line with reliability criteria.

The new view emerged from a blending of ideas about strategic interactions (economists) and energy systems (nonlinear relationality of energy inputs/outputs). It led to an understanding of markets as relational mechanisms that fed into the larger machine of grid management. In the process of exploring each other's perspective, the novel concept thus emerged in a reflexive discourse that merged and recombined the languages of economists and engineers.[104]

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[103] Ibid, 7.2.
[104] John F Padgett and Walter W Powell, "The Problem of Emergence," in *The Emergence of Organizations and Markets*, ed. John F. Padgett and Walter W. Powell (Princeton, NJ: Princeton University Press, 2012).

The new conception of the markets highlighted precisely those elements of the system that are relevant to market power: it was now clear that the ISO acted as a fiduciary of aggregate demand in real time and that market behavior reacted to that role. Since the market activities were oriented to the role of real-time system management, interrelations between forward and real-time markets became a crucial issue of concern. The following quote from a report by the market surveillance committee illustrates this new way of thinking. It concerns the price formation in ancillary markets: "As a general rule, the cost of ancillary services closely follows the pattern of prices in the energy market, with prices in all these markets being affected by overall system load and supply conditions."[105] In other words, forward and real-time markets are interrelated, and prices are determined by the overall balance of supply and demand, which construed as "system load," is seen as merely an input to be processed.

Since this directs the focus to the question of how aggregate demand can be met second by second, it becomes plausible to think that market players who can disrupt this process would have market power. From here, it was a small step to realize that a supplier's position in the supply stack relative to aggregate demand provides the key to market power. This is precisely what the Residual Supplier Index (RSI) measures. This metric determines whether the capacity available by all suppliers other than the supplier being tested would suffice to meet demand. If not, the company being tested has market power. For example, if one hour the amount of supply in the market is 110 without counting Seller A's capacity and the total market demand is 100 MW, the RSI is 110/100, or 1.1. An RSI less than one indicates that all suppliers other than Seller A are unable to meet demand and that Seller A is pivotal, i.e., necessary meet demand. Thus, fixing the problems in the

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[105] "Report on Redesign of California Real Time Energy and Ancillary Service Markets, Market Surveillance Committee of the California Independent System Operator, October 18, 1999," *FERC* ER98-2843, 20.

ancillary markets led the market monitoring team to revise their fundamental imagination of the market and enabled them to create a new metric for the discovery of market power.

The discussion shows that the adjustment of the oversight regime required a group of experts to cooperate closely with each other. In order to move to a different cognitive model of the market, they had to investigate a seemingly trivial issue deeply. Then, they had to wrestle with raw data to discover that their software infrastructure systematically missed crucial patterns of deviant behavior. In a long reflexive discourse, they then revised their beliefs. This allowed them to change how they collected and processed data and how they should measure signals of deviant behavior.

It was precisely these conditions that were absent at FERC. The regulators did not engage with raw system data or investigate routine problems in the California markets. They were two steps removed from the markets and acted on the basis of reports that slowly percolated through the bureaucratic channels. Since these reports and sources of data always conformed to the standards of the agency, and since these standards reflected the imagination of the market as a place, the regulators never had a reason to challenge their understanding of the markets. But from the perspective of the market as a "place," there seemed to be no reason to switch to a different metric for market power.

After California's regulators managed to revise their understanding of energy markets and developed the new metric to discover market power, members of the market monitoring unit went to FERC to convince them to change their approach as well. In a retrospective interview, a member described her experience to me like this:

> AS: I went and told them that I didn't agree with their accounting of what defines market power in the electricity markets.
>
> GR: And what did they say?

> AS: They had drunk the Kool-Aid. They thought that in every other market these supplier concentration ratios, HHI index, […] all worked—what are you talking about, why shouldn't they work in power?[106]

She found it impossible to convince FERC that tests of supplier concentration were "totally useless because they assume that demand is stagnant and supply changes, but not that much and not that often." The federal regulators did not accept her arguments because they did not consider this assumption problematic. From FERC's perspective, the Hub-and-Spoke test took care of the physical features of electricity systems as well as the characteristics of customer demand. Since FERC's staff did not receive market data that reflected the logic of market transactions directly and were removed from the ongoing oversight of the markets, they had no reasons to challenge the background understanding. After all, it provided a compelling explanation of the price spikes. Despite repeated warnings, FERC thus did not change their metric until January of 2001, when the California crisis had turned into a national disaster. At this point, the failure of the previous understanding became so obvious that FERC could no longer cling to the status quo without facing repercussions from Congress and the general public.

The analysis shows how difficult adaptation to a changing market environment is in a differentiated bureaucracy. If innovation affects the basic logic of the market, regulators' definition of undesirable outcomes and acceptable behavior may no longer apply.[107] This means the guiding heuristics for the analysis of the market are no longer valid. Adaptation requires monitors to

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[106] Interview with Anelise S. 12/13/2017.

[107] This problem is exacerbated if the desired outcomes of markets are less tangible than in the case of electricity markets—it is relatively easy to specify when something went wrong because we have a relatively clear idea what a "just" price for electricity is. But that does not always have to be the case. Some markets may not have an obvious definition of a "normal" baseline price for commodities. Most obviously this is the case in financial markets where the prices reflect disaggregated imagings of the future rather than a set of productive processes whose cost can potentially be calculated. Jens Beckert, *Imagined Futures* (Cambridge, MA: Harvard University Press, 2016). Interestingly, the same basic idea has been recognized by economists. Akerlof and Shiller, *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism*.

challenge their guiding heuristics and investigate the presuppositions of these heuristics.[108] But the analysis here suggests that this is an inherently local process that can quickly run up against the division of labor in an agency. Since the division of labor itself depends on assumptions about the way the markets work, and since the flows of information are highly standardized, the different departments are unlikely to receive the data that would aggravate their background assumptions.

In sum, since revision of the background assumptions about the market environment is a reflexive, local process in which experts need to wrestle with market data, it runs up against the standardized and mediated way information percolates through bureaucracies. Since market complexity requires larger bureaucracies, the control requirements are fundamentally at odds with each other. They render the market design project practically infeasible.

10.5. Concluding Thoughts

The difficulties in adapting the market monitoring regime suggest that California's intellectual project was internally flawed. Since the markets needed to operate in a very specific way to produce the optimal dispatch, they were incompatible with a market design that introduced room for innovative behavior. To reconcile the two sides, an adaptive oversight regime would have had to evaluate all transactions in the markets and constantly search for violations to the blueprint. As we have seen, this is difficult in complex bureaucracies.

This argument brings us back to insights from chapter four. There we noted that centralized planning often failed in the past because large bureaucracies are unable to process the vast amount

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[108] Reflexivity is an important topic in research on organizational learning and in work on regulation Julia Black, "Paradoxes and Failures: 'New Governance'techniques and the Financial Crisis," *The Modern Law Review* 75, no. 6 (2012); Christopher Carrigan and Cary Coglianese, "The Politics of Regulation: From New Institutionalism to New Governance," *Political Science* 14, no. 1 (2011); Charles Sabel and Jonathan Zeitlin, "Experimentalist Governance," in *The Oxford Handbook of Governance*, ed. David Levi-Faur (Oxford: Oxford University Press, 2012).

of information that matters in economic processes. The structure is too slow, the flows of information too rigid and standardized to reflect the dynamic nature of economic life. Market design was supposed to resolve this problem by leaving decisions with individuals. However, as soon as these decisions can deviate from the requirements of the blueprint via innovation, a control structure must be put into place. The more complex the potential deviations, the more complex the control that is required. As soon as the market mechanism itself can change, the bureaucracy needs to evaluate transactions individually because simplifying heuristics are no longer valid. At this point, the whole complexity of the market comes back into the bureaucracy, and so do the problems of centralized planning. Accordingly, market design collapses into its opposite when the allocation problem requires innovative behavior, interdependent market settings, and high internal complexity.

Interestingly, this problem remains even if the designers disciplined the markets by reducing the interactive complexity and the room for innovation in the markets. Since the allocation problem would still require technological and behavioral changes, these issues would no longer be sorted out in the markets, but in the oversight structure itself. Suddenly, the bureaucracy would have to make substantial decisions about issues of production and consumption that were supposed to be the purview of market participants. While this problem did not occur in California, we can observe it in PJM.

The PJM markets avoided many of the problems California experienced because the designers opted for a highly centralized market structure and less room for innovation, combined with a centralized oversight regime that is able to monitor the markets in real time.[109] The ISO

[109] Cameron and Cramton, "The Role of the I.S.O. In U.S. Electricity Markets: A Review of Restructuring in California and P.J.M."; Andrew L. Ott, "Experience with P.J.M. Market Operation, System Design, and Implementation," *IEEE Transactions on Power Systems* 18, no. 2 (2003).

runs all auctions in one integrated framework, and there is no separate market for transmission capacity—the ISO calculates nodal prices on the basis of locational energy bids. The interface is designed in such a way that generators have to break down their bid into discrete cost components. This makes it possible to use information about technical characteristics to ensure that the generators bid at marginal cost. With less room for innovative action and a simpler market structure, the PJM markets differed in three of the basic features in California's markets: the dynamic interrelations between markets are lower, complete oversight of the market is possible, and there is less room for innovation on the level of market participants' behavior.

But this means that PJM needs to make centralized decisions about how the market logic should be changed to accommodate technological innovations and changes. To deal with these deviations, PJM has put into place bureaucratic processes that involve all stakeholders. As one interviewee described it, "If you look at PJM now, there's a whole, probably forty or fifty committees and subcommittees and task forces that are looking, constantly looking at all kinds of issues. So as the problems come up, there is a longstanding process for looking at certain issues. Trying to see where there are incompatibilities, and trying to come up with a solution that fits within the market construct."[110] Now that the market extends over many different states and has hundreds of participants, the emphasis on technical expertise has receded from the burgeoning processes and the discussions have become political: "The stakeholder committee basically is more like Congress—you're looking for people with widely differing opinions and goals for the marketplace."[111]

Not only does this mean that rule changes are very sensitive to the balance of power between competing interests, the processes also take place far away from the contexts they address

[110] Interview with Dave Pratzon, 11/13/2018.
[111] Ibid.

(e.g., how to integrate batteries that are used to dampen the impact of demand fluctuations). This leads to the problems we have seen in historical examples—the bureaucracy makes decisions that overdetermine productive work on the local level. And so, to the outside observer, PJM begins to look more and more like a giant utility organizing the electricity system from a central location. Without developing this consideration further, these observations invite a few concluding reflections.

11. Conclusion

11.1. Introduction

If you have gone to a science fair recently, you may have seen the robots that can play soccer with each other. The players are little boxes that drive with hectic precision across a small field, joining and separating in intricate patterns to execute tactical maneuvers. The individual members position themselves in relation to each other, make passes, intercept, and score goals. If you have seen the emergent arabesques of their play, you were probably astonished by the technical sophistication of their coordination.

More likely than not, what you saw was the result of a synthetic market mechanism. To allocate tasks among members in the team, several of these robot teams conduct auctions for labor power. As tasks become clear in the process of the game, robots assign costs to their fulfillment. For example, if one robot has to invest two seconds to reach the ball, it has higher costs than a robot that only needs one second. If each robot strives to maximize their profits by minimizing their costs, they optimize the system by trading tasks. As a research paper puts it, “A robot may open another auction for selling a task that it won from another auction, two or more robots may cooperatively work and get a task which is hard to accomplish by a single robot, or, for a heterogeneous system, robots with different sensors/actuators may cooperate by resource sharing.”[1] At all times, the auctions are part of a larger algorithm that maximizes the efficiency of the team as a whole.

Robot soccer is market design in perfection. The basic architecture of decision-making is the product of centralized planning, but all decisions are decentralized. Given a global goal that

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[1] Hatice Köse et al., "All Bids for One and One Does for All: Market-Driven Multi-Agent Collaboration in Robot Soccer Domain" (paper presented at the International Symposium on Computer and Information Sciences, 2003), 3.

can be broken into many small decisions, the robots use information about their context to evaluate how well they are able to perform the tasks. The trading process then uses this information to shift the tasks to those robots who can do them best. As a flawless information processor, the market aggregates decentralized information in a way that is globally optimal but does not require substantial interference from a central location.

The robots are pristine images of the rational actor: they never deviate from the rules specified by the designers, they do not want to do anything but solve the tasks that contribute to the victory of the team, and their work feeds unvaryingly into the collective purpose. They need no other shackles than the code that establishes their subroutines. To them, there is nothing outside the world of the game, and they form willing participants of the rational calculation that executes the algorithm to optimize team performance.

But as much as the game expresses the spirit of market design, we cannot help but feel a sense of disappointment. In the dance of the robots, the old vision of the market has disappeared. We no longer sense Hayek's quasi-divine entity that is omniscient where humans' feeble faculties perceive only hints of a greater plan. The powerful evolutionary process that drives humanity toward self-perfection is supplanted by the whirring of deterministic machines, mindlessly pursuing disaggregated tasks.

This sense of unease derives from the deep contradiction between the normative justification for the use of synthetic markets and the practical knowledge that helps to realize them. In California, the promise of market design was a progressive dream of innovation and efficiency. Yet, the mechanism would have called for a control structure formidable enough to constantly evaluate the choices of individual traders and realign them with the ideal market process. In the attempt to strike a compromise between freedom and control, the dream burst and the experiment failed.

This dissertation has circled the contradiction between the market as machine and the market as evolutionary process time and again. We have encountered it in the history of market design, the blindspots of design work, the utopic hope of politicians, the failures of control, and the California markets themselves. On some level it is the contradiction between a causal image of the world drawn from the imagination of planetary physics, and a liberal image of the world drawn from the Enlightenment philosophy of freedom. But rather than tracing the problem further into the heart of Western thought, it is now time to bring the different observations together and ask what they mean for a sociology of economic engineering.

The California markets failed for two basic reasons. One reason is that designers suffered from a crisis of expertise, which led to problematic design decisions. These design decisions created incentives and opportunities for behavior that derailed the market mechanism. Though the problems that affected the market designers in their work have many different facets, they all go back to the same problem. The fragmentation of expertise between economists and engineers obscured the fundamental tension between the mechanistic vision of the market and the evolutionary vision. For different reasons, both sides were overly optimistic about the requirement to create a match between the logic of the blueprint and individual behavior. While economists thought that they could create stable incentive systems through static sets of rules, engineers underestimated the devastating interdependencies between different rule structures. Each side could have revealed the flaws of the other if they had investigated the tensions between their respective, conceptual frameworks. But since the math seemed equivalent, both sides continued with their limited perspective. They ended up creating a system that met the requirements of the blueprint only some of the time and continuously operated to undermine itself. In that sense, the Western energy crisis reflects a crisis of expertise.

However, this was not the only reason the grand experiment failed. It also failed because the intellectual project was conceptually inconsistent. The tension between the mechanistic and the evolutionary image of the market generates conflicting requirements for the markets. On the one hand, actors have to conform to the narrow rules of an algorithm that solves an optimization problem. On the other hand, actors have to innovate new and creative solutions to technological problems and push the system to greater long-term efficiency. These two requirements are at odds because competition creates constant pressure to use rom for innovation to *deviate* from the ideal market mechanism. Since competition makes it increasingly difficult for companies to profit, the evolutionary pressures encourage companies to circumvent it. This creates–or exploits—mismatches between the logic of the blueprint and the allocation problem. The only way to resolve this tension is to implement a control structure that ensures consistency between the blueprint and the market. The plan for California's markets overextended this contradiction. The allocation problem required an incredibly specific set of behaviors in the market to arrive at the optimal dispatch. The attempt to combine this with a complex market structure and unchecked innovative behavior would have required an impossible level of control.

These considerations suggest that the requirements for control spell out the limits of feasible market design. We must then ask what kind of design features give rise to control requirements, whether they can be avoided, and if not, whether they can be met. Of course these questions point beyond the dissertation to future research to other allocation problems and market design. But to prepare the ground, I will now draw different observations together and spell out the relation between market mechanisms and control requirements. This establishes some general proposition about the success and failure of market design and implications for economic sociology. In the third section, I come back to the discussion of market design as a process of design work. In a last section, I consider trajectories for future research.

11.2. Feasible and Infeasible Market Designs

Market designs generate control requirements whenever the market mechanism is at odds with the allocation problem. This can happen for at least three reasons: external information and incentives distort the market mechanism, the market mechanism itself is at odds with the allocation problem, or the state space of the market mechanism is so large that some of its trajectories move away from equilibrium. I will discuss these options in turn.

First, control requirements emerge when features of the environment can enter the artificial market system in ways that were not anticipated by the blueprint. Traders use information and respond to incentives that extend beyond the boundaries of the market mechanism. This moves the mechanism at odds with the allocation problem. In California, this happened whenever the design introduced discrepancies between the market representation and the physical reality of the electricity system. This problem stands behind the congestion games. Uber provides another useful example of this problem because it also shows how control structures can mitigate the problem.

From the perspective of the consumers, Uber requires no oversight at all: the user has so few options that there is no way to behave in ways that are inconsistent with the task of optimizing the allocation of drivers to consumers. But for drivers, this is not necessarily true. For a time, Uber drivers in Chicago managed to game the application to take advantage of surge pricing. The profitable surge pricing occurs whenever there is a sudden increase in demand without corresponding supply. As new drivers enter the area, the surge abates and prices drop. To generate and profit from the surges, a big group of Uber drivers would congregate around the Midway or O'Hare airport and shut off their phones. A scout would wait at the cab line and observe when a new plane came in and a big group of customers entered the waiting area.[2] Since there would be a sudden increase in demand, the app would activate surge pricing. As soon as prices went up, the scout would honk his horn to signal the other drivers. They would switch on their phone at once and thus cash in on the surge offers.

This example is interesting because it illustrates how social networks can disrupt the supply and demand logic of atomistic actors.[3] It also illustrates how information and actions that were not included in the market mechanism can suddenly affect the logic of the market. Frustrated Uber drivers who were excluded from the scheme started to avoid the airport, which guaranteed high rates to the gang of Chicago drivers. The scheme thus created additional scarcity where supply was needed most and the efficiency of the mechanism was impacted.[4]

Since the company records all transactions through the software interface, it could quickly figure out what was going on. Alerted to areas with high prices, the monitors saw that cabs just appeared from one moment to the next. They introduced a fix that excluded these drivers from the surge prices. Note that they could detect the anomalous behavior because there were clear indicators of problematic behavior. The Uber market is not subject to innovations that violate the logic of the market. Accordingly, the definition of undesirable outcomes and acceptable behavior remains constant and allows the use of simplifying heuristics to screen the data. In sum, the first

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[2] This game took place in many cities. An Uber driver explained to me how it worked in Chicago.
[3] This is, of course, one of the cherished insights that launched the "new economic sociology" in the 1980s. Mark Granovetter, "Economic Action and Social Structure: The Problem of Embeddedness," *American Journal of Sociology* 91, no. 3 (1985); "The Old and the New Economic Sociology: A History and an Agenda.".
[4] This was widely reported in the media. E.g., Solman, Paul, "How Uber Drivers Game the App and Force Surge Pricing," *PBS News Hour*, August 4, 2017, https://www.pbs.org/newshour/economy/uber-drivers-game-app-force-surge-pricing, last accessed 04/21/2020. Researchers associated with the university of Warwick studied the phenomenon extensively: https://warwick.ac.uk/newsandevents/pressreleases/uber_drivers_are/, last accessed 04/21/2020.

source of mismatches is external information and incentives that violate the logic of the market mechanism. They can be compensated by a control structure if data is recorded and if the monitors can use simplifying heuristics to screen it.

Control requirements also emerge when there is a mismatch between the requirements of the allocation problem and the market mechanism itself. Most allocation problems have more than one dimension. This has been a topic at several points in this dissertation. It is not enough to find the cheapest combination of generators to serve aggregate demand. This combination must also meet a variety of technical requirements that are independent of cost (e.g., location, ramp-rate, intermittency, etc.). If the synthetic market does not capture a dimension of the allocation problem, it turns into an externality that needs to be ensured by a control structure. This was the problem with the temporal logic of California's markets. By themselves, markets are unable to produce the gradual expansion of capacity that is required for the market to find the economic dispatch in the short run. A control structure has to determine the optimal amount of excess capacity and then find a way to enforce its provision.

Problems of this sort typically refer to systemic properties of allocation problems, which can change over time. A contemporary example concerns the mix of resources in the electricity system. When California's markets were redesigned after the crisis, expensive natural gas plants still served peak demand most of the time. When they set the market clearing price in the energy auctions, all resources received the price that reflected their relatively high marginal cost. These prices made it possible for baseload plants to continuously operate at the bottom of the supply stack. The introduction of renewables changed this logic. Solar panels have almost no operating costs after they are installed. As marginal generators with fluctuating output, they will serve peak demand and therefore set the market clearing price. But since their low operating costs push the price down to zero or even into the territory of negative prices, baseload plants can suddenly no longer recover their costs and will go bankrupt.[5]

At first, this may seem like a desirable result. More efficient renewables displace less efficient and polluting fossil generators. But the problem is that the renewables cannot replace the baseload plants without endangering the reliability of the grid as a whole. The baseload plants are necessary to compensate for the intermittency of the renewables. Without them, the system would become unstable. Accordingly, the low market clearing prices now undermine the reliable operation of the grid.[6] The problem is clear: the markets do not price the correct mixture of resources.[7] A control structure needs to step in and compensate for this problem. As the example shows, allocation problems can generate such externalities dynamically if the industry is characterized by technological change.

Lastly, control requirements emerge from the internal operation of the markets themselves. The requirements emerge from problems that can be described with the tools of control theory and concern the core of market design.[8] Interestingly, they emerge even if the market institutions work exactly as the blueprint specifies.

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[5] Negative prices ensue when renewables produce too much and have to be curtailed. This usually requires the ISO to pay adjacent states to take this output off their hands.
[6] Due to its ambitious plans for a low-carbon future, this is one of the main problems in California today, c.f., Joachim Seel, Andrew D. Mills, and Ryan H. Wiser, "Impacts of High Variable Renewable Energy Futures on Wholesale Electricity Prices, and on Electric-Sector Decision Making," (Berkeley, CA: Lawrence Berkeley National Laboratory, 2018); Bruce N. Stram, "Key Challenges to Expanding Renewable Energy," *Energy Policy* 96 (2016). Since the intermittency has to be counteracted by additional reliability products, the retail price for power goes up even as the cost for the production of renewable energy goes down.
[7] This is not exactly the same as a positive externality because the market mechanism *may* be able to provide the required mix. It just will not do so necessarily.
[8] In engineering applications, control is usually exercised by one system influencing another system via feedback loops. Both systems are deterministic and condition each other. The classic example is that of centrifugal governor, where the shaft of a steam engine is connected to a flyball mechanism. As the speed of the engine increases, the flyballs spread apart. It is connected to a throttle on the steam engine. As the flyball extends, the throttle on the steam engine closes. This slows down the engine, which means that the flyballs come back together. The two systems keep each other in balance in a perpetual feedback mechanism. Karl J. Åström and Richard M. Murray, *Feedback Systems: An Introduction for Scientists and Engineers* (Princeton, NJ: Princeton University Press, 2008), 2.

In the world of control theory, markets appear as dynamical systems.[9] In a dynamical system, variables evolve over time (or in space) relative to the constraints of the system. Any combination of values that satisfies the constraints of the model are valid "behaviors" of the system. A "state" is a snapshot of the system at a given time point. While there are many different ways to represent dynamic systems, the most common forms are that of ordinary differential equations (ODE), or difference equations (for systems with discrete time steps).[10]

Engineers and economists use a variety of different tools to evaluate the stability properties of dynamical systems. For example, Chao and Peck demonstrate that all initial conditions of the transmission capacity rights tend toward an equilibrium by applying Lyapunov stability tests to their simulation of the trading process.[11]

However, nonlinear, dynamical systems do not always converge on a single equilibrium from all initial conditions—they are not necessarily "asymptotically stable." Equilibria can be unstable, or there can be several different equilibria, or they can be "saddle equilibria" that are only stable from one direction. Similarly, some initial states of the system can lead to radically different trajectories than others. Such complications can occur even in extremely simple, dynamical systems with few variables. For example, research has shown that the general equilibrium framework

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[9] A system is something that imposes constraints on, or enforces relationships between, variables. Joe Tranquillo, *An Introduction to Complex Systems: Making Sense of a Changing World* (Cham, CFH: Springer Nature Switzerland AG, 2019), 62-3. Control theory first used the methodological tools of planetary mechanics as developed in physics, but later merged them with the input/output models of electrical engineering. This led to a novel set of mathematical tools, called state-space models of input/output systems, in the 1960s. Åström and Murray, *Feedback Systems: An Introduction for Scientists and Engineers*, 28-31.

[10] Economists have long used these tools describe the behavior of economies (for example, the Merton-Scholes option pricing method is based on a dynamical model of the valuation process). *Feedback Systems: An Introduction for Scientists and Engineers*, 14. Since economies do not follow conservation laws, the most successful application of control theory has been with respect to issues in the planning of supply chains—quantities of products are preserved from one moment in time to the next, while valuations are not. The dynamic system of product flows from factories to warehouses to distributors to retailers and customers in response to orders can be modeled as a dynamic system where material and information flow through inventories. This use of control theory stands behind much of Amazon's success, but it goes back to Jay W. Forrester, *Industrial Dynamics* (Cambridge, MA: MIT Press, 1961).

[11] See above.

developed by Arrow and Debreu has these properties.[12] Despite relying on many simplifying assumptions, many trajectories through the states of the system point away from equilibrium. Some systems are so sensitive to initial conditions or perturbations that possible states may even appear random.[13] A control structure is therefore necessary any time the differential equations that capture the dynamic of the system do not simply converge on a globally stable equilibrium.

To give an example we have already discussed several times: in electricity systems we can observe "phase transitions" whenever demand moves to the level where the capacity limits are reached. As long as the capacity limit is not reached, the increase in demand does not inhibit the dynamic interplay between buyers and sellers and leads to equilibrium solutions. But as soon as the capacity limit is reached and sellers receive market power, they will no longer compete with each other and price at marginal cost. The relationship between the variables in the system changes as the point of phase transition is reached. At this point, the system moves off the course to equilibrium and becomes unstable.[14]

In sum then, there are three ways in which market mechanisms can create control requirements: through external interference, through mismatches between mechanism and allocation problem, and through their internal dynamics. If not checked by the control structure, the market generates strong incentives to detect these mismatches and exploit them. This is particularly true if we are dealing with markets that allow for financial speculation. Speculative activities are not directly related to the productive processes they ultimately refer to. Financial innovation can

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[12] Ackerman, "Still Dead after All These Years: Interpreting the Failure of General Equilibrium Theory."
[13] The discovery of chaos theory took place in the context of the analysis of dynamical systems with three dimensions. In some ways, it goes back to Poincare's proof that Newton's laws are insufficient to solve the "Three Body Problem" to specify the movements of three interacting planets. The theoretical meteorologist Edward Lorenz eventually proved that the three-body problem describes a chaotic system and can be solved as such. Tranquillo, *An Introduction to Complex Systems: Making Sense of a Changing World*, 90.
[14] Ibid., 233. Analytically, we can isolate the emergence of market power in the short run from the problem that generates the shortage of capacity in the long run.

therefore quickly move the market away from optimizing the productive processes. For example, by innovating derivative products for natural gas that were pegged to the physical natural gas markets, seemingly irrational moves in the physical market (e.g., first buying and then selling at rapid speed) could generate revenues in the derivative markets (e.g., by betting on movement of prices in a particular direction).[15]

Now, the crucial question becomes what control requirements can be met and which ones cannot be met. As the discussion in chapter four and chapter ten suggests, control becomes impossible or impractical when the regulators need to evaluate each transaction in the market in a complex division of labor, or if the information required to evaluate the trades is itself a product of the market. These control requirements emerge when the allocation problem requires substantial room for innovation, is high-dimensional, and requires a market process that is characterized by many interdependencies with other market processes. These features are all present in electricity markets.

These features also exacerbate the different ways in which the market mechanism can deviate from the requirements of the blueprint while reducing the power of simplifying heuristics. As soon as regulators cannot rely on computational tools to filter the data for clear signals of trouble, they have to introduce a division of labor to deal with the increase in data that they need to consider. However, this division of labor relies itself on assumptions about the market environment and is thus vulnerable to market change. With the need for qualitative assessment of individual transactions, the various problems of centralized planning thus come in through the backdoor of the control structure. Not only does the control structure have to keep up with the fast changes of

[15] "Final Report on Price Manipulation in Western Markets Fact-Finding Investigation of Potential Manipulation of Electric and Natural Gas Prices, March 2003," *FERC* PA02-2-000, IX-9.

a dynamic market process and must itself be ready to adapt; suddenly, the regulators must make decisions about the validity of local decisions and their compatibility with the blueprints for the market mechanism. Ironically, these problems (familiar from organizational sociology and discussed in chapter four) are usually the reason designers propose to shift from regulation to synthetic markets in the first place.

As a general conclusion, we can therefore state that whenever synthetic market mechanisms respond to high dimensional and evolving allocation problems that are tied to other economic processes, they require an oversight structure that is at least as complex as the bureaucratic structure that would have been necessary in a system of regulated monopolies. They are at least as complex because they must evaluate all transactions in the market and position themselves relative to innovation. Such market design processes overextend the tension between evolutionary and mechanistic imagination of markets and renders market design logically or practically infeasible.

The conclusion applies through time. Consider California's recent troubles. During the autumn of 2019, California's three utilities had to implement widespread blackouts across the state. High temperatures and strong winds endangered the stability of transmission lines for weeks. To prevent system collapse, the utilities shut down parts of the grid. Part of the story is PG&E's orientation to shareholder value and its attendant "short-termism."[16] But the other part of the story brings us back to the tension between the mechanistic and the evolutionary imagination of the market.

Wholesale markets affect the *patterns* of energy flows in the system. Different patterns of flows change the wear and tear of the lines. Since the cost of transmission line maintenance are

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[16] Michael Liedke, "PG&E, Gov. Newsom at Odds over Bankruptcy Plan," *The Press Democrat*, January 29, 2020, https://www.pressdemocrat.com/news/10647880-181/pge-gov-newsom-at-odds, last accessed: 04/26/2020. Others have pointed to corruption at PG&E, which has had cozy dealings with the CPUC for decades.

not reflected in the market price, companies will use the lines as much as possible to maximize profits. The market will always send energy from one location to another if a price difference promises profits.[17] This has increased the usage patterns substantially over the years. But since the grid was not designed to sustain such a high level of transmissions, California's lines have sustained disproportional wear and tear for years.[18] The costs of these practices only become visible when the blackouts push them into the market. At that point, it is too late to react. And thus, the ideal market mechanism for the allocation problem moves at odds with the behavior of companies in the market. The market logic pushes companies to profit by creating or exploiting misalignments between the market mechanism and allocation problem.

In electricity markets, the high-dimensional and constantly shifting requirements of the allocation problem constantly create such mismatches. In order to stay ahead of these developments, regulators would have to constantly check their background assumptions about how the markets work in relation to the allocation problem and how this impacts the kind of anomalies they can observe. But in a complex system like California's electricity market, this requires more resources than are available to regulatory agencies. And even if they could detect the problems, the bureaucratic processes would have trouble making the correct decision from a centralized location. How would FERC know what level of maintenance the different lines in the PG&E system would require, given changes of flows in power over time? Once the oversight requirements reach this level, market design becomes futile.

The first broad implication of this dissertation is thus a relatively general lesson for the restructuring of natural monopolies. Regardless of whether we are speaking of broadband access,

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[17] In other words, it will adjust the output of the generators and change the patterns of all energy flows to use more output from the cheaper resource.
[18] Perrow, *The Next Catastrophe: Reducing Our Vulnerabilities to Natural, Industrial, and Terrorist Disasters*.

water, garbage, telephone lines, trains, or environmental services, we should never just ask whether it is *possible* to use market design to transform the collective good into a commodity. We should also not simply ask how the political power of the stakeholders would skew the distribution of this commodity—though that is an important question in its own right. We should first ask whether we can enforce the immense control requirements that the synthetic markets demand. Then, we should consider whether the costs would outweigh those of the traditional approach. A regulator who has to watch three companies that get paid to provide a holistic service is probably in a better position than a regulator who has to watch two hundred companies who get paid to profit at the expense of the regulator. In sum, the discussion about the use of a synthetic market should be one about costs, limits, and complication of control, not efficiency.

This argument has implications for research on the "regulatory dialectic" and the sociology of markets.[19] The "regulatory dialectic" is the dynamic interplay between regulators and regulated in different industries. The two sides are locked into a cycle of mutual observation and adaptation. Most recent studies in this tradition ask why regulatory oversight failed during the financial crisis in 2007–08 and what more successful oversight looks like. One branch of research explores how market actors manage avoid regulatory oversight.[20] Another branch analyzes how different regulatory arrangements impact the success of regulation.[21]

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[19] Matthias Thiemann and Jan Lepoutre, "Stitched on the Edge: Rule Evasion, Embedded Regulators, and the Evolution of Markets," *American Journal of Sociology* 122, no. 6 (2017); Julia Black, "Regulatory Conversations," *Journal of Law and Society* 29, no. 1 (2002); Marc Schneiberg and Tim Bartley, "Regulating and Redesigning Finance: Market Architectures,Normal Accidents and Dilemmas of Regulatory Reform.," in *Markets on Trial : The Economic Sociology of the U.S. Financial Crisis*, ed. Michael Lounsbury and P. M. Hirsch (Bingley, UK: Emerald Group, 2010); Jodi L. Short, "Self-Regulation in the Regulatory Void: "Blue Moon" or "Bad Moon"?" *Annals of the American Academy of Political and Social Science* 649 (2013).

[20] Michael Lounsbury and Paul Morris Hirsch, "Markets on Trial: Towards a Policy-Oriented Economic Sociology," in *Markets on Trial: The Economic Sociology of the Us Financial Crisis* (Bingley, UK: Emerald Group Publishing, 2010); Funk and Hirschman, "Derivatives and Deregulation Financial Innovation and the Demise of Glass–Steagall."

[21] Neil Fligstein and Alexander F. Roehrkasse, "The Causes of Fraud in the Financial Crisis of 2007 to 2009 Evidence from the Mortgage-Backed Securities Industry," *American Sociological Review* (2016); Neil Fligstein,

But very little research in this tradition has considered how attempts to explicitly design market dynamics affect regulators' capacities. The use of market mechanisms is usually treated as a binary decision rather than a multifaceted choice between different mechanisms.[22] My findings suggest that features like market interdependency, adaptability, and behavioral complexity influence the regulatory dialectic and can themselves become the goal of regulatory reform.[23]

These findings also have implications for the literature on Normal Accident Theory (NAT) and organizational disasters. NAT suggests that accidents are unavoidable in situations where high interactive complexity and tight coupling create cascades of interactions between problems in unrelated parts of a system. The claim is fundamentally about the epistemic limitations of controllers. If it is impossible to have a predetermined model of all possible interactions between elements in a system and if these interactions can quickly escalate, accidents cannot be prevented because they cannot be anticipated. This problem is the same that regulators of a synthetic market may face at a certain level of complexity. However, synthetic markets are vastly more likely to develop the basic problem NAT was concerned with because there are incentives to innovate in this direction. Read as an argument about the epistemic limitations of oversight rather than a deterministic

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Jonah S. Brundage, and Michael Schultz, "Seeing Like the Fed: Culture, Cognition, and Framing in the Failure to Anticipate the Financial Crisis of 2008," ibid.82, no. 5 (2017); Thiemann and Lepoutre, "Stitched on the Edge: Rule Evasion, Embedded Regulators, and the Evolution of Markets."

[22] E.g., in the influential work by Braithwaite, capitalism appears as a structure that can be regulated in a variety of ways, but it does not consider that market mechanisms themselves may differ by design. John Braithwaite, *Regulatory Capitalism: How It Works, Ideas for Making It Work Better* (Cheltenham, UK: Edward Elgar Publishing, 2008).

[23] Particularly to the extent that it studies the interrelation between industry behavior and legal processes, as in the "legal endogeneity" literature. Lauren B. Edelman and Robin Stryker, "A Sociological Approach to Law and the Economy," in *The Handbook of Economic Sociology*, ed. Neil J Smelser and Richard Swedberg (Princeton, NJ: Princeton University Press, 2005); Lauren B. Edelman and Shauhin A. Talesh, "To Comply or Not to Comply—That Isn't the Question: How Organizations Construct the Meaning of Compliance," in *Explaining Compliance: Business Responses to Regulation*, ed. Christine Parker and Vibeke Nielsen (Chelenham, UK: Edgar, 2011).

prediction where accidents will occur, NAT may still be too optimistic for the assessment of synthetic markets.[24]

Lastly, the argument has implications for studies that are interested in the relationship between markets and firms. Increasingly, studies examine how the new computational technologies associated with the Big Data revolution allow companies to resolve complex planning problems from a centralized position.[25] The enormous concentration of the American economy may have to do with this fact.[26] As Schumpeter already argued, these studies suggest that markets become superfluous where centralized planning is possible. Monopolistic enterprises like Wal Mart and Amazon begin to absorb entire supply chains because they can optimize these supply chains without the waste from competition, i.e., they can avoid the costs of excess stock, advertisement, redundancies, etc. that competition requires. Accordingly, they displace the market.

In contrast, my dissertation suggests that markets themselves have to be thought of as instruments of centralized planning, as a technology that melds decentralized competition together with centralized software infrastructure.[27] The difference between markets and organizations like

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[24] Nancy Leveson has criticized the typology of more and less accident-prone systems that derive from Perrow's analysis. She points out that many of the systems with tight coupling and high interactive complexity are safer than those who do not have these features. Nancy Leveson et al., "Moving Beyond Normal Accidents and High Reliability Organizations: A Systems Approach to Safety in Complex Systems," *Organization Studies* 30, no. 2-3 (2009); "Beyond Normal Accidents and High Reliability Organizations: The Need for an Alternative Approach to Safety in Complex Systems," *Organization Studies* 30, no. 2-3 (2000). However, I think the theory is better read as an argument about the limits of cognition in oversight structures. Attempts to transfer this argument to the financial crisis have not seen that the incentive structure of markets makes markets *more* prone to this epistemic problem than technological systems. Donald Palmer and Michael Maher, "A Normal Accident Analysis of the Mortgage Meltdown," *Research in the Sociology of Organizations* 30 (2010).
[25] E.g., Andrew Kusiak, "Smart Manufacturing Must Embrace Big Data," *Nature* 544, no. 7648 (2017); Zhaohao Sun, Lizhe Sun, and Kenneth Strang, "Big Data Analytics Services for Enhancing Business Intelligence," *Journal of Computer Information Systems* 58, no. 2 (2018).
[26] Carl Shapiro, "Protecting Competition in the American Economy: Merger Control, Tech Titans, Labor Markets," *Journal of Economic Perspectives* 33, no. 3 (2019).
[27] Phillips and Rozworski, *The People's Republic of Wal-Mart: How the World's Biggest Corporations Are Laying the Foundation for Socialism*; Cottrell and Cockshott, "Calculation, Complexity and Planning: The Socialist Calculation Debate Once Again."

Amazon lies not so much in the mechanisms that are used to coordinate complex productive processes; rather the differences lie in the structures of control that are put into place to implement the distributed optimization algorithms. After all, Big Data techniques are successful precisely because they allow the real-time coordination between thousands and thousands of decentralized decisions.

In sum, synthetic market mechanisms produce control requirements when there are mismatches between allocation problems and the market mechanism (the temporal structure of energy markets), external influences on the mechanism (the congestion games), or the permutations of possible behavior within the market mechanism (the arbitrage games). These problems emerge when the allocation problem is high dimensional and complex enough to produce more than just incremental innovation. As soon as the market approximates the evolutionary ideal of the market, effective enforcement of any given blueprint becomes either logically or practically infeasible.

11.3. The Success and Failure of Market Design Work

So far, I have presented conclusions about market design as an intellectual project. This represents only one side of the analysis, however. The second part of the dissertation has examined concrete processes of market design work. Here, the failure of California's design experiment appears as a crisis of expertise.

In political processes, market designers were unable to reclaim jurisdiction over questions that were crucial for the success of market design. In technical processes, they suffered from blindspots that were embedded in their mathematical models. In regulatory discourses, finally, market designers underestimated the requirements for control that the complex market architecture had created. Even if the blueprints for market design projects are conceptually sound, market design work can thus lead to decisions that create structural mismatches between the market mechanism and allocation problem.

In the California case, we have seen that many of the problematic decisions were driven by the fragmentation of the intellectual project. Though they used the same conceptual tools, engineers and economists had fundamentally different ways of thinking about the theories their blueprints spelled out. Each side missed requirements that the other side had been aware of. Engineers underestimated the need to control the dynamic interactions between markets because they did not analyze their conceptual frameworks from the perspective of incentives. Accordingly, they underestimated the complexity of the systems they were analyzing.

Since the California crisis, engineers have begun to take these interdependencies into account. But the dynamical equations that characterize systems with many subsystems do not usually admit of analytical solutions. Today, they therefore use complex simulations with Agent Based Models. These simulations reproduce the models and allow analysts to investigate the behavior of the model under different conditions. Such simulations do not just include the markets, adaptive agents, the different interest groups, weather conditions, and all elements of the physical infrastructure, but also a layer of regulatory decision-making (e.g., the EMCAS system).[28] In a recent publication, researchers at Argonne National Laboratory echo the comments of George Backus when they criticize conventional equilibrium analysis, stating that "neither of these techniques, however, can capture transitory fluctuations driven by system evolution, nor identify inflection points, phase transitions or critical conditions under which systems diverge from the past in new

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[28] Incidentally, such a simulation was used in Illinois to demonstrate problems that would derive from fully deregulated wholesale markets in Illinois. R. Cirillo, P. Thimmapuram,T.D. Veselka, V. Koritarov, et. al. *Evaluating the Potential Impact of Transmission Constraints on the Operation of a Competitive Electricity Market in Illinois*, (Chicago, IL: Illinois Commerce Commission, 2006), http://www.dis.anl.gov/pubs/56153.pdf, last accessed 02/10/2020.

and totally unanticipated ways."[29] These simulations reveal problems with market dynamics that then become the subject of control structures.

The complexity of these simulations highlights a finding from chapter eight. The more complex synthetic markets, the more interdependencies there are between different submarkets. This means that market design processes cannot be *modularized* easily. Decisions about the software infrastructures and protocols for the subsystems have to be made in relation to each other. This requires a flexible division of labor with many feedback loops between the different teams.

The resulting design decisions have to be very consistent with each other. This can quickly turn into a problem of jurisdiction because the market designers now have to enforce sequential decisions in line with their blueprints. As we have seen, market designers struggle to build this jurisdiction in democratic processes. We thus note that increasing market complexity pits the market designers increasingly against democratic politics. One crucial factor for the success of market design work is thus the degree to which the complexity of synthetic markets can be reduced. Designers need to be able to isolate the markets from external factors to minimize the requirements for consistency across many different domains of the design project.

This argument has two implications for research on economic expertise. This literature often characterizes economics as the most influential social science and identifies many ways in which economics shapes political decisions in the U.S.[30] However, research on expertise

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[29] Energy, Environmental, and Economic Systems Analysis, *Electricity Market Complex Adaptive System (EMCAS): A New Long-term Power Market Simulation Tool*, (Chicago, IL: Argonne National Laboratory), https://ceeesa.es.anl.gov/pubs/60358.pdf, last accessed: 02/10/2020.
[30] Hirschman and Popp-Berman, "Do Economists Make Policies? On the Political Effects of Economics"; Fourcade, *Economists and Societies: Discipline and Profession in the United States, Britain, and France, 1890s to 1990s*.

frequently finds the opposite. Like all policy sciences, economics suffers from a steady decline in public confidence, and their expert advice is usually ignored by politicians.[31]

My analysis of market designers' struggle to establish jurisdiction in the political processes resolves this contradiction. The success of economic *language* contravenes the success of academic economists as expert witnesses. In order to exercise jurisdiction, it is necessary to have a monopoly on the conceptual framework of the discipline. Since economic concepts have a common sense interpretation and are tools in many different disciplines, experts have trouble asserting their jurisdiction relative to audiences who do not have stable standards to evaluate competing claims. The success of economics thus works against academic economists—their expertise frays and is diluted by overuse.[32]

Second, my research responds to the demand for a sociology of expertise that accounts for expertise as "capability." As Eyal puts in a recent book, "to account for expertise as a capability would require an analytical framework that brings together conditions internal to the expert—training, tacit knowledge, embodied skills—and that are the product of socialization into a group of experts. But the analytical framework would also include conditions external to the expert […]."[33] My dissertation heeds this call by showing, on the one hand, how market design work takes place in specific social contexts that condition how their knowledge can be used. On the other, it shows how the substance of market designers' expertise influences the feasibility of the design projects. Here, the concept of the blindspot is crucial because it reveals how practice differs from normative claim to competency. Exploring the internal tensions between aspiration and the

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[31] Eyal, *The Crisis of Expertise*.
[32] As economists are quick to note themselves: Banerjee and Duflo, *Good Economics for Hard Times: Better Answers to Our Biggest Problems*.
[33] Eyal, *The Crisis of Expertise*, 41.

blindspots embedded in the applied expertise shows what a "capability based" approach could look like. These concluding thoughts point to an agenda for future research on economic engineering.

11.4. Directions for Future Research

The California case marks an *extreme* form of market design. By creating markets with many different operating protocols, interdependencies, and little oversight of individual decision making, the designers set themselves up for failure. They maximized the contradiction between the evolutionary and mechanistic imagination of markets. But while the nature of the allocation problem ensured that this contradiction haunted the project, not all market design projects suffer from these problems. If California's market design is one extreme of the spectrum, the other end is occupied by a variety of synthetic markets that address allocation problems with fewer dimensions and interdependencies. Famous examples of successful market design are the matching markets for the distribution of organs to donors and food to food banks.

Designers solve these problems by creating virtual markets that exist as self-contained worlds of human interaction. By controlling the form and parameters of economic interactions, designers can scale the complexity of the market process. They can tailor the process to the level of control that is feasible, given the resources of the regulators. For example, they can rule out innovation. They can also seal the market off from other markets. Some synthetic markets use scrip currencies and constantly reset the balances to ensure that the money only serves as a signal for supply and demand and not a store of value. These market systems also allow synoptic control of decentralized decisions. Regulators can record all transactions. They can monitor and investigate them at will. Since the market logic is static, regulators can use simplifying heuristics to screen data and search for anomalous behavior.

If allocation problems can be addressed in virtual environments, market designers can potentially avoid all sources of deviant behavior I have discussed in this dissertation. It is the great strength of experimentalist market design that they use software in this way. In the laboratory, the market rules can be simplified and tweaked until all behavior matches the desired mechanism. Designers have created many matching markets with fictional currency over the years, and this is a testimony to the success of this approach.[34] At the other end of the spectrum, market design is thus quite successful. Problems emerge in the field between static, independent, one-dimensional allocation problems and their opposites.

One line of future research could therefore be cooperative. As we have seen, market design work suffers from blindspots embedded in the structural form of the models. These blindspots lead to decisions that violate implicit assumptions and potentially derail the market mechanism. Despite advances in agent-based modeling and the insight that interdependent market systems are complex and often chaotic, economic market designers do not generally develop their proposals in the context of such simulations. As during the California crisis, economists continue to operate in the methodological framework of optimization theory that argues from the perspective of equilibria.[35] This means that they will likely continue to underestimate how design decisions drive control requirements and how they can be enforced. Here, sociologists could come to the aid of market designers.

Blindspots do not necessarily invalidate blueprints. Designers may be able enforce the implicit assumption if they become aware of them, or they may be able to alter the blueprint to remove

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[34] Roth, "What Have We Learned from Market Design?"; Kominers, Teytelboym, and Crawford, "An Invitation to Market Design."

[35] See, for example, the existing work that tries to account for some of the problems with strong assumptions of the dominant modeling framework (e.g., nonprobabilistic uncertainty about agents' beliefs). Carroll, "Robustness in Mechanism Design and Contracting."

infeasible or contradictory assumptions. Market construction involves iterative attempts to build infrastructures according to theoretical blueprints. In the course of this process, economists modify blueprints to accommodate problems that become visible during testing. The sociological analysis of economists' blueprints can contribute to this process because it may identify blindspots in the blueprints of economists.

In other words, the basic approach of qualitative sociology is complementary to that of market designers. Designers identify sources of market failure by looking for deviations from ideal models of the market. These market failures become the subject of market design. The blindspots refer to mismatches between the real market and the model that economists have ignored. Qualitative work in economic sociology can identify these mismatches because it starts inductively with the social process and derives the theory from this analysis. Accordingly, it will pick up features of the social process that contradict the model but do not constitute violations of *explicit* assumptions. Sociologists should thus begin to analyze the blueprints for ongoing market design experiments, identify problematic blindspots, and discuss with economists how they might be resolved. As recent attempts to utilize insights from sociology and political theory indicate, market designers are interested in such a collaborative approach.[36]

The findings in this dissertation also suggest a second direction for future research. At the extreme, market design becomes infeasible. Allocation problems can require market mechanisms that create impossible control requirements. Even if market design is feasible and desirable, the designers may not be able to wrest sufficient jurisdiction from political processes, and they may

[36] Nicole Immorlica, Matthew O. Jackson, and Glen E. Weyl, "Verifying Identity as a Social Intersection," (SSRN, 2019); Hitzig, "The Normative Gap: Mechanism Design and Ideal Theories of Justice."

have to work in organizational structures that prevent them from dealing with interactions between market processes. Or, they may suffer from the consequences of fragmented expertise.

Generally, my dissertation suggests that successful market design work is very difficult because economists need to be able to understand all dimensions of the allocation problem and then reflect on all interactions between market settings in relation to that allocation problem. Since the requirements for control do not often feature in discussions about market design, a sociology of economic engineering can play a critical role as well.

Future research should therefore explore the space between the extremes to identify where the limits of successful market design are. This dissertation has pointed to some basic conditions that must be met for market design to succeed. But it has not revealed how *much* complexity, adaptation, and interdependency synthetic markets can handle. Future research should therefore examine other cases that systematically differ with respect to system closure, innovation, and required market behavior.

In each case, the guiding questions should be: Do the requirements of the blueprint render the realization of the market mechanism infeasible? How do the requirements relate to the working conditions of market designers who attempt to realize them in political, technical, and regulatory contexts? Are some market mechanisms more at odds with democratic decision-making than others? Do market designers succeed if they overcome the fragmentation of expertise into competing imaginations of the market? How complex, adaptive, and interdependent can synthetic market designs become *before* the requirements for their implementation overwhelm design processes and exceed what an oversight structure can accomplish?

These questions sketch an agenda for a sociology of economic engineering. At its end, we would gain a general account of the conditions for the success and failure of market design. This work would help sociologists identify where market design might be useful and where it might not. It would show which design proposals are inherently flawed and which ones can be realized. With such a theory, we would be able to shape the discussion about the solution of some of the most pressing problems of our day. By reconstructing the fundamental tensions and contradictions that drove the design project in California, I have tried to make a first step in this direction.

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