

THE UNIVERSITY OF CHICAGO

QUALITY-DRIVEN SYNERGIES IN HORIZONTAL MERGERS:
A STUDY OF THE U.S. AIRLINE INDUSTRY

A DISSERTATION SUBMITTED TO
THE FACULTY OF THE UNIVERSITY OF CHICAGO
BOOTH SCHOOL OF BUSINESS
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

BY
CHUHAN GUO

CHICAGO, ILLINOIS

JUNE 2025

Abstract

This dissertation comprises two chapters that examine firm integration decisions in Industrial Organization, focusing on horizontal, vertical, and conglomerate structures. The first chapter develops an empirical framework to examine how mergers generate synergies through endogenous product repositioning. It begins by estimating demand and cost structures, then simulates post-merger market equilibrium, allowing firms to optimize product quality and positioning endogenously. Using the JetBlue-Spirit merger as a case study, the analysis shows that simply combining the two firms does not generate synergies. Instead, quality-driven synergies arise from reallocating higher-quality services to large-city markets, where consumers place greater value on quality. The chapter also highlights the distributional implications of the merger for consumer welfare, with surplus shifting toward less price-sensitive consumers and large-city markets. The second chapter develops a theoretical model in which firms use integration strategies to mitigate return volatility from industry-specific shocks. When firms are risk-averse or risk-neutral but benefit from financial market advantages that are functionally equivalent to risk aversion, their ability to manage ex-post risks influences their ex-ante boundary choices. The model demonstrates that conglomerate stabilizes profits by diversifying exposure to demand shocks, while vertical integration reduces uncertainty from upstream price fluctuations. By analyzing both forms of integration within a unified framework, the chapter provides new insights into how risk considerations shape firm boundaries.

TABLE OF CONTENTS

LIST OF FIGURES	vi
LIST OF TABLES	vii
1 QUALITY-DRIVEN SYNERGIES IN HORIZONTAL MERGERS: A STUDY OF THE U.S. AIRLINE INDUSTRY	1
1.1 Introduction	1
1.2 Market Setting	7
1.2.1 The U.S. Domestic Airline Industry	7
1.2.2 The JetBlue-Spirit Merger	10
1.3 Data Sources	13
1.4 Airline Decision-Making and Operational Constraints	16
1.4.1 Decision-Making in Airline Operations	16
1.4.2 Fixed Inputs and Limited Contractibility	18
1.5 Model	21
1.5.1 Stage 2: Demand	22
1.5.2 Stage 2: Prices	24
1.5.3 Stage 1: Routes and Departure Frequency	30
1.6 Estimation Strategies and Identification	31
1.6.1 Stage 2: Demand	31
1.6.2 Stage 2: Cost	33
1.7 Empirical Results	35
1.8 Counterfactual Simulation	39
1.8.1 Status Quo and Market Segmentation	40
1.8.2 Counterfactual Description	42
1.8.3 Welfare Analysis of the JetBlue Spirit Merger	46
1.8.4 Relaxing the Fixed Input Restriction	52
1.9 Conclusion	56
2 FIRM BOUNDARIES AND RISK MITIGATION	58
2.1 Introduction	58
2.2 The Firm's Optimal Boundary Decision	63
2.2.1 The Specialized Downstream Firm	64
2.2.2 The Vertical Firm with Surplus Downstream Capacity	67
2.2.3 The Vertically Integrated Firm with Deficit Downstream Capacity	70
2.2.4 The Conglomerate Firm	72
2.2.5 The Firm's Ex-ante Choice of Type	75
2.2.6 A Brief Discussion of the Specialized Upstream Firm	76
2.3 Risk Mitigation Through Integration	77
2.3.1 Risk Mitigation under Industry-Specific Supply Shocks	77
2.3.2 Risk Mitigation under Industry-Specific Demand Shocks	79

2.3.3	A Brief Discussion of the Specialized Upstream Firm and Its Expansion	80
2.4	Conclusion	81
REFERENCES		83
APPENDIX		93
A	Figures and Tables: Chapter 1	93
B	Model Supplements: Chapter 1	99
B.1	Derivations for Optimal Pricing	99
C	Counterfactual Supplements: Chapter 1	101
D	Proofs for Section 2.2	103
D.1	Proof for Lemma 1	103
D.2	Proof for Lemma 2	105
D.3	Proof for Lemma 3	112
D.4	Proof for Theorem 1	119
D.5	Proof for the Discussion of the Specialized Upstream Firm	120
E	Proofs for Section 2.3	123
E.1	Proof for Theorem 2	123
E.2	Proof for Theorem 3	134

LIST OF FIGURES

1.1	Density Distribution of Own-price Elasticity	37
1.2	Cost Per Available Seat Mile: Estimation vs. Financial Reporting	39
1.3	Distributional impact of the merger on consumer surplus	50
1.4	Distributional impact of the merger across market types	51
A.1	Total ULCC Passengers v. Mean Ticket Size	93
A.2	Travel Intensity by City	94
A.3	Mean Fare by City	95

LIST OF TABLES

1.1	Summary Statistics for Major U.S. Domestic Airlines	9
1.2	Demand Estimation	36
1.3	Marginal Cost Estimation per Standardized Seat	38
1.4	Market Outcomes of the JetBlue-Spirit Merger	47
1.5	Quarterly Changes in Market Outcomes by Annual Sunk Cost per A320	55
A.1	Marginal Cost Estimation per Standardized Seat, Assuming a \$10.00 Marginal Cost per Passenger	96
A.2	Cost Per Available Seat Mile: Estimation vs. Financial Statement	97
A.3	Markup and Marginal Costs by Carrier and Distance	98
C.1	Observed Data vs. Simulated Counterfactual Baseline: Market Conditions . . .	101
C.2	Observed Data vs. Simulated Counterfactual Baseline: Product Changes	102

Acknowledgments

I am grateful to Thomas Wollmann for his unwavering support. His mentorship has profoundly shaped the way I think about economic research, and his feedback has been invaluable at every stage of this dissertation. I am also thankful to Chad Syverson, Eric Budish, and Matthew Notowidigdo for their insightful guidance and continued support from the earliest days of my doctoral journey. Their academic advice and personal encouragement have been instrumental in helping me grow as a researcher and navigate the challenges of graduate training. I would also like to thank the faculty and peers at the University of Chicago Booth School of Business, whose thoughtful feedback and friendship have made this experience both intellectually enriching and personally meaningful.

On a personal note, I am especially appreciative of my family and friends. To my parents, thank you for your belief in me. You have been lifelong role models, encouraging me to pursue my goals with resilience and integrity. To my partner, thank you for your patience, support, and faith through every high and low. I am grateful to have shared this journey with you by my side. To my friends, thank you for standing by me. You have made the difficult moments lighter and the milestones more memorable.

CHAPTER 1

QUALITY-DRIVEN SYNERGIES IN HORIZONTAL MERGERS: A STUDY OF THE U.S. AIRLINE INDUSTRY

1.1 Introduction

Williamson (1968) and Farrell and Shapiro (2010) establish a canonical welfare tradeoff in horizontal mergers between upward pricing pressure and efficiency gains, or synergies. While efficiency gains from mergers are typically associated with marginal cost savings, they can also arise through product quality improvements. Realizing synergies often requires more than simply combining two companies. It may involve endogenous adjustments to input decisions, which can reshape the firm's competitive positioning and market dynamics. Understanding how these synergies materialize and their broader implications for consumer welfare remains a key concern for regulatory agencies.

This paper develops a versatile framework to analyze how mergers generate synergies through endogenous quality adjustments. It conceptualizes and estimates the primitives of demand and cost structures, then systematically models the firm's endogenous post-merger quality decisions, which reveals the mechanism through which these quality-driven synergies are realized. The framework is applicable across industries and adaptable for studying various types of efficiency gains, whether they originate from cost reduction or quality improvements. The counterfactual analysis explicitly enables the firm to identify and capture potential post-merger efficiency gains through strategic product positioning.

The realization of these quality-driven synergies has important implications for consumer welfare. While cost-saving synergies directly lead to lower prices, quality-driven synergies simultaneously affect both pricing and quality characteristics. As a result, the impact of such mergers on consumer welfare varies across consumer segments based on their sensitivity to price and quality. The model quantifies the heterogeneous impact of these quality

adjustments, highlighting how some markets and consumers benefit while others are harmed, ultimately resulting in an uneven distribution of consumer welfare.

I apply this framework to the domestic U.S. airline industry, using the recent JetBlue-Spirit merger as a case study. In this setting, product quality is reflected in hardware, firm reputation, nonstop service provision, and frequent departures. The merger’s efficiency gains stem from integrating the fleets of both airlines to enhance product quality and strategically reallocating these resources to markets where consumers derive the highest value from the increased quality provision. The airline industry and the JetBlue-Spirit merger provide a valuable case for several reasons. First, it exemplifies a contentious horizontal merger that involves potential post-merger synergies in quality improvement. Second, the airline industry provides a unique advantage for analysis, as vertical product qualities, such as legroom, carrier type, and departure frequency, are relatively observable and measurable. Third, the industry’s diverse consumer base and varied market types provide an ideal setting to examine how the efficiency gains from quality improvements impact consumer welfare across different segments.

My structural model integrates consumer preferences for qualities with the firm’s decisions on input allocation and quality provision. On the demand side, the model incorporates heterogeneous consumer preferences for product qualities. For example, higher-income consumers tend to place greater value on convenience while being less sensitive to price. On the supply side, I analyze the compartmentalized decision-making processes within airline companies, focusing on their short-run seasonal choices on departure frequencies of nonstop service and ticket pricing. These two decisions are mapped into a two-stage supply-side framework, following the approaches of Fan (2013) and Wollmann (2018), and adapted to the airline industry. To ensure the validity of my demand and cost estimates, I calculate the cost per available seat mile (CASM), a standard measure of cost efficiency in the airline industry, and compare it with the figures reported in airline 10-K financial statements.

The supply-side model highlights the airline industry’s high fixed-cost structure nature, where expenses like crew salaries, depreciation, and takeoff and landing fees remain unchanged regardless of the number of passengers. To estimate these costs, I establish an interdependent framework that links departure-level costs with their allocation across passengers. My model also incorporates key operational constraints faced by airlines, such as limited aircraft and pilot availability, which restrict short-term capacity adjustments. This limitation translates into the question of optimizing the allocation of existing input resources. As a result, this model offers a robust framework for future research in the airline industry and other industries facing similar operational challenges.

Finally, I simulate the counterfactual scenario in which JetBlue elevates Spirit’s product quality and combines the operations of both airline companies. I then compare the simulation outcomes under two scenarios: one where JetBlue maintains its existing service levels, and another where it endogenously adjusts nonstop service provision and departure frequencies. How JetBlue reallocates its aircraft following the merger illustrates the realization of the anticipated synergies. I address the fixed input constraints faced by airline companies by proposing a novel within-firm resource reallocation method in the counterfactual analysis. Given that airlines cannot flexibly introduce new capacity, their product positioning decisions are driven by the relative marginal profits expected in the second stage for each possible first-stage choice. This approach contrasts with the typical entry model, where firms base production decisions on whether net profits exceed a zero-profit threshold.

The simulated outcomes of the JetBlue-Spirit merger reveal substantial quality-driven efficiency gains in large-city markets connecting the top 12 metropolitan areas. These gains arise from the endogenous reallocation of aircraft resources to business-heavy markets, where consumers are less price-sensitive and derive greater surplus from higher-quality service, primarily characterized by increased nonstop products and more frequent departures. In the simulation where firms are restricted from adjusting routes and departure frequencies, large-

city markets incur a \$15 million quarterly surplus loss following the merger. However, when firms can reallocate their aircraft, these markets realize a \$419 million quarterly surplus gain. This difference highlights that simply merging JetBlue and Spirit’s existing departures does not yield substantial surplus gains from improved product quality. Instead, the merger’s quality-driven synergy is realized through the strategic allocation of high-quality service to the markets that value it most. A closer examination of departure patterns shows that overall departures, particularly those operated by the merged firm, increase by more than 10% in these large-city markets.

On the other hand, the simulated merger outcomes show significant variations in welfare implications across different market types. Following the merger, airlines endogenously shift capacity away from leisure markets defined by six major tourist destinations, resulting in a decline in service quality. Combined with rising ticket prices, this leads to substantial welfare losses for consumers in these markets. Moreover, welfare effects vary even within the same market. In large-city markets, where overall consumer welfare increases significantly, high-income consumers benefit considerably from enhanced product quality, while low- and middle-income consumers experience slight welfare declines.

This paper is closely related to the literature on efficiency gains following the merger. Economists have increasingly emphasized efficiency gains as a counterbalance to the potential anti-competitive effects of mergers. Farrell and Shapiro (2010) and Caradonna et al. (2024) incorporate efficiency gains into theoretical models to assess the regulatory implications of mergers. On the empirical front, researchers have extensively examined post-merger cost reductions across various industries, including the brewing industry (Miller and Weinberg, 2016), the airline sector (Borenstein, 1990), the power sector (Demirer and Karaduman, 2024), and hospital mergers (Craig et al., 2021). Beyond cost savings, mergers can also drive efficiency gains through quality improvements. Prince and Simon (2017) and Das (2019) analyze the impact of airline mergers on vertical service quality, such as on-time

performance and cancellation rates. Berry and Waldfogel (2001) and Fan and Yang (2020) examine how mergers affect product variety, with evidence from the radio music and the smartphone industries, respectively.

Building on this literature, this paper develops an empirical framework that estimates demand and costs while allowing firms to endogenously optimize product positioning after a merger. This framework offers a structured approach to understanding the mechanisms through which post-merger synergies are realized.

This paper is also associated with work that examines firms' endogenous product positioning following the merger. While the Horizontal Merger Guidelines assume that product characteristics remain unchanged in merger simulations (Carlton, 2010, 2024), this assumption may lead to inaccurate predictions of post-merger outcomes (Peters, 2006). A growing body of literature underscores the critical role of firms' endogenous product choices in shaping market dynamics and competitive outcomes. Gandhi et al. (2008) and Qiu (2018) develop theoretical frameworks that can be applied to analyze post-merger product repositioning across industries. Empirical studies provide insights into specific industries. Berry and Waldfogel (2001) and Sweeting (2010, 2013) analyze post-merger product-level variety and explore how radio stations adjust their music genres within the context of the radio broadcasting industry. Fan (2013) uses a two-stage model to study that newspaper mergers affect both pricing and editorial content, with firms determining editorial content in the first stage and setting prices in the second.

This paper contributes to this body of literature in two significant ways. First, it endogenizes firms' vertical quality choices after a horizontal merger and quantifies the merger's distributional impact on consumer welfare across different market types and consumer segments. Second, extending the two-stage decision frameworks of Fan (2013) and Wollmann (2018), this paper introduces an innovative input reallocation approach to capture firms' stage-one decisions when production inputs, such as fleet size and pilot availability, are fixed

and entry is restricted.

Lastly, this paper contributes to the empirical literature on the airline industry and airline mergers. Many researchers have investigated the impact of horizontal mergers from a retrospective standpoint.¹ Recent studies have increasingly used structural models to predict post-merger market equilibrium. Peters (2006) and Berry and Jia (2010) apply static discrete choice models to estimate nested logit demand for consumers and assume static Bertrand competition among airlines. Lee (2013) adapts a two-stage model where airlines first determine product characteristics, such as flight cancellation rates, and then set prices. Li et al. (2018), Park (2020), and Yuan and Barwick (2024) extend this framework by incorporating route selection into the first stage. Ciliberto and Tamer (2009) and Ciliberto et al. (2021) model firms' entry and pricing decisions in a simultaneous, single-stage framework under the assumption of complete information. Benkard et al. (2010) and Aguirregabiria and Ho (2012) apply dynamic discrete choice models to examine the industry's long-term evolution.

This paper contributes to the literature by explicitly modeling airlines' choices on routes, departures, and aircraft types. It is also the first to incorporate two key characteristics of the airline industry into the supply-side model. First, operating a flight departure incurs a fixed cost regardless of the number of passengers on board. Second, while reallocating aircraft across routes is relatively cost-free, fleet size and pilot availability remain fixed in the short run. Accounting for these operational and strategic constraints, the model offers a more precise structural framework for analyzing airline market dynamics.

The structure of this paper is as follows. Section 1.2 provides backgrounds of the U.S.

1. See (Kim and Singal, 1993; Brueckner and Whalen, 2000; Kwoka and Shumilkina, 2010; Hüscherlath and Müller, 2014; Das, 2019). Additionally, numerous studies have examined factors that influence ticket pricing, such as carriers' dominance at airports and frequent flyer programs (Borenstein, 1989, 1991; Gordon and Jenkins, 1999; Lee and Luengo-Prado, 2005; Lederman, 2007, 2008; Ciliberto and Williams, 2010). Studies like Gerardi and Shapiro (2009) and Lazarev (2013) delve into airline price dispersion and intertemporal pricing strategies, while Richard (2003), Mazzeo (2002), and Das (2019) examine post-merger changes in airline product quality, such as departure frequency and delay and cancellation rates.

domestic airline industry and the JetBlue-Spirit merger. Section 1.3 discusses data sources. Section 1.4 highlights two key industry characteristics that serve as the foundation for the supply-side model. Section 1.5 establishes the model and Section 1.6 discusses the estimation of model parameters. Section 1.7 reports estimation results for demand and cost parameters, while Section 1.8 simulates post-merger market outcomes. Finally, Section 1.9 concludes.

1.2 Market Setting

This section examines the U.S. domestic airline industry and the JetBlue-Spirit merger. Section 1.2.1 outlines the industry’s market structure, key players, and the positioning of each airline along the vertical quality spectrum. Section 1.2.2 explores the quality-driven synergies of the JetBlue-Spirit merger and its varied welfare implications for different consumer groups.

1.2.1 The U.S. Domestic Airline Industry

The direct sectors of aviation, comprised of airlines, airport operations, and aircraft manufacturing, accounted for 1.3 percent of U.S. GDP in 2020 and contributed 2.5 million jobs.² The domestic airline industry is an essential part of the aviation sector. In 2019, the domestic airline industry served more than 800 million passengers.³ Despite the disruptions caused by COVID-19, the industry has been steadily recovering and continues to expand as travel demand increases.⁴

Only a few key players dominate the domestic airline market. This dominance is largely the result of significant industry consolidation over the past two decades. From the early 2000s to the 2010s, a wave of bankruptcies and mergers reshaped the U.S. airline landscape,

2. See the Economic Impact of U.S. Civil Aviation: 2020 published by Federal Aviation Administration.

3. See the U.S. Air Carrier Traffic Statistics published by the Bureau of Transportation Statistics.

4. See the U.S. Air Carrier Traffic Statistics. For example, the total domestic passenger enplanements in July 2024 reached 78.9 million. In comparison, the pre-COVID historic high was 75.4 million, recorded in July 2019.

which eventually forged the three full-service legacy carriers today: American, Delta, and United. These legacy carriers maintain hubs spread across the country, fly frequent departures on key routes, and offer high-quality services. Traditionally, the legacy airlines have operated using a hub-and-spoke system, funneling passengers from smaller cities through central hubs before connecting them to their final destinations. This model has enabled them to maximize efficiency and offer a wide range of destinations through fewer direct flights. However, in recent years, these carriers have increasingly shifted focus toward offering more nonstop services.⁵

Southwest Airlines, renowned for its budget-friendly approach, has grown to become the largest domestic carrier in terms of daily departures. Like the three legacy carriers, Southwest has a significant presence in markets across the country. However, Southwest differentiates itself by operating under a low-cost model. Southwest employs a point-to-point system rather than relying on central hubs, offering more nonstop products. Additionally, Southwest exclusively offers coach-class seating, and often flies into secondary airports in major cities. For instance, it operates out of Midway Airport in Chicago rather than O'Hare, and Love Field in Dallas instead of Dallas-Fort Worth. Despite its low-cost positioning, Southwest offers industry-standard legroom, two free checked bags, and consistently earns positive reviews for customer satisfaction.⁶ Together, these four airlines—commonly referred to as the "Big Four"—account for over 80% of U.S. domestic air travel. Table 1.1 presents the summary statistics of the U.S. domestic airline industry in 2019.

Following its acquisition of Virgin America in 2016, Alaska Airlines became the fifth-largest airline in the United States.⁷ The acquisition allowed Alaska to integrate Virgin

5. See, for example, a Forbes article discusses how airline routes have evolved over the past few decades: <https://www.forbes.com/sites/mitsubishiheavyindustries/2018/07/31/from-spoke--hub-to-long--thin-how-airline-routes-are-changing/>

6. For example, Southwest ranked first in customer satisfaction for economy class in 2024, its third consecutive year at the top according to J.D. Power.

7. Alaska Air Group announced plans to acquire Hawaiian Airlines for \$1.9 billion in December 2023 and the U.S. Department of Justice completed its antitrust review without challenging the merger in August

Table 1.1: Summary Statistics for Major U.S. Domestic Airlines

	Passengers (million)	Fleet size	Daily departures	Mean ticket price
Southwest	158.42	747	4000	174.24
Delta	152.18	1340	5400	231.70
American	146.15	1547	6800	235.62
United	110.26	1133	4900	241.83
Alaska	33.60	331	1300	188.83
JetBlue	33.76	259	1000	198.38
Spirit	30.74	145	630	74.17
Frontier	21.87	98	390	79.38

Notes: Passenger volume data is derived from *the 2019 Traffic Data for U.S. Airlines and Foreign Airlines U.S. Flights* tables, published by the Bureau of Transportation Statistics. These figures represent enplaned domestic passengers, with connecting passengers counted twice if their journey involves two flight segments. For Skywest Airlines and Republic Airways, passenger numbers are allocated to the three ticketing carriers: American, Delta, and United, based on each carrier's capacity agreements with these two third-party operators. Fleet size figures are sourced from the 2019 Annual 10-K filings of each airline and include airplanes operated by wholly-owned and third-party carriers. Although Frontier did not go public until March 2021, its subsequent financial reports provide fleet information for 2019. Daily departure figures are approximate numbers as reported in the respective 10-K reporting. Fleet size and daily departures account for airplanes used in operating both domestic and international flights. The mean ticket price is calculated as a weighted average from the raw ticket prices in the DB1B data sample published by the Department of Transportation.

America's hubs in San Francisco and Los Angeles with its existing hubs in Seattle and Portland, Oregon, thereby strengthening its presence on the West Coast. JetBlue, the sixth-largest U.S. airline, positions itself as a budget-friendly carrier while delivering premium coach-class services. Notably, it offers the most spacious legroom in coach class and seat-back TV screens for personalized entertainment.⁸ JetBlue maintains a strong presence in New York City, Boston, and Florida. Because these two airlines offer similar vertical product quality, operate within comparable price ranges, and maintain a regional focus, I classify them as "hybrid" carriers.⁹

The seventh and eighth largest airlines in the U.S. are Spirit Airlines and Frontier Airlines. These carriers differentiate themselves by focusing on the ultra-low-cost niche of the industry, positioning themselves further down the vertical quality spectrum. Targeting "value-conscious" travelers, they offer "low, unbundled base fares" supplemented by a range of optional services.¹⁰ Comparable in size to JetBlue, Spirit has a strong presence in leisure destinations like Florida and Las Vegas, while also maintaining operations in several "focus cities" across the country. Frontier Airlines operates under a nearly identical business model but is smaller in size than Spirit. Frontier's largest markets are Denver and Orlando.

1.2.2 The JetBlue-Spirit Merger

In July 2022, Spirit accepted JetBlue's \$3.8 billion acquisition offer, a deal that would have created the fifth-largest airline in the United States. The combined airline would have surpassed Alaska Airlines in size and transported approximately 60% of United Airlines' passenger volume. However, in March 2023, the U.S. Department of Justice filed a lawsuit

2024. This merger further solidified Alaska's position as the fifth-largest airline in the United States.

8. See JetBlue's 10-K financial reportings, with legroom data also supported by SeatGuru.

9. In the Findings of Fact and Conclusions of Law for the JetBlue-Spirit merger case, the court determines that Alaska Airlines and JetBlue "operate as hybrids of the low-cost and legacy carrier models" and designates them as "hybrid carriers."

10. See Spirit's 10-K financial reporting from 2019

to block the merger, citing antitrust concerns. The case went to trial in October 2023, and in January 2024, the court ruled to block the merger.

JetBlue's acquisition of Spirit was largely driven by its desire to "diversify and expand [its] network" in order to emulate and compete more effectively with the legacy carriers.¹¹ Legacy airlines have long relied on price-insensitive business travelers, a crucial segment for profitability.¹² They have even structured their business models around frequent departures and nonstop service on key business routes to cater to these travelers' preference for convenience.¹³ JetBlue is well-positioned to attract this market segment due to its strong brand reputation and high-quality onboard experience.¹⁴ However, its limited fleet size restricts its ability to provide the necessary nonstop routes and high-frequency departures at scale. This capacity constraint has made it difficult for JetBlue to compete with legacy carriers on service quality, particularly in terms of nonstop service provision and flight frequency.

Acquiring Spirit's fleet and pilots provides a fast and efficient solution for achieving the desired operational capacity.¹⁵ A quick calculation indicates that the acquisition price JetBlue paid is reasonably aligned with the actual market value of Spirit's fleet, suggesting that JetBlue sees value primarily in Spirit's fleet and pilot resources, rather than in its brand equity.¹⁶ Had the merger been cleared by the court, JetBlue would have proceeded with

11. For more details, see JetBlue's press release published on July 28, 2022, available on the JetBlue investor relations website: <https://ir.jetblue.com>.

12. This is a well-established strategy among legacy airlines. For instance, a Wall Street Journal article discusses how these carriers sought to regain business travelers following the pandemic: <https://www.wsj.com/articles/the-battle-to-lure-back-premium-travellers-has-begun-11624977777>.

13. See an article by Simple Flying, available at: <https://simpleflying.com/big-3-airline-won-2024-guide/>.

14. JetBlue offers the most spacious coach class seats, free onboard Wi-Fi, and seatback entertainment. A Simple Flying article reviews that JetBlue "provides amenities and services on par with full-service carriers." See <https://simpleflying.com/is-jetblue-a-budget-airline/>

15. Several factors constrain JetBlue's ability to expand through purchasing or leasing additional aircraft, including production backlogs and pilot shortages. Section 1.4.2 provides a detailed discussion of these capacity limitations in the airline industry.

16. I begin with Spirit's 2022 10-K financial report, which shows total assets of \$9.18 billion, a book value of equity of \$1.57 billion, and operating lease liabilities of \$2.45 billion, implying a total debt of \$5.16 billion.

consolidating the fleets of both airlines. As highlighted in a SEC complaint, prior to Spirit's shareholders opting to be acquired by JetBlue rather than Frontier, JetBlue had "admitted that it [would] permanently remove capacity from the market by retrofitting Spirit's fleet to remove seats." In other words, JetBlue intended to phase out the Spirit brand and enhance Spirit's product quality to align with JetBlue's higher standards. Additionally, by integrating the routes and departures of both airlines, JetBlue enhances its product quality by providing more frequent departures and more nonstop service.

The quality-driven synergies from the JetBlue-Spirit merger extend beyond simply merging the operations of the two airlines. Consumers who highly value nonstop service and frequent departures gain the most surplus when an additional airline enhances these offerings. As a result, these synergies are realized through the strategic reallocation of departures to markets where improved service quality provides the greatest value—primarily business-heavy markets. For JetBlue, shifting capacity to these markets also enables higher markups, as business travelers tend to be less price-sensitive. This strategy is evident in JetBlue's planned post-merger route adjustments. According to JetBlue's press release following Spirit's board approval of the acquisition, JetBlue aimed to increase its presence on key business routes.¹⁷

Due to JetBlue's potential post-merger product repositioning and the resulting synergy in product quality improvements, this merger could lead to different welfare outcomes across consumer groups and market segments. While consumers in targeted markets and those

Spirit's current assets amount to approximately \$2 billion. Thus, the effective cost of acquiring Spirit's 106 Airbus A320 family aircraft (excluding leased planes) can be calculated as \$3.8 billion (purchase price) + \$5.16 billion (debt) - \$2 billion (current assets), totaling \$6.96 billion. This is equivalent to about \$65.6 million per aircraft. Although this price may seem slightly high for just Spirit's fleet, with an average age of seven years, JetBlue also gains access to Spirit's pilots, staff, and ground facilities, as well as the option value of Spirit's long-term aircraft leases.

17. See JetBlue's press release published on July 28, 2022. JetBlue announced its plan to expand its presence in "key focus cities and major hubs of the Big Four airlines." In a subsequent release on March 7, 2023, JetBlue highlighted its commitment to bringing "competition to additional cities and to hubs dominated by legacy carriers." Sources available on the JetBlue investor relations website: <https://ir.jetblue.com>

who prefer higher-quality products would benefit from the improvement in JetBlue’s product quality and increased supply in these markets, those in non-targeted markets may face fewer choices and reduced competition. Additionally, the elimination of the Spirit brand would remove one of the two ultra-low-cost options available to price-sensitive consumers. These consumers might either be pushed out of the market entirely, face higher prices from the only remaining ultra-low-cost carrier, Frontier, or be forced to choose more expensive, higher-quality alternatives. Therefore, evaluating only the overall changes in consumer surplus would obscure the merger’s varied pro-competitive and anti-competitive impacts across different market segments and consumer preference groups.

1.3 Data Sources

Two main sources of data are used. The Airline Origin and Destination Survey (DB1B) data is a 10% sample of all U.S. airline tickets at the quarterly level. The T-100 Domestic Segment Data (T-100) contains detailed departure-level information. Both data sources are published by the U.S. Department of Transportation through the Bureau of Transportation Statistics (BTS) website.

The DB1B data includes ticket-quarter-level information such as the fare, the ticket size, the itinerary, and the ticketing and operating carriers for each flight segment. The T-100 data provides flight segment-month-level information, including the operating carrier, the number of passengers, the available seating capacity, and the aircraft types. I aggregate individual ticket data from the DB1B to the quarter-product level and calculate the market share for each product. I then merge it with the T-100 data to include additional details such as departure frequency, aircraft type, total seating capacity, and load factor.

I define a market as encompassing all trips between an origin city and a destination city. Each city is identified by a unique City Market ID in the DB1B dataset, which generally

aligns with the definition of Metropolitan Statistical Areas (MSAs) ¹⁸ and may encompass multiple airports. I define a product as a carrier-specific itinerary. Two itineraries are treated as distinct products if they involve different carriers, different airports within the same city, or different layover connections. Notice that products are inherently market-specific as they differ by itinerary. There is no "universal product" across markets.

I use data from 2017 to 2019. I focus on the lower 48 states and Washington D.C. (Berry and Jia, 2010) and analyze the largest 75 U.S. cities by air passenger volume. Markets with fewer than 200 daily passengers are excluded from the sample (Ciliberto and Williams, 2014). Individual tickets priced below \$12.50 or above \$1,250 are removed (Park, 2020). Within each market, products with more than one connection are also dropped (Berry and Jia, 2010). Additionally, products with fewer than 10 passengers or less than 0.1% of the market share, whichever is smaller, are excluded.

In processing the sample data, I attribute tickets issued or operated by wholly-owned and third-party regional carriers to their respective mainline ticketing carriers. For example, if the operating carrier is American Eagle, I consolidate it under American Airlines. Legroom space varies by aircraft type, and I manually collect this information from SeatGuru. When a carrier operates multiple configurations for a single aircraft type, I compute the legroom as the weighted average across different configurations. The departure frequency of the connecting flight is calculated as the geometric mean of the frequencies of the two flight segments (Berry and Jia, 2010).

Furthermore, I adjust ticket prices to account for ancillary fees. Airlines generate revenue not only from ticket sales but also from ancillary services such as checked baggage and seat selection. These revenues are particularly significant for ultra-low-cost carriers. Spirit and

18. In some cases, a single City ID encompasses adjacent MSAs. For example, while the Riverside–San Bernardino–Ontario MSA and the Los Angeles–Long Beach–Anaheim MSA are distinct metropolitan areas, airports in both MSAs share the same City Market ID (32575). Other notable examples include the San Francisco–Oakland–Fremont MSA and the San Jose–Sunnyvale–Santa Clara MSA, which share City Market ID 32457, as well as the Washington–Arlington–Alexandria MSA and the Baltimore–Columbia–Towson MSA, which share City Market ID 30852.

Frontier offer low base ticket prices but rely heavily on ancillary fees, with approximately 48% of their revenues coming from these sources in 2019.¹⁹ In contrast, legacy carriers derive a much smaller proportion (around 5% to 6%) of their revenues from ancillary fees, and Southwest is notable for its minimal ancillary fees despite being a budget carrier.²⁰ Since average ticket prices do not capture the total expenses paid by consumers—especially for ultra-low-cost carriers—I adjust the product prices by adding back the ancillary fees. Given that only carrier-level ancillary fee ratios are available from the financial reportings, I assume these ratios are consistent across all products within each carrier.

I include additional data sources to enhance my analysis. The Inter-Airport Distance data, published by the Bureau of Transportation Statistics, is used to compute travel distances between airports in my sample. The individual-level records from the American Community Survey are used to construct the empirical income distribution, while the population is constructed using the SEER population data and the county-MSA crosswalk published by the Bureau of Economic Analysis (BEA). Additionally, the Origin and Destination Survey data from the Bureau of Transportation Statistics is utilized to construct the outside market share. A detailed discussion of the outside share calculation can be found in Section 1.5.1.

Certain limitations in the available data remain that, if addressed, could enhance the robustness of the estimation. One notable limitation is the absence of detailed departure schedule information. While the T-100 data provides monthly aggregated flight segment data, it lacks specific departure times. Departure times can significantly affect ticket prices; flights during prime hours often command higher fares. If the preferred departure time is positively correlated with ticket prices, the estimation will suffer from omitted variable bias, causing the pricing coefficient in the demand estimation to be biased toward zero, which leads to an underestimation of consumer price sensitivity. Another limitation is the

19. See Spirit’s 10-K financial reporting from 2019 and Frontier’s 10-K financial reporting from 2023.

20. See each carrier’s 2019 financial reportings.

absence of detailed ticket fare class information, which would be valuable for distinguishing between consumer and market segments. Incorporating this data would enable a more precise identification of segmentations and provide a more accurate estimation of consumer preferences and price sensitivities. With the hope that more detailed data will become available in the future, researchers could address these limitations and assess the extent to which resolving them enhances the estimation of consumer behavior.

1.4 Airline Decision-Making and Operational Constraints

This section explores two key aspects of the airline industry that inform and motivate my supply-side modeling framework. Section 1.4.1 analyzes how airlines manage core operational decisions, such as route planning and pricing strategies, through distinct departments. Section 1.4.2 highlights input constraints faced by the airline industry, including fixed airline capacities and pilot shortages, as well as factors that restricts airline companies from outsourcing their production.

1.4.1 Decision-Making in Airline Operations

Airlines' core operational costs can be categorized into two primary expenses: sunk costs related to aircraft depreciation or leasing and the costs incurred for each flight departure. Within the cost structure of one flight departure, expenses can be further divided into "fixed" costs of operating an empty plane and variable costs of accommodating additional passengers on board.

According to industry experts, decisions regarding aircraft purchase and leasing, route and departure frequencies, and pricing are handled by different departments within an airline. Long-term decisions about fleet adjustments and large-scale pilot recruitment are made by top-level management. These decisions are influenced not only by the airline's current operational status but also by strategic considerations related to the company's long-term

growth and future market positioning.

Prior to each new International Air Transport Association (IATA) scheduling season,²¹ the network planning department adjusts the route network and departure schedules based on the previous season's decisions. As revealed by a director in this department at a major Chinese airline, these decisions are made by considering the current fleet composition as exogenously given. Since expenses associated with aircraft depreciation and base crew salaries remain constant regardless of whether the aircraft is grounded or flying during the season, these costs do not factor into the network planning department's decision-making. A route is considered economically viable if its expected revenue exceeds the expected variable costs of operation. When aircraft and crew resources are constrained, the airline allocates these resources to routes that offer the highest "benefits" per diem, defined as the average expected revenue minus cost per operating hour.

Subsequently, decision-making shifts to the pricing team, which determines the menu of fares and applicable restrictions. Finally, responsibility transfers to the revenue management department, which conducts demand analysis and dynamically adjusts prices based on ticket sales as the departure date approaches.²²

A more detailed discussion of the evolution of an airline's organizational structure and pricing practices is available in Vinod (2021). Hortaçsu et al. (2024) also provides a concise overview of the airline's internal organization. Their analysis examines the operational model of a major U.S. airline, breaking down its decision-making process into three key components, aligning with the discussion in this section.

21. Airline schedules worldwide are adjusted twice a year: the summer season begins on the last Sunday of March and the winter season starts on the last Sunday of October.

22. Some airlines incorporate an additional stage of decision-making in the final days before departure. According to a director of the revenue management department of a Chinese airline, by the time the flight is one week to two days away from departure, most tickets have already been sold. At this stage, the airline can decide whether to deploy a larger aircraft to accommodate strong demand, use a smaller aircraft, or even consolidate two departures into one to reduce operational costs. The DB1B data provides supporting evidence for this practice; for example, it is common to observe that out of 150 quarterly departures, 130 were operated by an Airbus A320, and 20 by a similar but larger Airbus A321.

1.4.2 Fixed Inputs and Limited Contractibility

This section examines the fixed input constraints in the U.S. airline industry. The U.S. airline industry operates at or near full capacity, making it difficult to increase supply without additional operational resources. However, acquiring new aircraft is slow due to production backlogs and the prevalence of long-term leasing contracts. Capacity expansion is further constrained by pilot shortages, limited pilot mobility, and regulatory and union restrictions that hinder outsourcing to other airlines. These constraints inform the supply-side modeling in Section 1.5, where airlines optimize route networks and departure frequencies within the limits of their existing fleet. Such constrained optimization reflects the decision-making of the network planning department in Section 1.4.1. Capacity limitations also provide a key motivation for the JetBlue-Spirit merger. JetBlue’s inability to rapidly expand its fleet through conventional channels made acquiring Spirit’s aircraft an attractive strategic option.

Major U.S. airlines are operating at or near full capacity. T-100 data from 2019 indicates that the average daily scheduled operating hours per aircraft for all major carriers exceeded 10 hours, with JetBlue leading at 12.3 hours per day. Importantly, this calculation excludes the downtime between consecutive scheduled flights for the same aircraft. According to an industry expert, an average daily operating time above 10 hours signals that an airline is nearing maximum capacity. As a result, expanding new routes or increasing flight frequency without additional capacity is a significant challenge.

Capacity adjustments in the airline industry are not instantaneous. Acquiring new aircraft typically requires significant lead times. As of 2023, Airbus’s current backlog represents approximately 11.7 years of production at the 2023 delivery rate. For Boeing, the backlog equates to around 7.7 years of production at 2018 delivery rates or 11.9 years at 2023 delivery

rates.²³ ²⁴ While leasing aircraft might seem like a viable alternative, it often involves long-term commitments. For example, airlines like United Airlines and Delta Air Lines enter into lease agreements that span multiple years. According to United Airlines' 2023 10-K financial report, their operating lease terms range from three to twelve years. Similarly, Delta Air Lines reports lease obligations with terms extending up to fifteen years in their 2023 10-K report. Furthermore, the extended duration of these leases restricts aircraft leasing agencies from promptly redeploying aircraft to carriers experiencing immediate needs. As a result, these long-term leases and production delays limit airlines' ability to adjust capacity swiftly in response to market changes.

Another major factor that restricts the operational capacity of airline companies is the availability of pilots. A 2021 report by the consulting firm Oliver Wyman highlights an ongoing pilot shortage in the airline industry, which has been exacerbated in recent years due to the mandatory retirement of experienced pilots at the age of 65 and a slow pipeline of new entrants into the profession.²⁵ A 2023 report by Oliver Wyman observes that "airlines reduced or eliminated many regional flights and routes in response to the lack of pilots."²⁶ The pilot shortage is further complicated by the tenure system prevalent in the industry, where "seniority does not carry over when pilots move from one company to another."²⁷ This restriction discourages pilot mobility and makes switching unattractive, thereby limiting

23. These are forecasts provided by Forecast International. <https://flightplan.forecastinternational.com/2024/10/21/airbus-and-boeing-report-september-2024-commercial-aircraft-orders-and-deliveries/>

24. The year 2018 was the most recent "normal" year for Boeing. Since then, Boeing's production backlog has been significantly impacted by the 737 Max crisis, airplane safety issues, and ongoing delays in the 777X series deliveries.

25. Oliver Wyman, "After COVID-19, Aviation Faces a Pilot Shortage." March 2021: <https://oliverwyman.com/our-expertise/insights/2021/mar/after-covid-19-aviation-faces-a-pilot-shortage.html>

26. Oliver Wyman. "North American Pilot Shortage Shows Smaller Gap." October 2023: <https://www.oliverwyman.com/our-expertise/insights/2023/oct/north-american-pilot-shortage-shows-smaller-gap.html>

27. Simple Flying. "The Ultimate Guide To Pilot Seniority & How It Works": <https://simpleflying.com/pilots-seniority-guide/>

the flexibility of airlines to quickly address labor shortages. Massive pilot unionizations and strict Federal Aviation Administration (FAA) regulations, such as the 1,500-hour rule, have restricted the supply of new pilots.

U.S. airlines also face stringent restrictions on outsourcing flight operations. Under Federal Regulations Title 14 CFR Part 119.53, wet leasing, an arrangement where an airline leases an aircraft along with its crew, maintenance, and insurance from another operator, is highly regulated. U.S. carriers are prohibited from wet leasing aircraft from foreign carriers not authorized by the FAA to conduct common carriage operations. Even domestic outsourcing is restricted, as airlines cannot easily transfer operational control of flights to another U.S. carrier without meeting strict FAA requirements.

Furthermore, pilot union agreements, such as those negotiated by the Airline Pilots Association (ALPA), place additional restrictions on outsourcing. For example, ALPA prohibits its pilot groups from "signing 'B Scale' contracts" with other carriers.²⁸ This limits the mobility of pilots and the flexibility of airlines to manage labor shortages, even if they have sufficient spare aircraft capacity. Efforts to address pilot shortages through international hiring face significant obstacles, as U.S. airlines typically do not sponsor work visas for foreign pilots. Additionally, visa restrictions and the FAA's rigorous certification process make international recruitment a lengthy and complex endeavor.

While airlines face significant constraints related to aircraft and pilot availability, other potential input limitations are generally less restrictive. For instance, although gate access at airports can be limited, the FAA has implemented several measures to support new entrant carriers in overcoming these barriers.²⁹ At highly congested airports, takeoff and landing

28. In this context, "B Scale" contracts refer to lower pay scales for outsourced pilots. This clause aims to reduce pilot mobility and prevent wage undercutting within the pilot workforce. See <https://www.aapilots4alpa.info/hot-topics>.

29. FAA requires airports to "adopt gate assignment protocols with considerations for new entrants" and to "reduce burdens on new entrants" in gate allocation. Additionally, FAA mandates an increase in common-use gates and the adoption of "use-or-lose" or "use-or-share" policies for underutilized exclusive-use gates, ensuring more equitable access for all carriers. See FAA's Airport Competition Plans for more details.

slots are regulated by the FAA through a slot allocation system.³⁰ However, not all airlines are equally impacted by these restrictions. For instance, American Airlines holds a significant number of slots in New York City but has been under-utilizing these slots.

1.5 Model

This section presents a two-stage model that captures airline decision-making and consumer demand. In the first stage, carriers decide on routes, departure frequencies, and the aircraft types assigned to each departure. In the second stage, carriers observe demand and cost shocks and set prices for each product. Carriers solve this problem by first working with the second stage, determining equilibrium pricing and profits for any potential set of product offerings. They then optimize their route and departure frequency decisions in the first stage, informed by their calculations from the second stage. Econometricians approach this problem in the same order.

This two-stage model closely mirrors the real-world decision-making process of airlines. The first stage aligns with the responsibilities of the network planning team, while the second stage corresponds to the pricing team, which sets fare schedules.

To maintain tractability, the model abstracts certain complexities of airline decision-making, including long-term fleet evolution and dynamic pricing. Given that regulatory agencies primarily focus on the short- to medium-term effects of a merger,³¹ my model abstracts from the airline's long-term fleet evolution. Furthermore, due to the absence of time-varying ticket pricing data and that dynamic pricing is not the primary focus of this paper, this model does not account for the revenue management department's role. This

30. Currently, three U.S. airports are subject to FAA slot-controlled regulations: LaGuardia (LGA), John F. Kennedy (JFK), and Reagan National (DCA).

31. For example, the 2023 Horizontal Merger Guideline requires the agencies to assess whether the potential entry is "rapid enough to replace lost competition before any effect from the loss of competition due to the merger may occur." A merger may still be deemed harmful even if long-term entry could eventually restore competitive conditions lost due to the merger.

simplifies the airline's pricing decision to a single, static choice in the second stage of the model.

1.5.1 Stage 2: Demand

The demand model follows a random-coefficient discrete-choice framework, allowing for flexible substitution patterns for consumers with varying preferences for price and product characteristics. The indirect utility u_{ijmt} for consumer i from consuming product j in market m at time t is given by

$$u_{ijmt} = \alpha_i p_{jmt} + X_{jm} \beta_i + \xi_{jm} + \epsilon_{ijmt} \quad (1.1)$$

Here, X_{jm} is a vector of observable product characteristics excluding price. The average ticket price of product j in market m at time t is denoted by p_{jmt} . Individual-specific tastes for price and observable product characteristics are denoted with α_i and β_i . ξ_{jm} captures product-specific characteristics unobservable to the econometrician, and ϵ_{ijmt} is a mean zero stochastic term.

The vector X_{jm} includes whether the product is nonstop or connecting, departure frequency, average legroom, and carrier-type dummies. The carrier-type dummies capture the "service quality" offered by carriers. Carriers within the same category offer similar features and quality. All else equal, I assume the average consumer perceive them as comparable.

The term ξ_{jm} is the unobserved product characteristics of product j in market m . Since consumers' tastes can vary across markets, I control for un-directed market fixed effects

$$\xi_{jm} = \xi_{\tilde{m}} + \Delta \xi_{jm}$$

where $\tilde{m}$ represents the two directed markets connecting two cities. The residual $\Delta \xi_{jm}$ is left as the error term.

The preferences of an individual consumer i can be decomposed into the average taste for product characteristics that are shared by all consumers and an idiosyncratic deviation. This deviation from the mean is modeled as a function of the consumer’s observable demographic attributes, as well as unobserved characteristics that are not observed by the econometrician. Specifically,

$$(\alpha_i \quad \beta_i)' = (\alpha \quad \beta)' + \Pi D_i + \Sigma v_i \quad (1.2)$$

where D_i is a $d \times 1$ vector of demographics variables, Π is a $K \times d$ matrix of coefficients that measure how the taste varies with demographics, v_i is an identity matrix of dimension K , and Σ is a scaling matrix.

Log income is the sole demographic variable used to represent an individual consumer’s demographic. I interact log income with product pricing and departure frequencies to capture how consumers’ income levels influence their varying preferences for price and frequency of departures. This approach helps to distinguish value-conscious, price-sensitive travelers from those who prioritize convenience over cost.

The final component of the demand model is the outside option, which accounts for consumers who choose alternative modes of travel, such as driving or taking a train, or those who decide not to travel. I use data from the annual Passenger Origin-Destination Survey, first available in 2022, to construct the ratio of travelers who choose the outside option.³²

32. The ratio of consumers who choose the outside option is constructed as follows. First, I calculate the travel intensity between two cities by dividing the number of travelers between them, as recorded in the 2022 Origin-Destination Survey, by the combined population of the two cities. This travel intensity metric is designed to measure the connectivity between the cities. For instance, higher travel intensity would be expected if both cities are large or geographically close, as more people are likely to travel between them in these cases. I then multiply this value by the ratio of total trips between the two cities that are taken by air. I call the resulting value air travel intensity. This process is designed to capture travelers’ choices between air and non-air transportation options. The minimal value for air travel intensity is 0.003, the median is 5.61, while the maximum is 102.75. Finally, I normalize and scale the vector of air travel intensity to fall between 1% and 99%. The outside market share is then calculated as 1 minus the scaled air travel intensity. The resulting median outside market share is 93.65%.

The indirect utility of the outside option is

$$u_{i0mt} = \xi_0 + \pi_0 D_i + \sigma_0 v_i + \epsilon_{i0mt}$$

Since this indirect utility is not identified, I normalize it to zero.

For each market, I simulate 50 consumers, drawing their incomes from the empirical income distributions of both the origin and destination cities, with the number of consumers from each city proportional to their respective population sizes.

By integrating over the total number of simulated consumers, I derive the market share for each product j in market m at time t . This setup assumes a static, unit-demand framework, where each individual consumer makes a single purchase decision within a given time period.

1.5.2 Stage 2: Prices

In the second stage, the firm's decision is to choose prices. The airline industry operates under a different framework than the classic economic setting, where the marginal cost of producing a product typically makes up a significant portion of its price, while fixed costs are primarily tied to establishing production capacity. For a flight departure, most operating costs are fixed, regardless of the number of passengers on board. These fixed costs include pilot and crew wages, the cost of flying the airplane, and miscellaneous expenses like insurance. In contrast, the marginal cost of accommodating an additional passenger is relatively low. It primarily includes costs for food and beverages, as well as a small increase in fuel consumption due to the added weight of an extra passenger. Based on a quick calculation, the additional fuel cost per passenger is approximately \$7.70.³³

33. An empty Airbus A320 weighs approximately 82,000 lbs. A typical Delta A320 has 157 seats, and with a load factor of 80%, there are around 125 passengers on board. Assuming each passenger, including personal items, weighs 200 lbs, the total passenger weight accounts for 23% of the aircraft's total weight. A fully loaded A320 typically burns 2,500 liters of fuel per hour. For a two-hour flight between New York City and Chicago, this translates to approximately 1,200 gallons of fuel. Assuming a fuel price of \$3.50 per gallon, the fuel cost of carrying one additional passenger is $1200 \times 3.5 \times 23\% / 125 = \$7.7$. Notice that \$7.70 is

To accurately capture the cost structure of an airline, the modeling of the carrier's second-stage decision focuses on the fixed costs of operating a flight. The demand elasticity implied by the ticket price and the minimal marginal cost of carrying an additional passenger would seem unrealistic. More importantly, this model is based on airlines' quarterly decisions. At the quarterly level, carriers have the flexibility to adjust departure frequencies based on the expected passenger demand for a given route. Therefore, at this level, the "fixed cost" of operating a flight behaves similarly to a step-variable cost. In contrast, it is the cost of purchasing or leasing airplanes that resembles the sunk costs associated with establishing production capacity in a classic economic setting.

In modeling the carrier's decision in the second stage, the costs associated with operating a flight are used to construct the carrier's pricing strategy. The model allocates flight-level costs to each individual passenger, allowing these costs and the consumer-level ticket prices to be jointly used to solve the carrier's cost structure.

Total Cost of Operating a Flight and Costs for Individual Travelers

Across all markets, carrier f operates a set of aircraft types $\mathcal{R}_f$, where $r \in \mathcal{R}_f$ denotes a specific aircraft type, such as Boeing 737-800. The seating capacity for carrier f 's type r aircraft is denoted by z_{fr} . The seating capacity of the same aircraft type may vary across different carriers.

A flight segment, denoted by s , refers to a nonstop departure between two airports and is different from the concept of a product. A flight segment may carry both nonstop passengers and connecting passengers who use this segment as part of a longer journey.

Based on carrier f 's stage-one decisions, carrier f allocates K_{fsr} departures of type r aircraft in segment s . As a result, the total seating capacity of carrier f in segment s can be

likely an overstatement, as a fully loaded airplane typically carries additional cargo. For the aircraft weight information, see <https://www.globalair.com/aircraft-for-sale/specifications?specid=639>. For the fuel consumption information, see <https://aviex.goflexair.com/flight-school-training-faq/how-much-fuel-do-commercial-planes-use>.

denoted by

$$C_{fs} = \sum_{r \in R_{fs}} K_{fsr} z_{fr}$$

I assume that when an airline makes stage-one decisions, it utilizes an expected load factor $\mathcal{L}$ in the decision-making. In expectation, $Q_{fs} = C_{fs}\mathcal{L}_s$, where Q represents the realized number of passengers. Therefore, ex-ante, when determining ticket prices, the carrier allocates the total operating cost of the flight among the $\mathcal{L}_s C_{fs}$ expected passengers, plus any marginal "beverage" costs per passenger.

I further assume that operating costs at the seat level are identical across different aircraft types. Therefore, the total cost for carrier f to operate a departure on flight segment s is assumed to have the following form:

$$Total\ cost_{fs} = X_{fs}^1 \gamma_1 C_{fs} + X_{fs}^2 \gamma_2 Q_s$$

The cost of operating a flight can be divided into two components. $X_{fs}^1 \gamma_1 C_{fs}$ represents the fixed costs of operating this flight, which remain constant regardless of the number of passengers. I assume the fixed cost spreads out to the seat level is a linear function of some cost shifters X_{fs}^1 with parameters γ_1 .³⁴ $X_{fs}^2 \gamma_2 Q_s$ represents the marginal costs. I assume the marginal cost of carrying a passenger is a linear function of cost shifters X_{fs}^2 with parameters γ_2 .

Notice that a flight departure serves both nonstop passengers and connecting passengers traveling. Thus, the total cost can also be expressed as

$$Total\ cost_{fs} = X_{fs}^1 \gamma_1 C_{fs} + \sum_{m \in \mathcal{M}(s)} q_{ms} X_s^2 \gamma_2$$

34. After estimating the demand parameters, I recover the implied markups and marginal costs. Graphical analysis indicates that the implied marginal cost is approximately a linear function of cost shifters, as opposed to alternative functional forms. A more detailed discussion can be found in Section 1.6.2.

where q_{ms} represents the number of passengers who travel in market m with this flight segment s as part of their journeys.

Spreading out the flight-level total cost to each of the Q_s individual passengers on board gives

$$X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_s} + X_s^2 \gamma_2$$

The cost incurred by an individual consumer flying product j in market m includes the costs associated with the set of flight segments S_j that make up this consumer's entire itinerary:

$$c_{jm} = \sum_{s \in S_j} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_s} + X_s^2 \gamma_2 \right) \quad (1.3)$$

The term $\frac{C_{fs}}{Q_{fs}}$ can be interpreted as the inverse of the load factor.³⁵ When a flight departure is relatively full, $\frac{C_{fs}}{Q_{fs}}$ is close to 1, and the cost spread to an individual consumer is relatively low. When a flight departure is empty, $\frac{C_{fs}}{Q_{fs}} > 1$, and the cost spread to an individual consumer is higher.

The Optimal Pricing

The aggregate profit of carrier f is calculated by first summing over the set of products J_{fm} it operates in market m , and then summing across all markets.

$$VP_f(S_f, S_{-f}) = \sum_m \sum_{j \in J_{fm}} (p_{jm} - c_{jm}) q_{jm}$$

35. In the airline literature, Park (2020) introduces a cost function similar to Equation 1.3. Park assumes that the marginal cost of a ticket consists of two components: the first is a linear function of observable product characteristics, such as distance and whether the airport is a hub, while the second is a nonlinear function of the load factor, capturing the relationship between cost and load factor discussed here.

In the second stage, the carrier determines the optimal price for each product it operates:

$$\frac{d VP_f}{d p_{jm}} = 0 \quad \forall j, m$$

Expanding this equation via total differentiation gives

$$\frac{d VP_f}{d p_{jm}} = q_{jm} + \underbrace{\sum_{k \in J_{fm}} (p_{km} - c_{km}) q_{km} p_{jm}}_{\text{direct costs}} - \underbrace{\sum_{l \in \mathcal{J}(S_j)} c_{lm'} p_{jm} q_{lm'}}_{\text{indirect costs}} = 0 \quad (1.4)$$

The change in the price of product j in market m affects the variable profits by changing the quantity of product j and the quantity of other products in the same market m via substitutions. The direct costs mirror the standard markup equation in a demand estimation model.³⁶ The change in product j 's price also affects the market competition indirectly.³⁷ It affects the load factor of any product that shares a flight segment with product j . The set of such products is denoted by $\mathcal{J}(S_j)$, where S_j is the set of segments utilized by product j . When p_{jm} goes up, passengers substitute away from this product, so the load factor of the products that share a segment with product jm also decreases. Since the fixed cost of operating the flight departure remains unchanged, the cost spread to each individual consumer increases.

For example, suppose market m represents the market from Los Angeles to New York City. Product j represents United Airline's product from Los Angeles International Airport (LAX) to LaGuardia Airport (LGA), with one layover in Chicago O'Hare (ORD). This product involves two flight segments, LAX-ORD and ORD-LGA. When the price of this product increases, the demand for this product decreases. This leads to a lower load factor on

36. See, for example, Nevo (2001) and Berry and Jia (2010).

37. In the airline literature, Park (2020) also discusses this concept. Park includes the load factor in his marginal cost function, which indirectly changes the cost structure for all products that share the same flight segment.

both LAX–ORD and ORD–LGA flights. As a result, the cost spread out to each passenger on these routes increases. For instance, consumers who fly United’s direct flight from ORD to LGA, or United’s connecting product from San Francisco International Airport (SFO) to LaGuardia with a layover at O’Hare, will face higher costs.

I derive equation 1.4 in Appendix B.1. The resulting first-order condition is:

$$\frac{d VP_f}{d p_{jm}} = q_{jm} + \sum_{k \in J_{fm}} (p_{km} - c_{km}) q_{km} p_{jm} + \sum_{s \in S_j} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_{fs}} \frac{\sum_{l \in \mathcal{J}(s) \setminus j} q_l}{Q_{fs}} \right) q_{jm} p_{jm} = 0 \quad (1.5)$$

where $\sum_{l \in \mathcal{J}(s) \setminus j} q_l / Q_{fs}$ represents the ratio of passengers on board this flight segment s that do not belong to this product j in market m .

Stacking Equation 1.5 into the matrix form gives:

$$q_m + \Omega_m(p_m - c_m) + \text{diag}(\Omega_m)\psi_m = 0 \quad (1.6)$$

where p_m , c_m , and q_m is the vector of price, marginal cost, and quantity, and

$$\Omega = \Omega^* S^*$$

where the (i, j) th entry of matrix S^* is $-\partial q_r / \partial p_i$ and the (i, j) th entry of Ω^* is equal to one when these two products belong to the same carrier and 0 otherwise. $\text{diag}(\Omega_m)$ is a diagonal matrix that contains the diagonal values of matrix Ω . The j^{th} row of the vector ψ_m is associated with product j in this market and is given by:

$$\psi_{m,j} = \sum_{s \in S_j} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_{fs}} \frac{\sum_{l \in \mathcal{J}(s) \setminus j} q_l}{Q_{fs}} \right)$$

1.5.3 Stage 1: Routes and Departure Frequency

In the first stage, the carrier selects the set of flight segments, departure schedules, and aircraft types for each departure to maximize its expected payoffs. I assume that carriers only know the distributions of demand and marginal cost shocks. This allows the carrier to form expectations about variable profits to facilitate the optimal allocation of resources in the first stage.

Building on the discussion in Section 1.4.2, I explicitly model the input constraints faced by airline companies and assume that the current mix of fleet and the total operational hours for each aircraft type are fixed. As a result, the carrier's first-stage decision is to optimally reallocate its limited aircraft resources and seating capacity across markets and products. It is important to note that no actual costs are incurred at this stage.

The carrier's decision in stage one can be expressed as

$$VP_f(S_f^*(K_f^*, R_f^*), S_{-f}) \geq VP_f(S_f(K_f, R_f), S_{-f}) \quad \forall S_f, K_f, R_f \quad (1.7)$$

subject to the input constraint:

$$\sum_{s \in S_f} t_{f sr} K_{f sr} \leq \bar{T}_{fr} \quad \forall s, r$$

Inequality 1.7 indicates that any deviation from the market equilibrium choice of route, departure frequency, and aircraft type weakly decreases total profits. The fixed input constraint states that, for each aircraft type r , the total operational hours summed across all flight segments s must not exceed the total available operational hours for that aircraft type, which is denoted by $\bar{T}_{fr}$. Here, $K_{f sr}$ denotes the number of departures operated by carrier f on segment s using aircraft type r . $t_{f sr}$ represents the hours required to complete one such departure.

I do not explicitly model the sunk costs associated with entering a route. These costs, such as expenses for relocating staff to a new airport and leasing gates, represent only a small fraction of an airline’s total operating costs.³⁸ Given their relatively minor impact, I exclude them from my model.

1.6 Estimation Strategies and Identification

1.6.1 Stage 2: Demand

The demand estimation closely follows Nevo (2001). Based on the market shares (aggregate quantities) and prices, parameters that minimize the gap between the predicted and observed market shares are selected. The key identification strategy requires a set of instrumental variables that are correlated with price but not with the unobservable product characteristics. Valid instrumental variables should also provide adequate variation after controlling for undirected market fixed-effects.

I introduce two sets of instruments, exogenous marginal cost shifters and exogenous markup shifters. For marginal cost shifters, I will include whether the airport is a hub for the carrier, the number of departures the carrier operates from both the origin and destination airports,³⁹ the gasoline costs, and the Hausman instrument (Hausman, 1994).

When the airport is a hub for the carrier, the carrier can typically benefit from economies

38. In related literature, Park (2020) and Yuan and Barwick (2024) use partial identification strategies to estimate such costs. Their estimates are \$0.84 million to \$2.92 million per quarter and \$0.46 million to \$0.51 million per quarter, respectively. In practice, airlines often secure long-term contracts for and even directly invest in exclusive-use space at hub airports. These costs tend to be high due to the carrier’s massive presence in the hub airport. For example, Delta has invested \$4 billion in its new terminal in New York’s LaGuardia Airport. See <https://www.anewlga.com/about-the-project/terminal-c/>. On the other hand, at non-hub locations, airlines may choose joint-use or common-use facilities to maintain flexibility. For instance, at San Francisco International Airport, the quarterly fee for utilizing common-use facilities for a single arrival-departure cycle is approximately \$1,000. See the Fiscal Year 2022-2023 Summary of Airport Charges at San Francisco International Airport: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.flysfo.com/sites/default/files/2022-06/FY22-23_Summary_of_Airport_Charges_0.pdf.

39. Lederman (2007) and Berry and Jia (2010) use these two types of cost shifters as instruments for airline ticket prices.

of scale, leading to reduced operating costs. The second marginal cost shifter captures a similar effect. I assume that gasoline costs are exogenously given, meaning that the price of gasoline influences the carrier's operating costs but is not affected by the carrier's demand. As for the Hausman instrument, in my context, the Hausman instrument is constructed as follows. I assume that, after controlling for demographics and product-specific factors, the route-specific valuation of a product is independent across markets. Given this assumption, if I further assume the marginal cost for two flights of the same travel distance is equivalent, then the prices of products with similar travel distances in other markets serve as valid instrumental variables. Specifically, I use the mean ticket price of the same carrier's other products with a travel distance difference of within 50 miles, in the same quarter, as instruments.

For the markup shifters, I draw on the economic principle that increased competition reduces markups, as well as the well-known "Southwest Effect," where prices drop significantly following the entry of the budget carriers.⁴⁰

I incorporate measures of market concentration to capture the impact of competition on markups (Berry and Jia, 2010). Additionally, I use the number and the market share of low-cost carriers and ultra-low-cost carriers, measured by nonstop departures, as a key indicator of market competition. I also include the number of potential entrants and potential products as instrumental variables (Li et al., 2018). In my context, a potential entrant is defined as a carrier that has a hub at either the origin or destination airport but does not currently operate in that market. A potential product can be either a direct flight or a connecting flight, with connecting flights considered potential direct flights to a layover airport, followed by an existing flight on the same carrier from the layover airport to the final destination.

The validity of these instruments relies on the timing assumptions of the model. Any

40. The impact of Southwest's entry on lowering market prices is well-documented in the literature (e.g., Morrison (2001)). Moreover, a study by Goolsbee and Syverson (2008) find that even the mere threat of Southwest entering a market can drive prices down.

changes in market structure, including the carrier's choice of routes and departure frequencies, are determined in stage 1 of the game. Since unobserved demand shocks occur in stage 2, market structure changes are not correlated with these unobserved variables.

1.6.2 Stage 2: Cost

To calculate the total cost of operating a flight departure, the per-passenger cost is estimated and combined with the seating capacity and load factor to determine the overall operating cost of the flight. The first-order condition of the carrier's pricing decisions in market m , expressed in matrix form, is represented by Equation 1.6, where each row corresponds to a product j operated by the carrier. Rewrite this equation gives

$$p_m + \Omega_m^{-1} q_m = c_m - \Omega^{-1} \text{diag}(\Omega) \psi_m \quad (1.8)$$

The left-hand side of the equation represents the "marginal cost" faced by the carrier, where $-\Omega_m^{-1} q_m$ can be interpreted as the markup charged for the product. It's important to note that the marginal cost faced by the carrier in this context is equivalent to the total cost of operating a flight distributed across each individual traveler. The right-hand side of the equation contains the cost parameters to be estimated.

Each row of the right-hand side of Equation 1.8 can then be expanded as

$$\begin{aligned} &= \sum_{s \in S_j} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_{fs}} + X_s^2 \gamma_2 \right) - \left(\Omega^{-1} \text{diag}(\Omega) \right)_j \sum_{s \in S_j} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_{fs}} \frac{\sum_{l \in \mathcal{J}(s) \setminus j} q_l}{Q_{fs}} \right) + \omega_{jm} \\ &= \sum_{s \in S_j} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_{fs}} \left(1 - \left(\Omega^{-1} \text{diag}(\Omega) \right)_j \frac{\sum_{l \in \mathcal{J}(s) \setminus j} q_l}{Q_{fs}} \right) \right) + \omega_{jm} \end{aligned}$$

The vector X_{fs}^1 represents flight-level fixed cost shifters allocated to each individual traveler, while X_s^2 captures the marginal cost of serving an extra passenger. Since the marginal cost of serving an additional passenger is small compared to the overall cost of operating the

flight, I exclude this cost from the estimation.

The flight-level cost shifters X_{fs}^1 include three key components. First, takeoff and landing costs are assumed to be uniform across all carriers, meaning that each carrier incurs the same expenses for these operations. Second, I account for per-mile flight distance costs, which represent the cost of flying a given distance. These costs vary across different carrier types: legacy carriers share the same distance cost, while ultra-low-cost carriers (Spirit and Frontier) are grouped under a different cost structure. Additionally, budget carriers (Southwest) and hybrid carriers (Alaska and JetBlue) each have their own cost structures. Lastly, I introduce carrier-specific deviations from the mean take-off and landing costs, recognizing that each carrier has distinct operational strategies and efficiencies. This allows for variation in operational costs among carriers, even within the same type, reflecting their unique business models.

The identification of costs relies on an explicit linear functional form assumption. To validate the choice of a linear functional form, I perform two tests. First, I plot the left-hand side of Equation 1.8 against both a linear and a quadratic function of travel distance. The plots reveal no significant difference between the two functional forms. Next, I assess whether the relationship between the left-hand side of Equation 1.8 and the right-hand side variables follows a linear or log-linear pattern. Graphically, the recovered marginal costs appear roughly linear in the continuous explanatory variable travel distance interacted with carrier type.

The left-hand side variables, p_m , Ω , and q_m , can either be directly observed from the data or reverse-engineered using the estimated demand parameters. The right-hand side variables needed to estimate γ_1 are all directly sourced from observed data. These include total capacity C_{fs} , total passenger quantity or market share Q_{fs} , the sum of passengers from other markets that share a flight segment with product j , and the cost shifters X_{fs}^1 .⁴¹

41. Ideally, I would specify distinct cost shifters for each aircraft type. However, it is nearly unfeasible to include all interactions between carriers and aircraft types. To ensure traceability, I simplify by assuming

1.7 Empirical Results

This section presents the empirical findings on consumer demand and airline cost structures. Table 1.2 reports the results from estimations of the demand system, with column (4) representing the most comprehensive specification. Estimates from column (4) will be used in subsequent analyses. The key explanatory variables in the model include fare, an indicator for whether the product is nonstop or connecting, daily departure frequency, legroom, and dummy variables representing different carrier types. In columns (3) and (4), fare is instrumented using the instrumental variables described in Section 1.6.1.

The fare coefficient is estimated at -0.017 , indicating that a one dollar increase in price reduces indirect utility by -0.017 . Flying nonstop increases indirect utility by 2.551 , suggesting that the average consumer is willing to pay $2.551/0.017 = \$150.1$ to avoid a connecting flight. Similarly, the point estimates for departures and legroom are 0.109 and 0.065 , respectively, implying that the average consumer is willing to trade $\$6.4$ for one additional daily departure and $\$3.8$ for an extra inch of legroom.

Among carriers, legacy carriers are the most preferred, followed by hybrid carriers, Southwest, and ultra-low-cost carriers. Relative to ultra-low-cost options, consumers are willing to pay a premium of $\$70.2$ for legacy carriers, $\$42.5$ for hybrid carriers, and $\$34.8$ for Southwest. Furthermore, higher-income consumers exhibit lower price sensitivity and a stronger preference for more frequent departures.

The median own-price elasticity is -3.92 , with a mean of -4.01 . Figure 1.1 illustrates the distribution of average demand elasticity at the product level. These values align with estimates in the existing literature.⁴² For instance, Ciliberto and Williams (2014) reports a

that per-passenger costs are homogeneous across all aircraft types for the purposes of estimation. Given that legroom space is inversely related to aircraft capacity, I scale the vector of cost shifters in the estimation to account for the varying legroom spaces offered by different airplane types and carriers.

42. As discussed in Ciliberto and Williams (2014), their elasticity estimates are slightly higher than those reported in Berry and Jia (2010). This discrepancy is likely due to differences in product aggregation methods between the two studies. The definition of a product in this paper follows the approach used by Ciliberto

Table 1.2: Demand Estimation

	(1) OLS	(2) OLS	(3) IV	(4) Full model
Fare	-0.008*** (0.002)	-0.006*** (0.002)	-0.018*** (0.004)	-0.017*** (0.002)
Nonstop dummy	2.565*** (0.230)	2.547*** (0.245)	2.544*** (0.426)	2.551*** (0.399)
Departures	0.182*** (0.006)	0.185*** (0.006)	0.230*** (0.015)	0.109*** (0.012)
Legroom	0.025*** (0.007)	0.038*** (0.014)	0.072*** (0.024)	0.065*** (0.022)
Legacy dummy		-1.264** (0.541)	1.299*** (0.360)	1.194*** (0.182)
Hybrid dummy		-0.511 (0.670)	0.756*** (0.233)	0.722*** (0.137)
Southwest		-0.964** (0.417)	0.556*** (0.176)	0.592*** (0.098)
$\ln(\text{income}) \times \text{fare}$				0.003* (0.002)
$\ln(\text{income}) \times \text{departures}$				0.113*** (0.019)
Undirected market FE	Yes	Yes	Yes	Yes
Observations	83,807	83,807	83,807	83,807

Notes: *** < 0.01, ** < 0.05, * < 0.10. The dependent variable is the difference between a product's market share and the market share of the outside goods. Standard errors are clustered at the undirected market level. Legroom is measured in inches. The base category for the legacy, hybrid, and Southwest dummies is ultra-low-cost carriers. Log(income) is normalized to have a mean of zero.

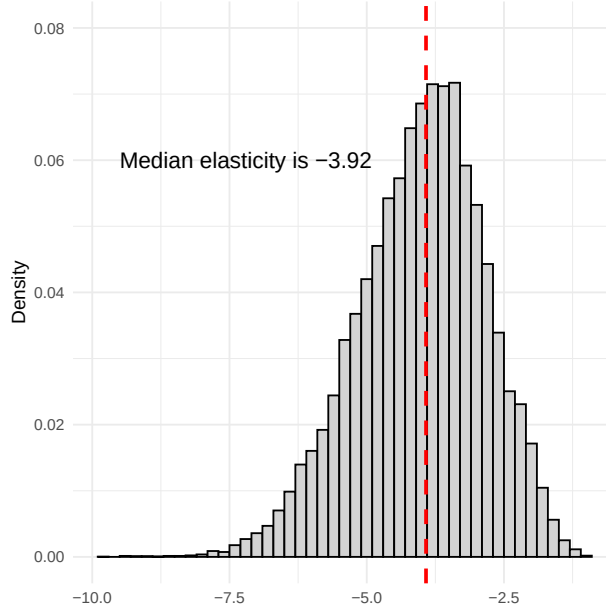


Figure 1.1: Density Distribution of Own-price Elasticity

mean elasticity of -4.32 , while Park (2020) estimates a median elasticity of -4.10 .

Table 1.3 presents the estimated marginal costs for a seat on an aircraft. The "takeoff and landing" cost represents a fixed cost component associated with each departure, irrespective of flight distance. It is estimated at \$58.21. Each carrier type is assigned a unique marginal cost per additional mile traveled. For legacy carriers, this cost is estimated at 5.1 cents per mile, while hybrid carriers and Southwest incur a slightly lower cost of 5.0 cents per mile. Ultra-low-cost carriers have a significantly lower marginal cost of just 0.42 cents per mile. Furthermore, the fixed cost of operating a departure is allowed to vary by carrier. Frontier serves as the baseline carrier, with its fixed costs captured by the "takeoff and landing" variable. Among the other carriers, legacy airlines incur an additional fixed cost of roughly \$36 per seat, while Southwest's fixed costs are approximately \$10 higher than Frontier's. Hybrid carriers and Spirit demonstrate similar fixed cost efficiencies to Frontier.

As a robustness check, I re-estimate the cost structure, assuming each passenger incurs a marginal cost of \$10.00, which includes \$7.70 for fuel and an additional \$2.30 for catering.

and Williams (2014).

Table 1.3: Marginal Cost Estimation per Standardized Seat

Parameters	Estimate	Standard error
Takeoff and landing	58.212	4.769
Distance $\times$ legacy	0.051	0.007
Distance $\times$ hybrid	0.050	0.002
Distance $\times$ Southwest	0.050	0.002
Distance $\times$ ultra-low-cost	0.042	0.004
American	34.091	8.547
United	36.907	9.446
Delta	35.939	8.525
Alaska	-2.146	2.903
JetBlue	0.420	2.726
Southwest	10.532	4.770
Spirit	-3.144	1.176
Observations	83,654	

Notes: This table presents the marginal cost estimates for a "standard seat." To ensure comparability across carriers, I standardized seating capacity by adjusting legroom to a uniform benchmark of 31.83 inches, the average legroom in the sample. To calculate the actual cost of operating a flight, these per-seat estimates should be adjusted by the ratio of the actual legroom to the "standard" 31.83 inches and then multiplied by the total number of seats on the aircraft. Observations with negative predicted marginal costs using demand estimates (153 in total) are excluded from the regression sample.

Table A.1 in Section A presents the results. Overall, the estimates closely align with those in Table 1.3. The primary difference is a decrease in the estimated "takeoff and landing" costs, which drop from 58.212 to 48.944, largely absorbing the assumed \$10.00 marginal cost per passenger.

To illustrate the quality of my demand and cost estimates, I calculate the cost per available seat mile (CASM) using these estimates and compare it to the CASM reported in carriers' 10-K financial statements. CASM is a key efficiency metric for airlines and is cal-

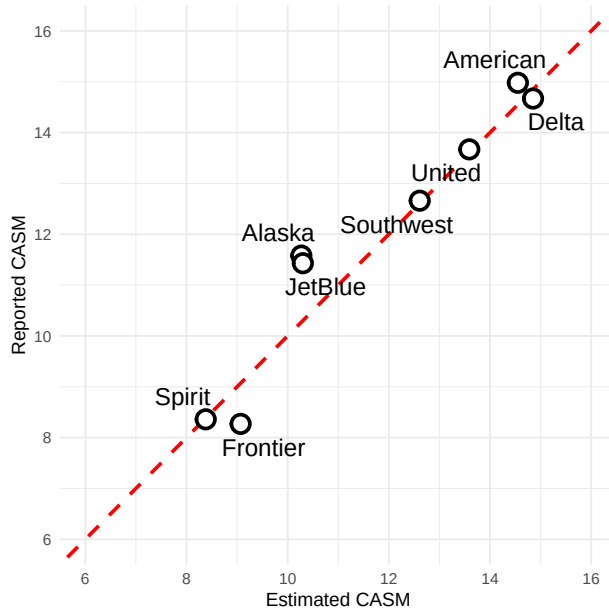


Figure 1.2: Cost Per Available Seat Mile: Estimation vs. Financial Reporting

Notes: This plot compares the estimated Cost per Available Seat Mile (CASM) with the actual values reported by airlines in their 10-K financial reportings for the fiscal year ending December 2019. Values are measured in cents. Note that although Frontier did not go public until March 2021, its 2023 financial statements provide detailed cost data for 2019, which I have used for this comparison.

culated by dividing total operating costs by total available seat miles. Figure 1.2 plots the estimated CASM against the reported CASM for each carrier.⁴³ It demonstrates that the model-based estimates closely match the financial statement data. Table A.3 in Appendix A presents detailed estimates of marginal costs and markups across different distance categories. This table provides a breakdown of average ticket fares, estimated marginal costs, and estimated markups for each carrier and segmented by travel distance groups.

1.8 Counterfactual Simulation

This section simulates the counterfactual post-merger conditions if the JetBlue-Spirit merger had been approved by the court. The simulation results illustrate how the merged entity

43. Data used to generate this figure can be found in Table A.2 in Appendix A.

generates quality-driven synergies through endogenous product repositioning and assess the merger’s distributional welfare impact across various consumer segments and market types. Section 1.8.1 introduces the context for the counterfactual. Section 1.8.2 describes the simulation methodology. Section 1.8.3 discusses the main simulation results. My main simulation is constructed around the assumption of fixed airline inputs and limited contractibility. In the long-run equilibrium, this restriction is lifted, allowing carriers the flexibility to reach the most profitable fleet size and mix. Section 1.8.4 examines the shifts in market equilibrium when carriers can freely adjust their fleet and assess the welfare loss resulting from carriers’ inability to make fleet adjustments in the short and medium term.

1.8.1 Status Quo and Market Segmentation

This section examines key dynamics of the airline industry that form the foundation for the counterfactual analysis of the JetBlue-Spirit merger. First, I discuss how the merger influences vertical product quality, specifying which features are endogenized and which remain fixed in the counterfactual simulation. Second, I discuss the operational constraints airlines face due to fixed inputs and how these restrictions shape the counterfactual framework. Finally, I categorize markets into three types: leisure, large-city, and other markets. I use this classification to distinguish between different markets and illustrate how the merger’s impacts vary across these segments.

Following the merger, JetBlue plans to phase out the Spirit brand, consolidate Spirit’s fleet, and upgrade the Spirit fleet to match JetBlue’s quality standards. I lay out the quality characteristics treated as exogenous and endogenous in the counterfactual simulation based on these dynamics. Exogenous quality characteristics include brand qualities, airplane configurations, and legroom. I assume that all carriers, except Spirit, maintain their existing quality provisions for these characteristics after the merger. For Spirit, I assume its airplanes adopt JetBlue’s brand quality and configuration standards post-merger. In contrast, quality

characteristics such as nonstop service (routes) and departure frequency are treated as endogenous variables. Carriers are assumed to have the flexibility to adjust their provision of nonstop service and departure frequency in the counterfactual analysis. The way the merged entity repositions its products reveals how quality-driven synergies are realized.

Another notable industry characteristic that feeds into the counterfactual setup is the fixed input restriction. As outlined in Section 1.4.2, this resource constraint limits the airline’s ability to adjust capacity flexibly, significantly influencing the firm’s stage-one decision in the supply-side model. Consequently, when evaluating whether to add a departure to a specific route, the decision is not solely based on whether the additional departure generates a net positive profit. Instead, the decision also considers whether allocating this departure to the given route is more profitable than assigning it to any alternative route. This approach contrasts with the standard practice in the entry literature, where firms decide to enter based on positive net profit alone. In Section 1.8.2, I detail how my simulation algorithm is adapted to account for this distinction.

To evaluate the effects of the merger on different market types, I classify markets into three categories to account for the inherent differences in consumer composition across markets. The literature has extensively documented that travelers on business-heavy routes differ significantly from those on leisure routes (Borenstein, 1989; Berry and Jia, 2010). For example, flights between New York City and Chicago typically attract a high density of price-insensitive business travelers. In contrast, such travelers are far less common on flights to Orlando.

In this section, I define leisure markets as those involving routes to Orlando, Las Vegas, Denver, Atlanta, Miami, or Tampa — cities commonly associated with leisure travel. Figure A.1 in Appendix A presents proxies for leisure travel at the city level and details the selection of these six cities. Figure A.2 and A.3 in Appendix A further validate my choice of these six leisure destinations. On the other hand, markets connecting any two of the twelve most

populous U.S. metropolitan areas are classified as large city markets, which are generally characterized by higher business traffic.⁴⁴ Notably, routes that fall under both the large city and leisure market categories are still classified as leisure markets. The remaining markets are classified as "other markets".

This classification is further supported by how different airlines establish their presence across the country. Legacy carriers typically set up hubs in major U.S. cities, positioning themselves in key business and travel centers. Southwest, while also basing its operations in major cities, often focuses on secondary airports to reduce costs and congestion. The two major ultra-low-cost carriers, Spirit, based in Fort Lauderdale, and Frontier, based in Denver, are both headquartered in popular leisure cities. They also focus their operations on other key leisure destinations like Las Vegas and Orlando, catering primarily to price-sensitive travelers.

1.8.2 Counterfactual Description

My counterfactual simulations use data from the third quarter of 2019 and rely on demand and marginal cost estimates from Section 1.7.

To evaluate how quality-driven synergies following the merger are realized, I compare predictions from three models: one that allows only ownership changes, one that includes both ownership and product quality changes, and a third model that allows for changes in ownership, product quality, route choices, and departure frequency.

The first model represents a simple change in Spirit’s ownership, where JetBlue acquires Spirit but operates it as a separate brand. In this scenario, both JetBlue and Spirit remain

44. The top 12 Metropolitan Statistical Areas (MSAs) in the U.S., ranked by population, are New York, Los Angeles, Chicago, Dallas, Houston, Atlanta, Washington D.C., San Francisco, Philadelphia, Miami-Fort Lauderdale, Boston, and Phoenix. Although the Riverside–San Bernardino–Ontario MSA is also considered a major metropolitan area, in the DB1B and T100 datasets, its airports share the same market ID (32575) as the Los Angeles MSA. Therefore, I combine these areas into a single “city.” Similarly, I group San Jose, CA with San Francisco (32457) and Baltimore with Washington, D.C. (30852). Note that Miami and Atlanta are classified as leisure destinations. Routes flying to these two cities are excluded from large city markets.

as separate brands while coordinating pricing strategies.

The second model incorporates the post-merger changes in product quality for Spirit’s fleet and JetBlue’s consolidation of these assets. Building on the first model, I adjust Spirit’s observed product quality—such as average legroom and brand equity—to align with JetBlue’s standards, replace Spirit’s brand and cost structure with JetBlue’s, and consolidate their departure frequencies on overlapping routes.

The third model builds on the second by allowing carriers the flexibility to adjust their routes and departure frequencies. This allows for an analysis of how quality-driven synergies materialize through post-merger product repositioning and examines the merger’s distributional impact on consumer surplus across different income groups. Implementing such flexibility, however, introduces significant complexity in modeling the strategic choices of carriers.

In positioning games such as this, with thousands of possible routes and numerous potential departure configurations for each, multiple equilibria are likely to occur. Additionally, the large number of potential strategies makes an exhaustive search computationally prohibitive. For tractability, I draw on the methods of Lee and Pakes (2009) and Wollmann (2018), adapting a sequential iterative best response algorithm for the domestic airline industry. This approach facilitates convergence to a unique equilibrium by establishing a predetermined order of moves among carriers, ultimately resulting in a simultaneous-move Nash equilibrium. The algorithm is implemented as follows:

1. The algorithm begins with an initial set of routes and departure frequencies based on a pre-merger market condition and establishes a predetermined sequence in which airlines will make their moves.
2. The first carrier in the sequence evaluates its affected markets, which includes both existing routes and potential routes for new nonstop services. It calculates the marginal profit of adding one departure to each feasible route and the marginal cost savings of

reducing a departure from each existing route.⁴⁵

3. The carrier then removes one departure from the least profitable route and reallocates this spare flight resource to the most profitable route. After each reallocation, it updates the marginal profit and marginal cost metrics for the two affected routes.
4. The next carrier in the sequence proceeds similarly, optimizing the positioning of its flight resources based on the current market condition and the updates from the first carrier's best response.
5. This process continues for each subsequent carrier, with each carrier adjusting its route and departure frequency choices based on the updated best responses made by all preceding airlines in the sequence.
6. After the last carrier in the sequence has made its best responses, the algorithm returns to the first carrier. The sequence repeats until all airlines have cycled through without finding any further profitable deviations from their current choice of routes and departure frequencies.

A natural consideration in this algorithm is the order in which airlines make their moves. For markets where JetBlue and Spirit operate as separate entities, I simulate using the sequence: American, Delta, United, Southwest, Alaska, JetBlue, Spirit, and Frontier. This order reflects both the business model of each airline—ranging from full-service carriers to Southwest's unique model, followed by hybrid carriers and ultra-low-cost carriers—and generally follows the decreasing size of the airlines, with the exception that Southwest, the largest in domestic operation, is placed after the full-service carriers. In the post-merger

45. I calculate the marginal profit of adding a departure by using the most frequently operated aircraft type for that carrier. To determine the marginal cost of reducing a departure, I consider reducing operations by the most frequently used aircraft type on the route. If the departure frequency of a route falls below 1.5, I then compute the marginal cost of fully withdrawing that route from the market.

case, JetBlue leads the sequence, followed by American, Delta, United, Southwest, Alaska, and Frontier.

Several simplifying assumptions are incorporated into the simulation to enhance computational feasibility. First, when adding or reducing departures, I focus solely on direct flight pricing and abstract away from connecting flights that involve this segment for better traceability.⁴⁶ Second, for the same reason, newly initiated nonstop flights are assumed not to attract connecting passengers, thereby limiting the simulation to a single market. Non-legacy carriers like JetBlue and Southwest operate using a point-to-point business model, with connecting passengers not being their business focus. On the other hand, legacy carriers have increasingly focused on expanding their nonstop service offerings.⁴⁷ Third, only round-trip services are considered for new route additions, and any new routes must originate from the carrier’s hub or focus airport. Finally, the simulation adheres to existing policy constraints and industry norms. These include perimeter rules at LaGuardia (LGA) and Washington National (DCA) airports. Additionally, the simulation reflects industry norms: for example, American and United Airlines avoid operations at Chicago Midway Airport (MDW), while United and Southwest Airlines do not operate at JFK Airport.⁴⁸

To analyze market outcomes, I compare the counterfactual baseline with simulated post-merger market data. The counterfactual baseline is constructed by inputting observed market data into the model that implements the iterative best response algorithm. Since the current market is assumed to be in equilibrium, the counterfactual baseline is expected to closely align with the observed data. A detailed comparison between the counterfactual baseline and the observed market data can be found in Appendix C.

46. When removing an existing nonstop flight segment, I focus exclusively on the market for the direct flight itself. Once all possible reallocations for this carrier are completed, I eliminate connecting products that involve any removed direct flights and then re-optimize market conditions and consumer choices in the affected markets.

47. See footnote 5.

48. Most of these exclusions pertain to airports in Southwest’s focus cities, such as Houston, Dallas, Oakland (San Francisco metropolitan area), and Baltimore (DC metropolitan area).

1.8.3 *Welfare Analysis of the JetBlue Spirit Merger*

This section analyzes the overall impact of the JetBlue-Spirit merger on market outcomes, focusing on two key aspects. First, it explores the mechanisms through which quality-driven synergies materialize post-merger. Second, it examines how the merger affects consumer surplus across different market types and income levels. I begin by analyzing the merger's effects using the three simulation models discussed in section 1.8.2.

The results indicate that endogenous product repositioning following the merger is essential for the merged entity to achieve the desired quality-driven synergies. The full model reveals that airlines are reallocating aircraft to large-city markets, where a higher concentration of travelers values nonstop service and frequent departures. This shift results in quality improvement and substantial surplus gains in these markets. A closer examination of the merger's welfare implications across the income distribution indicates that the overall surplus increase is primarily driven by high-income consumers. In contrast, consumers in leisure markets and other markets suffer from surplus loss.

I measure changes in consumer surplus following the approach of Small and Rosen (1981). From an econometric perspective, the expected utility of the consumer is represented as the log-sum-exponential of the consumer's expected indirect utility over all available alternatives, plus an unknown constant term. The expected consumer surplus can then be calculated by dividing this expected utility by the consumer's price sensitivity α . Although the exact level of consumer surplus is indeterminate due to the normalization of the outside option in the expected utility function, changes in consumer surplus from shifts in market conditions can still be measured, as the unknown constant term cancels out.

Table 1.4 summarizes the impact of the merger on equilibrium market outcomes at the quarterly level using three simulation models. Incorporating endogenous adjustments in routes and departures reshapes product quality dynamics and consumer welfare.

Regarding average prices, both the ownership change and brand change models show only

Table 1.4: Market Outcomes of the JetBlue-Spirit Merger

	Group	Level	Changes		
		Baseline	Ownership change	Brand change	Full algorithm
<i>Average price</i>	All markets	212.68	0.63	2.95	14.54
	Large city markets	253.74	0.36	1.35	10.50
	Leisure markets	187.43	1.35	4.12	15.50
<i>Merging parties' departures</i>	All markets	1043	—	—	-1
	Large city markets	214	—	—	35
	Leisure markets	420	—	—	-56
<i>Total departures</i>	All markets	7971	—	—	-67
	Large city markets	1859	—	—	180
	Leisure markets	3264	—	—	-358
<i>Consumer surplus</i> <i>(\$ Million per quarter)</i>	All markets	—	-10.17	-50.04	-74.12
	Large city markets	—	-2.85	-15.47	418.80
	Leisure markets	—	-4.32	-18.04	-440.02

Notes: The results in this table pertain to markets where JetBlue and Spirit operated prior to the merger. In the simulation, carriers are free to allocate assets across both these and other markets. The Baseline column presents data for the market without any merger. The Ownership change column shows changes when JetBlue becomes Spirit's parent company. JetBlue and Spirit continue to operate independently while coordinating on pricing. The Brand change column reflects changes in equilibrium prices when JetBlue consolidates Spirit's fleet and eliminates the Spirit brand, but total departure frequencies and routes remain unchanged. The Full algorithm column presents changes in post-merger market outcomes, allowing for adjustments to routes and departure frequencies.

modest price increases, with the brand change model exhibiting a slightly larger increase. However, under the full algorithm model, the average price surges by over \$14, with a \$15 hike in leisure markets.

Regarding carriers' endogenous adjustments in product positioning and quality, in the full model, airlines actively shift flights from leisure markets to large-city markets. Notably, the merged entity increases its departures in large-city markets by over 15%. This resource reallocation has significant implications for quality provision. The rise in total departures in large-city markets enhances nonstop service availability and increases flight frequency, leading to an overall improvement in product quality. In contrast, leisure markets experience a decline in overall product quality due to reduced service levels.

The endogenous reallocation of product positioning and quality following the merger illustrates how quality-driven synergies materialize in the airline market. Under the brand change model, JetBlue integrates Spirit's fleet into its own quality standard and consolidates operations across the two airlines. This consolidation involves combining departures from both JetBlue and Spirit on overlapping routes, leading to increased departure frequencies and, consequently, higher product quality in these markets. However, this reallocation alone does not generate the efficiency gains JetBlue seeks. Since Spirit primarily serves leisure markets, where travelers place less value on high product quality compared to those in business-heavy markets, maintaining increased quality in these areas is less effective. To maximize the value of quality improvements driven by the merger, post-merger JetBlue would need to enhance quality provision in business-heavy markets rather than leisure markets. This prompts JetBlue to shift flight departures from leisure markets to large-city markets, where higher-quality service is more valued.

As a result, the merger's welfare implications vary across market types. In large-city markets, despite an average ticket price increase of \$10, total consumer surplus rises by \$418 million due to improved product quality. In contrast, consumers in leisure markets

experience significant losses of \$440 million dollars, facing both higher prices and a decline in service quality.

Since the merger changes both product quality and prices, and consumers vary in their price sensitivity and quality preferences, the merger's welfare implication differs even among consumers within the same market. An illustration is presented in Figure 1.3, where changes in consumer surplus for consumers with varying income levels is plotted. When estimating demand and simulating counterfactual outcomes, I simulate 50 representative passengers per market, each with a different income level. These passengers are ranked from lowest to highest income, indexed from 1 to 50, where the lowest index represents the lowest income, and the highest index represents the highest income. In these figures, I aggregate consumers by their index across all markets.

Figure 1.3 highlights the significance of accounting for endogenous changes in product quality and positioning. In this figure, the bar height represents the total change in consumer surplus across all relevant markets, measured in millions of dollars. Panels (a) and (b) show results from models without endogenous product repositioning, while Panel (c) uses the full model that allows endogenous product repositioning. In Panels (a) and (b), high-income consumers bear the largest surplus losses, whereas low-income consumers see relatively minor losses.

After allowing carriers to endogenously adjust their routes and departure frequencies, the distribution of consumer surplus change shows a U-shape in Panel (c). Consumer surplus shifts from low- and medium-income consumers to high-income consumers. This shift highlights the mechanism through which post-merger quality-driven synergies materialize. Airlines reallocate aircraft resources to markets where consumers place a higher value on product quality and exhibit lower price sensitivity. According to my demand estimates, these consumers tend to have relatively high incomes. As a result, they benefit significantly from the merger, while lower-income consumers bear the cost.

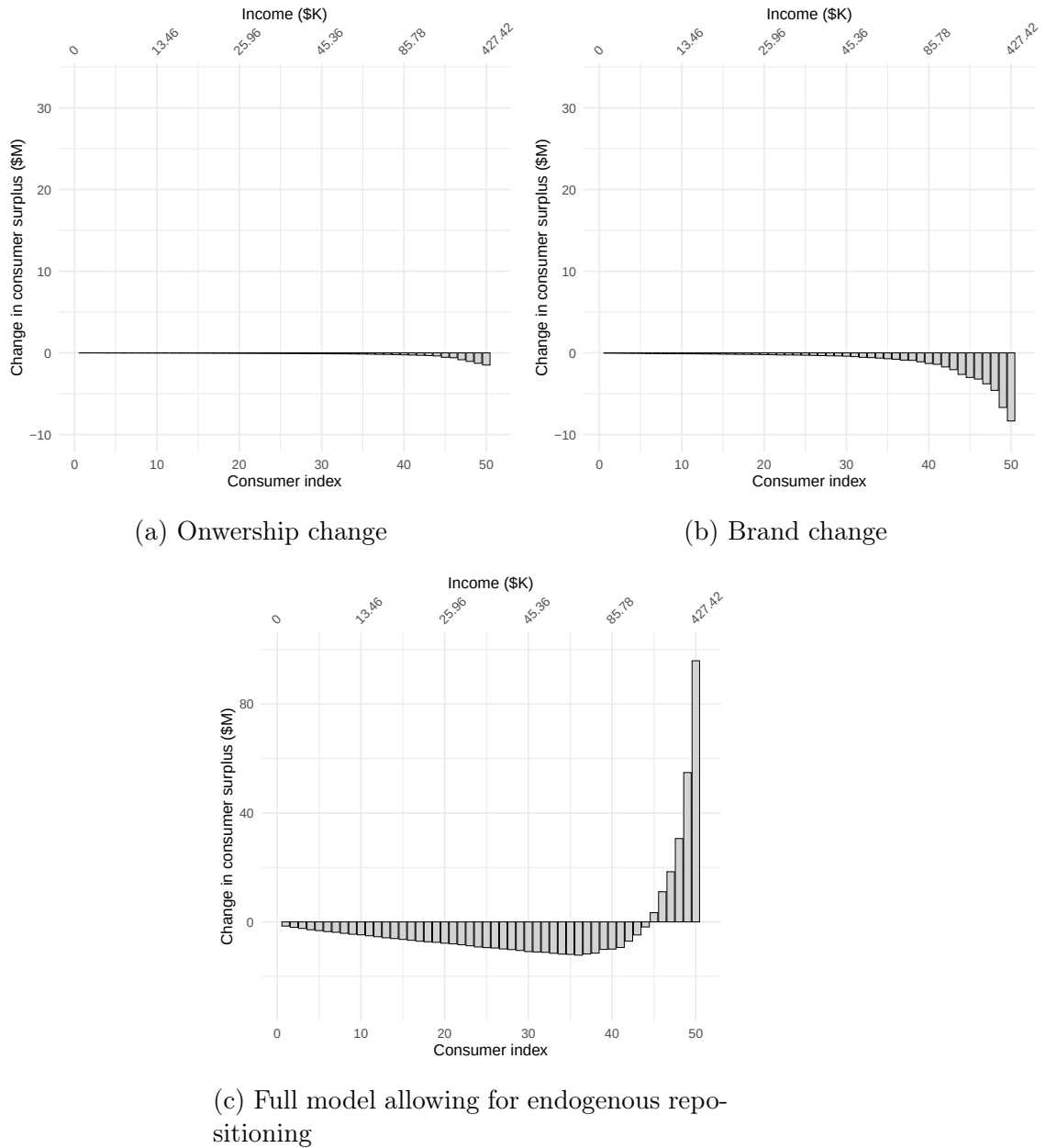


Figure 1.3: Distributional impact of the merger on consumer surplus

Notes: This figure presents the aggregate quarterly change in consumer surplus across all markets, with its y-axis measured in millions of dollars. Panels (a) and (b) share the same y-axis scale, whereas Panel (c) uses a larger y-axis range. Panel (a) presents the simulation results when only Spirit's parent company changes to JetBlue. Panel (b) shows the results when JetBlue consolidates Spirit's fleet and removes the Spirit brand from the market. Panel (c) presents changes under the full algorithm that allows endogenous product repositioning.

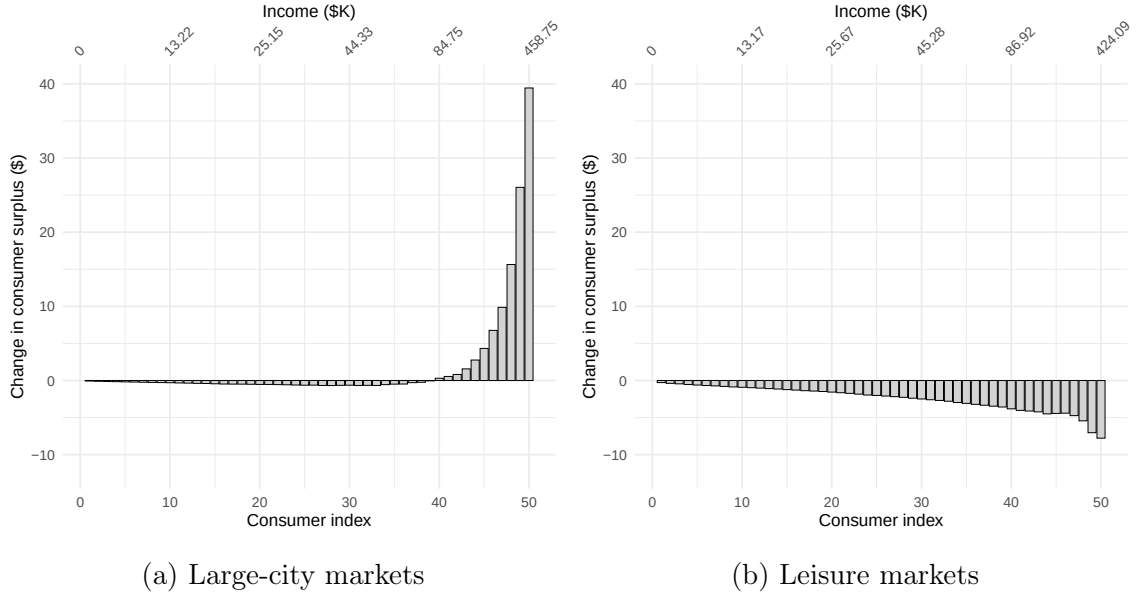


Figure 1.4: Distributional impact of the merger across market types

Notes: Panel (a) and Panel (b) show the average quarterly changes in consumer surplus by income rank for large-city and leisure markets, respectively. Both panels share an identical y-axis, measured in dollars. It is important to note that income distributions differ across markets, meaning that consumers with the same income rank may have varying actual income levels depending on the market. Additionally, the income gap between adjacent income ranks can vary across both consumer pairs and markets.

Next, I examine the merger's distributional impact on consumer welfare across different market types, focusing on results from the full algorithm simulation model. Figure 1.4 presents the results. Panel (a) and Panel (b) of Figure 1.4 display the surplus changes for simulated consumers in large-city markets and leisure markets. In these two panels, the height of each bar represents the average change in surplus per individual consumer, measured in dollars and weighted by market size. Since the total size of the two market groups is not comparable, my analysis centers on individual consumer outcomes rather than aggregate surplus changes.

In Panel (a), the combined effects of higher prices, increased total departures, and products with more frequent departures result in a negative but slight surplus change for low- and medium-income consumers. Although these consumers experience surplus losses, substantial

gains among high-income consumers push the overall surplus change into positive territory. Their impact on the overall surplus change becomes more pronounced due to their low price sensitivity⁴⁹ in the surplus calculation and the fact that very few of them choose the outside option. In contrast, as presented in Panel (b), consumers in leisure markets experience a unanimous decline in consumer surplus. Higher-income consumers are harmed more than lower-income consumers.

1.8.4 *Relaxing the Fixed Input Restriction*

The classic economic question of entry and production often centers on the sunk cost of entry, the variable cost of production, and the variable revenue from sales. Typically, a firm would decide to enter the market if the total expected variable profit, net of sunk costs, is positive. However, in the airline industry, a firm's decision-making process differs, as the entry decision is constrained by fixed inputs. Therefore, I model the firm as optimizing its route selection and departure frequencies conditional on its existing pool of available operational hours.

In an ideal world, airline companies would have the flexibility to optimize both the size and composition of their fleet to maximize profits. This can also be viewed as the long-run equilibrium of the market. Comparing market outcomes between the ideal scenario, where airline companies have full flexibility to optimize their fleet, and the reality, where they face constraints in aircraft and pilot availability, reveals two important insights.

First, it highlights the extent of consumer surplus loss due to these short- and medium-term constraints on airplane and pilot resources. Although rapidly increasing production rates for Boeing and Airbus is unrealistic, this issue could be mitigated through more strategic long-term planning by airlines, along with policy considerations for pilot unions and airplane wet leases.

Second, while existing economic models can readily simulate an ideal world scenario,

49. Consumer surplus is calculated by dividing the indirect utility by the price sensitivity parameter α .

they may not be well-suited for cases with fixed inputs, such as the airline industry. The discrepancy between these simulation results highlights the importance of my method for capturing the impacts of such production constraints.

I use a similar iterative best-response algorithm to derive a simultaneous-move Nash equilibrium for the ideal world scenario. Compared to the algorithm in Section 1.8.2, steps 1 and 4-6 remain unchanged. However, I modify steps 2 and 3 as follows to reflect the airline company's entry and exit decisions based on variable profits net of sunk entry costs:

2. For each existing route and potential route for new nonstop services, the first carrier in the sequence assesses the marginal profit of adding an additional departure. If the marginal profit is sufficient to cover the sunk cost associated with leasing an additional aircraft ⁵⁰, the carrier incurs the sunk cost and adds a departure to that route.
3. Similarly, the carrier evaluates the marginal cost of reducing one departure on each existing route. If this marginal cost is lower than the sunk leasing cost of the aircraft, the carrier decreases the departure frequency and sells the aircraft to avoid the sunk cost.

The sunk cost of operating an aircraft can be estimated either through annual depreciation or leasing costs. Note that the exact figures for both are not publicly available. While Boeing and Airbus provide estimated listing prices for their aircraft, the final price depends on several factors, including cabin configuration and engine selection.⁵¹ Additionally, airlines don't pay the full listing price; they typically receive substantial discounts. The actual amount paid by an airline varies depending on factors like order size, delivery timeline, and payment terms, and these contract details are generally not disclosed.⁵² As for leasing costs,

50. I assume that the carrier uses the most heavily utilized aircraft type on the route for this new departure.

51. See an article on Simply Flying: <https://simpleflying.com/how-much-do-airbus-aircraft-cost/>.

52. According to a Simple Flying article, Airlines negotiate significant discounts from the list price, "with

airlines only report total leasing expenses for their entire fleet in annual financial reports, which means individual aircraft leasing costs can only be estimated approximately based on these aggregate figures.

JetBlue's fleet primarily consists of A320 and A321 aircraft, while Spirit operates an all-A320 family fleet. To start, I focus on uncovering the annual leasing cost for an A320 aircraft as a basis for analysis. Based on the financial statements of both companies for the 2019 fiscal year, the annual leasing cost for an A320 is estimated to be between \$3.5 million and \$4 million.⁵³ In the analysis, I simulate annual leasing costs of \$6 million, \$5 million, \$4 million, and \$3 million to examine how different sunk costs affect market outcomes.

Other airlines operate a more complex mix of fleets, which makes estimating the annual leasing cost for each of the 23 aircraft types in the dataset a challenging task. To address this, I assume that leasing costs are proportional to seating capacity. I calculate the average seating capacity for each aircraft type across all carriers and estimate their annual leasing costs based on their capacity relative to that of the A320. For instance, with the A320's average seating capacity at 150 and an annual leasing cost of \$6 million in this simulation model, the annual leasing cost for a 180-seat A321 would be estimated at \$7.2 million.

Table 1.5 compares the pre-merger market conditions with simulation results that incorporate flexible fleet adjustments. The remaining columns show how these market conditions change when carriers have the flexibility to lease or phase out part of their fleet, with adjustments based on varying annual sunk costs per A320.

As annual sunk costs for leasing an aircraft decrease, the weighted average price steadily declines, with a reduction of \$10.93 at the \$3 million cost level. This price decrease is

most airlines receiving up to a 50% discount on orders." In fact, Airbus has even chosen to stop publishing list prices, as they do not accurately reflect actual sale prices. See <https://simpleflying.com/how-much-do-boeing-aircraft-cost/>.

53. In 2019, JetBlue leased a total of 149 A320 and the larger A321 aircraft, and incurred a total depreciated leasing cost of \$566 million, averaging approximately \$3.8 million per aircraft. Spirit operated a mixed fleet of A319, A320, and A321 aircraft, with a combined depreciation and leasing expense of \$632 million. This is equivalent to around \$4 million per aircraft.

Table 1.5: Quarterly Changes in Market Outcomes by Annual Sunk Cost per A320

	Pre-merger level	Quarterly changes by annual sunk cost per A320			
		\$6 Million	\$5 Million	\$4 Million	\$3 Million
Weighted average price	212.58	-1.91	-2.95	-6.70	-10.93
Total passengers (K)	978.25	43.96	100.75	195.84	395.70
Total departures	7987	593	1136	1932	3630
Total JetBlue departures	629	29	124	291	388
Total airplanes	2890	280	586	1063	1308
Total JetBlue airplanes	240	11	43	116	150
Consumer surplus (\$M)	—	214.73	411.19	1033.42	2123.83

Notes: The values in this table are measured on a quarterly basis. Annual leasing costs of \$6 million, \$5 million, \$4 million, and \$3 million are adjusted to daily and hourly levels for the simulation. Both total JetBlue departures and total JetBlue airplanes represent figures for JetBlue prior to the merger.

accompanied by a significant rise in passenger numbers, which surge by approximately 40% at the \$3 million cost level.

Total departures also expand dramatically as fixed costs decline, increasing by 593 at \$6 million and soaring to 3,630 additional departures at \$3 million. This growth highlights the severe capacity constraints airline companies face in the real world. As for JetBlue, it adds 291 and 388 departures at the \$4 million and \$3 million cost level, respectively. In terms of fleet expansion, the entire industry would need to grow its fleet size by over 30% at both the \$4 million and \$3 million cost levels to reach long-run equilibrium. JetBlue's fleet expansion slightly exceeds that of the overall industry.

Airlines would be worse off if the fixed cost of leasing an aircraft remains relatively high, likely due to the substantial costs associated with adding new planes while also coping with increased market competition from flexible capacity adjustments. However, as the

sunk leasing costs decrease, airlines benefit from alleviating capacity constraints, leading to improved profitability.

Consumers experience a substantial gain in consumer surplus at the \$4 million and \$3 million cost levels. This is driven by lower ticket prices and improved product quality. The increase in flight departures reflects the expanded availability of nonstop service and increased departure frequency.

1.9 Conclusion

The synergies and efficiency gains resulting from a horizontal merger serve as a crucial counterbalance to the merger’s potential anti-competitive effects. Such efficiency gains can stem from either cost reductions or quality improvements. However, the mechanisms through which these efficiency gains are realized remain largely underexplored.

This paper examines how horizontal mergers generate quality-driven synergies through endogenous product adjustments. I focus on the recent JetBlue–Spirit airline merger, should it be approved by the court. First, I estimate consumer preferences for product quality and firms’ cost structures. Then, I simulate a model that allows firms to optimize their post-merger quality provision subject to short-run constraints on airplane resources. I find that simply merging the two firms does not automatically generate efficiency gains. Instead, these synergies materialize through the strategic reallocation of high-quality service to markets where consumers derive the greatest surplus from improved quality.

Since quality-driven synergies shape both pricing and product quality, the impact of such mergers on consumer welfare varies across consumer segments depending on their sensitivity to price and quality. Overall, large-city markets experience significant welfare gains driven by substantial quality improvements, while leisure markets suffer welfare losses due to both higher prices and reduced service quality. Within large-city markets, price-insensitive consumers benefit from enhanced product quality, while price-sensitive consumers find that the

gains from improved quality are outweighed by the burden of higher prices.

Furthermore, I simulate counterfactual long-run equilibrium in which airlines do not face short-run input constraints. These scenarios align with existing economic models of firm entry, where a firm enters the market if variable profits net of sunk costs are positive. Assuming an annual leasing cost of \$4 million for an Airbus A320, with corresponding pricing adjustments for other aircraft types, total departures increase by 24%, and quarterly consumer surplus rises by \$1.03 billion. These findings underscore the importance of accounting for short-run input constraints when evaluating industries characterized by fixed assets and limited capacity flexibility.

CHAPTER 2

FIRM BOUNDARIES AND RISK MITIGATION

2.1 Introduction

The boundaries of firms are a key topic in Industrial Organization. Economists have identified several explanations for vertical integration, such as the transaction costs (Coase, 1937), contractual failure and incompleteness (Grossman and Hart, 1986), foreclosure incentives (Bolton and Whinston, 1993), and the elimination of double marginalization (Spengler, 1950). However, as Holmström and Roberts (1998) argue, these theories do not fully capture the range of firms' integration incentives. While integration patterns in some industries may align with these theories, others may diverge significantly.¹

This paper proposes and examines an alternative incentive for firm integration: mitigating return volatility caused by unexpected industry-specific shocks. When industry-specific supply shocks impact the upstream segment and drive up prices, downstream firms experience reduced output and lower profits. Conversely, when upstream prices fall, downstream firms benefit from increased production and higher profitability. Integration internalizes pricing and profitability fluctuations across different segments of the supply chain, as opposing movements in upstream and downstream markets offset each other. Effectively, integration serves as a hedge against pricing volatility. Although hedging instruments like futures and options are available in some industries, many industries lack such tools, making integration an effective risk management strategy.

Additionally, integration alters the firm's assessment of its sunk investments in production capacity. Ex-ante, the firm incurs a sunk cost to establish plant capacity, which cannot be adjusted once in place. In a frictionless world without shocks that affect market prices, the firm's ex-post production quantity always aligns with its ex-ante capacity decision. How-

1. For instance, Holmström and Roberts (1998) highlights airline alliances as substitutes for integration.

ever, industry-specific shocks can drive price fluctuations, causing the firm’s optimal ex-post production quantity to deviate from its capacity. As a result, the firm may leave capacity idle half of the time and face unmet demand due to capacity constraints in the other half. The value of risk mitigation incentivizes the firm to incur additional sunk costs and expand capacity in segments that hedge against profit uncertainties. When adverse shocks affect the firm’s profits, increased capacity in alternative segments enables the firm to scale up production in those areas, effectively offsetting the decline in returns. However, this also causes the firm to choose a capacity larger than what its productivity level would otherwise imply, increasing the likelihood of idle capacity.

Firms may value risk mitigation in their profits for various reasons. One key reason is risk aversion — given the same expected returns, a risk-averse firm prefers the option with lower return variance. Even if the firm is risk-neutral, several financial market advantages are isomorphic to risk aversion in shaping the firm’s decisions. The corporate finance literature shows that income stability enhances debt capacity (Lewellen, 1971), lowers tax burdens through increased interest tax shields (Berger and Ofek, 1995), and leverages the asymmetric tax codes (Majd and Myers, 1987).² In accounting, reducing net income fluctuations across reporting periods is linked to agency issues (Lambert, 1984; Dye, 1988), which drive risk-averse managers to stabilize income, and investor preferences (Ronen, 1981; Wang and Williams, 1994).

An industry example of integration’s role in reducing return volatility can be found in the photovoltaic (PV) industry, commonly known as the solar panel industry. In recent years, vertical integration across the four major segments of the PV supply chain has become a notable trend. With each segment containing between 40 and 400 producers, market competition remains strong. The homogeneity of outputs within each segment reduces the relevance of hold-up issues, and industry managers report that free-riding and intangible asset

2. Firms pay taxes on profits but cannot fully deduct losses.

transfers between upstream and downstream segments are minimal concerns. Instead, they highlight that significant volatility in upstream production and pricing introduces uncertainty in downstream outputs and profitability. Vertical integration, they argue, helps stabilize expected profits and boost share prices, making it an effective risk management strategy.

In this paper, I develop a theoretical model that examines the risk-reducing effects of integration and how these effects influence the firm's ex-ante decision to integrate or remain specialized. The model considers a supply chain with two vertical segments and a specialized downstream firm characterized by given productivity parameters. The firm faces two types of industry-specific shocks: demand shocks and supply shocks. An industry-specific demand shock shifts the demand curve in this industry and affects final goods prices and profits. An industry-specific supply shock stems from exogenous changes in market structure that affect prices. In this context, the aggregate quantity is modeled as the sum of the firm's own output and the output supplied by other producers, with the latter treated as a random variable. These supply shocks are defined to impact the output levels of other producers while leaving the firm's own output unchanged.

Ex-ante, the specialized downstream firm decides whether to expand and determines its capacity levels across selected segments. It can choose to remain specialized, expand through vertical integration, which refers to entering an adjacent stage of the supply chain such as upstream production, or pursue conglomeration, which involves operating a subsidiary in a separate industry. Capacity remains fixed once established. Ex-post, industry-specific supply and demand shocks drive market prices away from expectations, and the profit-maximizing firm subsequently selects the optimal production quantity. Firms in the market face potentially asymmetric costs and compete à la Cournot.

The model identifies the conditions under which the specialized downstream firm chooses to remain specialized, backward integrate into the upstream segment, or become a conglomerate. Results show that integration reduces the impact of industry-specific shocks: vertical

integration reduces supply chain uncertainty, while conglomeration mitigates profit volatility from industry-specific demand shocks when the output of the related subsidiary serves as a substitute. These findings demonstrate how risk mitigation drives the firm’s boundary decisions and underscores the value of integration in addressing uncertainties.

This paper contributes to the literature on firms’ choices regarding organizational structure and boundaries. The classic discussion of vertical integration began with concerns over transaction costs: when the cost of using the market exceeds the cost of internal coordination, firms internalize production to minimize inefficiencies (Coase, 1937; Williamson, 1971). Another early strand of the literature highlights the elimination of double marginalization as a motivation for vertical integration. By integrating upstream and downstream operations, the firm no longer needs to negotiate transfer prices between upstream and downstream. Instead, it can maximize total profit across the supply chain and eliminate the inefficiencies caused by double markups (Spengler, 1950).

Subsequent research has proposed various theories to explain firms’ incentives for vertical integration. A significant body of work focuses on contractual failure and incompleteness. The hold-up problem highlights how relationship-specific investments and incomplete contracts can lead to inefficiencies (Klein et al., 1978; Grout, 1984). Ownership and profit sharing are proposed as a solution, offering stronger protection for investments and more efficient responses to unforeseen changes. Grossman and Hart (1986) provide a classic theoretical framework for the hold-up problem.³ Baker and Hubbard (2004) empirically studies the trucking industry and find that contractual improvements reduce bargaining costs, leading to greater integration in asset ownership.

Another notable stream of literature examines the anti-competitive effects of vertical integration, focusing on the firm’s incentives to foreclose rivals and raise their costs. Studies

3. Other theoretical contributions to this strand of literature include Williamson (1975, 1981), Holmström and Roberts (1998), Grossman and Hart (1986), Hart and Moore (1990), Hart (1995), De Meza and Lockwood (1998), and Rajan and Zingales (1998).

such as Bolton and Whinston (1993) and Hart et al. (1990) develop game-theoretic models that show how vertical mergers can distort competition by restricting supplies to rivals or monopolizing markets under specific scenarios.⁴ Empirical evidence on foreclosure effects is mixed and often industry-specific. For example,⁵ Hastings and Gilbert (2005) show that vertical integration between gasoline refineries and gas stations raises costs for competing gas stations, while Hortaçsu and Syverson (2007) report no anti-competitive effects in the integration between cement and ready-mixed concrete producers.

As Holmström and Roberts (1998) argue, classic explanations for integration, such as foreclosure and hold-up issues, fail to fully account for many observed ownership patterns. The literature offers alternative explanations, including transferring intangible assets and creating internal capital markets. The transfer of intangible assets is an alternative motivation for vertical integration. Studies like Hortaçsu and Syverson (2007) and Atalay et al. (2014) provide suggestive evidence of improved management practices following vertical mergers. Internal capital markets offer another rationale for integration by enabling more efficient internal resource allocation, thereby enhancing productivity and resilience. For example, Matvos and Seru (2014) shows that a well-functioning internal market helps mitigate the adverse effects of financial market dislocations.⁶

This paper contributes to the literature by proposing an alternative motivation for firms' boundary decisions: concerns over return uncertainties from unexpected industry-specific shocks. It also extends the analysis of firms' incentives to achieve imperfectly correlated income streams to the context of vertical integration and unifies the discussion of vertical integration and conglomeration within a single framework.

4. Other theoretical works in this direction include Ordover et al. (1990), Salop and Scheffman (1987), Riordan and Salop (1994), McAfee (1999), and Hendricks and McAfee (2000).

5. Additional empirical studies include Waterman and Weiss (1996), Chipty (2001), Cuellar and Gertler (2003), Delgado and Waterson (2003), and Asker (2016).

6. Similar studies include Weston (1969), Chandler (1977), Berger and Ofek (1995), Lamont (1997), Stein (1997), Shin and Stulz (1998), Rajan et al. (2000), and Almeida et al. (2015).

The structure of this paper is as follows. Section 2.2 presents the model and derives the firm's optimal decision making. Section 2.3 examines the differing risk mitigation effects of vertical integration and conglomeration. Section 2.4 concludes.

2.2 The Firm's Optimal Boundary Decision

In this section, I develop a theoretical model to examine the firm's integration choices. I first derive the firm's optimal decisions regarding capacity and production quantity, conditional on its organizational type. Using these results, along with the firm's productivity parameters, I then determine the firm's optimal boundary choice.

Consider a specialized firm operating in the downstream industry d . In time period 1, it draws productivity shifters for the downstream industry d , the upstream industry u , and the related industry r . The firm faces three choices: remain specialized, integrate backward into industry u , or conglomerate and operate a subsidiary in industry r . In time period 2, the firm incurs sunk costs to establish production capacity in its chosen industries. Once established, this capacity is fixed and cannot be altered. In time period 3, supply and demand shocks are realized, and the firm makes its production decisions.

Firms with potentially asymmetric costs compete à la Cournot. I do not impose symmetry across firms. Instead, my model directly solves the Cournot system by incorporating the quadratic assumption of the variable cost. As a result, each firm chooses its own production quantity based on its productivity shifters, and exerts a distinct influence on the equilibrium market price through its production quantity.

In this section, my model parametrizes the value of risk mitigation and incorporates it into the firm's ex-ante decisions on integration strategies and production capacity in time periods 1 and 2. I assume the value of risk mitigation is the product of two components: the firm-specific valuation of risk mitigation per unit of production σ_i , and the firm's relevant production quantity. The value of σ_i is determined by the firm's risk aversion or financial

market advantages that function as risk-aversion equivalents. In Section 2.3, I formally demonstrate that integration generates value by reducing the volatility of realized returns, thereby justifying this parametrization.

2.2.1 *The Specialized Downstream Firm*

In this section, I examine the scenario in which a firm, having chosen to remain as a specialized downstream firm in time period 1, determines its capacity in time period 2 and its production quantity in time period 3. I begin with the Neo-classical assumption of total variable costs by Coase (1937) and Lucas Jr (1978). The total variable cost function for firm i is assumed to be increasing and convex in quantity q_i . Mathematically, $C'_i(q_i) > 0$ and $C''_i(q_i) > 0$. I further impose the following linear functional form for the marginal production cost:

$$c_i(q_i) = \alpha_i + \frac{1}{2}\beta_i q_i$$

where α_i and β_i are productivity shifters of firm i .⁷

At time period 3, the plant capacity is treated as exogenously given. The joint production decision of all firms together with the realized shocks lead to realized prices. Fixed cost for firm i to set up its production capacity is assumed to be linear in firm i 's capacity t_i . The level of per unit fixed cost for firm i is denoted by f_i .⁸ The ex-post profit function of firm i

7. Productivity shifter β_i gives rise to the curvature in the total variable cost function. The constant part of the marginal cost α_i can be interpreted as the constant part of the unit production costs, such as inputs. The linear part can be interpreted as the labor cost. This interpretation follows Maksimovic and Phillips (2002), which provides a detailed argument and literature reference on why it is increasingly expensive for the management to monitor a larger plant.

8. One way to interpret the fixed cost is the monthly debt repayment associated with financing these expensive plants, or the monthly depreciation of fixed assets.

in time period 3 is

$$\begin{aligned}\pi_i &= q_i[p - c_i] - f_i t_i \\ &= q_i \left(p^d(Q_d^{supply}, Q_d^{demand}) - p^u(Q_u^{supply}, Q_d^{demand} + Q_o^{demand}) - \alpha_i - \frac{1}{2}\beta_i q_i \right) - f_i^d t_i\end{aligned}$$

where p^d represents the realized market price for the downstream output in the final goods market, p^u represents the realized price of the intermediate goods produced by upstream firms, and Q_o represents the demand for the intermediate output from other downstream industries.

In time period 2, the firm's expected profit is calculated by integrating the ex-post profit function over the domain of all price pairs (p^u, p^d)

$$\pi_i = \int_{p_u} \int_{p_d} \left[q_i \left(p^d(\cdot) - p^u(\cdot) - \alpha_i - \frac{1}{2}\beta_i q_i \right) - f_i^d t_i \right] dp_d dp_u$$

which gives the following Lagrangian

$$\mathcal{L} = \int_{p_u} \int_{p_d} \left[q_i \left(p^d(\cdot) - p^u(\cdot) - \alpha_i - \frac{1}{2}\beta_i q_i \right) - f_i^d t_i \right] dp_d dp_u + \lambda(t_i - q_i)$$

where the constraint ensures that the firm's production cannot exceed its established capacity.

Lemma 1 below examines the specialized downstream firm's optimal choice of capacity in time period 2 and production quantity in time period 3.

Lemma 1. *The specialized downstream firm establishes the following capacity in time period 2:*

$$t_i^{sd*} = \frac{\mathbb{E}[p^d] - \mathbb{E}[p^u] - \alpha_i^d - f_i^d}{\beta_i^d + \mathbb{E}[p_{qd,i}^u] - \mathbb{E}[p_{qd,i}^d]}$$

In time period 3, it produces at full capacity when $p_d - p_u \geq \mathbb{E}[p_d] - \mathbb{E}[p_u]$ and below full capacity when $p_d - p_u < \mathbb{E}[p_d] - \mathbb{E}[p_u]$. When it produces below full capacity, its production quantity is given by

$$q_i^{sd*} = \frac{p^d - p^u - \alpha_i^d - f_i^d}{\beta_i^d + p_{qd,i}^u - p_{qd,i}^d}$$

Proof. See Appendix D.1. □

Here, $\mathbb{E}[\cdot]$ denotes expected values, $p_{qd,i}^d$ is the partial derivative of downstream price with respect to firm i 's downstream production, and $p_{qd,i}^u$ is the partial derivative of upstream price with respect to firm i 's downstream production, or equivalently, firm i 's demand for the intermediate goods. These two terms represent the change in equilibrium market price, after firm i increases quantity by one unit, and the corresponding equilibrium reaction of all firms. Therefore, $p_{qd,i}^d < 0$ and $p_{qd,i}^u > 0$. These two terms can also be interpreted as the firm's market power in the upstream and the downstream markets and are unique to each firm. For larger firms, these two partial derivative terms tend to be larger because they would react to the same price change with more quantity change.

The cutoff price difference is the price difference at which the specialized downstream firm is indifferent of producing at full capacity or below full capacity. Mathematically, I derive this cutoff value using the capacity constraint in the Lagrangian. Economically, the firm chooses the ex-ante capacity in time period 2 such that the expected marginal cost is equal to the expected return. If the realized price is greater than the expected marginal cost, then the firm will produce at full capacity.

Note that when the firm has no influence on the market price, the partial derivatives with respect to market power terms become zero, and the Cournot model reduces to the model of perfect competition. In this scenario, the firm will, as a direct result, choose a higher

capacity in period 2 and produce a higher quantity in period 3 at every possible price level.

2.2.2 *The Vertical Firm with Surplus Downstream Capacity*

In this section, I analyze the scenario in which a firm, having chosen vertical integration in time period 1, determines its capacity in time period 2 and its production quantity in time period 3. For mathematical clarity, I separate the discussion into two cases: a vertically integrated firm with surplus downstream capacity and one with surplus upstream capacity. The latter case is examined in Section 2.2.3.

The firm's profit varies slightly depending on whether each of the two segments operates at full capacity or below full capacity:

1. The upstream produces at capacity, and the downstream produces below capacity
2. The upstream produces below capacity, and the downstream produces below capacity
3. The upstream produces at capacity, and the downstream produces at capacity
4. The upstream produces below capacity, and the downstream produces at capacity

For illustration purposes, I assume that the firm's downstream segment prioritizes sourcing inputs from its own upstream segment. It relies on the intermediate goods market only to acquire any additional inputs required for its operations.⁹

When case 1 is true, the expected profit in time period 2 is:

$$\pi = \int_{p_d} \int_{p_u} \left[t_u \left[p_d - \alpha_d - \alpha_u - \frac{1}{2} \beta_u t_u - \frac{1}{2} \beta_d t_d \right] + (q_d - t_u) \left[p_d - p_u - \alpha_d - \frac{1}{2} \beta_d t_d \right] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma_i^v t_u$$

9. Ultimately, this assumption does not affect the results, as the firm can sell its upstream output in the intermediate market and repurchase it at the same price for its downstream production.

In this case, $q_u = t_u$ represents the upstream production quantity, while $\sigma_i^v t_u$ captures the parameterized value of risk reduction. Since the upstream segment operates at full capacity, the firm procures additional $q_d - t_u$ units of intermediate goods from the open market to meet its downstream production needs.

Similarly, when case 2 is true, the expected profit in time period 2 is:

$$\begin{aligned} \pi = \int_{p_d} \int_{p_u} & \left[q_u \left[p_d - \alpha_d - \alpha_u - \frac{1}{2} \beta_u t_u - \frac{1}{2} \beta_d t_d \right] \right. \\ & \left. + (q_d - q_u) \left[p_d - p_u - \alpha_d - \frac{1}{2} \beta_d t_d \right] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma_i^v q_u \end{aligned}$$

When case 3 is true, the expected profit in time period 2 is:

$$\begin{aligned} \pi = \int_{p_d} \int_{p_u} & \left[t_u \left[p_d - \alpha_d - \alpha_u - \frac{1}{2} \beta_u t_u - \frac{1}{2} \beta_d t_d \right] \right. \\ & \left. + (t_d - t_u) \left[p_d - p_u - \alpha_d - \frac{1}{2} \beta_d t_d \right] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma_i^v t_u \end{aligned}$$

When case 4 is true, the expected profit in time period 2 is:

$$\begin{aligned} \pi = \int_{p_d} \int_{p_u} & \left[q_u \left[p_d - \alpha_d - \alpha_u - \frac{1}{2} \beta_u t_u - \frac{1}{2} \beta_d t_d \right] \right. \\ & \left. + (t_d - q_u) \left[p_d - p_u - \alpha_d - \frac{1}{2} \beta_d t_d \right] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma_i^v q_u \end{aligned}$$

Lemma 2 below examines the firm's optimal choice of capacity in time period 2 and production quantity in time period 3. Note that in this section, the firm does not sell any upstream output to the intermediate goods market. This implies $p_{qui}^{ui} = 0$.

Lemma 2. *For the vertical firm with surplus capacity in the downstream segment, its capacity*

choices in time period 2 are:

$$t_i^{v_u*} = \frac{\mathbb{E}[p^u] - \alpha_i^u - f_i^u + \sigma_i^v}{\beta_i^u}$$

$$t_i^{v_d*} = \frac{\mathbb{E}[p^d] - \mathbb{E}[p^u] - \alpha_i^d + t_i^{v_u*} \mathbb{E}[p_{q_d,i}^u] - f_i^d}{\beta_i^d + \mathbb{E}[p_{q_d,i}^u] - \mathbb{E}[p_{q_d,i}^d]}$$

There exists a cutoff intermediate goods price $\hat{p}_u = \mathbb{E}[p_u] + \sigma_i^v$ such that when $p_u \geq \hat{p}_u$, the firm's upstream segment produces at full capacity in time period 3; when $p_u < \hat{p}_u$, the upstream chooses a production quantity of

$$q_i^{v_u*} = \frac{p^u - \alpha_i^u - f_i^u}{\beta_i^u}$$

For the downstream segment, there exist cutoff price tuples $(\hat{p}_u, \hat{p}_d) : \{\hat{p}_d - \hat{p}_u = \mathbb{E}[p_d - p_u] + \mathbb{E}[p_{q_d}^u] \sigma_i^v\}$ such that when $p_d - p_u \geq \mathbb{E}[p_d - p_u] + \mathbb{E}[p_{q_d}^u] \sigma_i^v$, the downstream segment produces at full capacity in time period 3; when $p_d - p_u < \hat{p}_d - \hat{p}_u$, the downstream chooses a production quantity of

$$q_i^{v_d*} = \frac{p^d - p^u - \alpha_i^d + q_i^{v_u*} p_{q_d,i}^u - f_i^d}{\beta_i^d + p_{q_d,i}^u - p_{q_d,i}^d}$$

Proof. See Appendix D.2. □

The existence of an upstream segment increases the downstream's capacity by $t_i^{v_u*} \mathbb{E}[p_{q_d,i}^u] / [\beta_i^d + \mathbb{E}[p_{q_d,i}^u] - \mathbb{E}[p_{q_d,i}^d]]$. This capacity expansion arises due to the elimination of double marginalization. On top of that, the value of risk mitigation increases the firm's upstream capacity by σ_i^v / β_i^u relative to the scenario where σ_i^v is 0. Intuitively, the value of risk reduction applies only to the portion of production where upstream and downstream quantities are matched. When the downstream segment has surplus capacity, the firm's risk reduction

concerns directly incentivize expanding its upstream operations.

Note that the cutoff price $\hat{p}_u$ exceeds $\mathbb{E}[p_u]$ in this case. This occurs because risk mitigation increases the firm's upstream capacity, requiring a higher realized price to fully utilize that capacity. It is also easy to show that $t_i^{vd*} > t_i^{sd*}$ at every possible price level. In other words, the vertical firm expands outputs at every possible price level compared to the specialized firm.

2.2.3 *The Vertically Integrated Firm with Deficit Downstream Capacity*

In this section, I analyze how a vertically integrated firm with a downstream capacity deficit determines its capacity in time period 2 and its production quantity in time period 3. This is the symmetric case of Section 2.2.2.

The firm's profit functions depend on whether each of its two segments operates at full capacity or below it:

1. The upstream produces at capacity, and the downstream produces below capacity
2. The upstream produces below capacity, and the downstream produces below capacity
3. The upstream produces at capacity, and the downstream produces at capacity
4. The upstream produces below capacity, and the downstream produces at capacity

Under case 1, the expected profit function is:

$$\begin{aligned} \pi = \int_{p_d} \int_{p_u} & \left[q_d [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d t_d] \right. \\ & \left. + (t_u - q_d) [p_u - \alpha_u - \frac{1}{2}\beta_u t_u] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma_i^v q_d \end{aligned}$$

Under case 2, the expected profit function is:

$$\begin{aligned}\pi = \int_{p_d} \int_{p_u} & \left[q_d [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d t_d] \right. \\ & \left. + (q_u - q_d) [p_u - \alpha_u - \frac{1}{2}\beta_u t_u] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma_i^v q_d\end{aligned}$$

Under case 3, the expected profit function is:

$$\begin{aligned}\pi = \int_{p_d} \int_{p_u} & \left[t_d [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d t_d] \right. \\ & \left. + (t_u - t_d) [p_u - \alpha_u - \frac{1}{2}\beta_u t_u] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma_i^v t_d\end{aligned}$$

Under case 4, the expected profit function is:

$$\begin{aligned}\pi = \int_{p_d} \int_{p_u} & \left[t_d [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d t_d] \right. \\ & \left. + (q_u - t_d) [p_u - \alpha_u - \frac{1}{2}\beta_u t_u] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma_i^v t_d\end{aligned}$$

Lemma 3 derives the firm's optimal capacity decisions in time period 2 and its optimal production choices in time period 3. In this case, the firm faces a downstream capacity deficit, meaning its upstream output fully meets its downstream needs. The firm engages in the intermediate market exclusively as a seller, and this implies $p_{q_d,i}^{u_i} = 0$.

Lemma 3. *For the vertical firm with a capacity deficit in the downstream segment, the optimal capacity decisions in time period 2 are:*

$$\begin{aligned}t_i^{v_u*} &= \frac{\mathbb{E}[p^u] - \alpha_i^u - t_i^{v_d*} \mathbb{E}[p_{q_u,i}^u] - f_i^u}{\beta_i^u - \mathbb{E}[p_{q_u,i}^u]} \\ t_i^{v_d*} &= \frac{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_i^d - f_i^d + \sigma_i^v}{\beta_i^d - \mathbb{E}[p_{q_d,i}^d]}\end{aligned}$$

There exists a cutoff intermediate goods price $\hat{p}_u = \mathbb{E}[p_u] - \mathbb{E}[p_{q_u,i}^u] \sigma_i^v$, above which the firm's

upstream segment operates at full capacity in time period 3 and below which it selects a production quantity of:

$$q_i^{v_u*} = \frac{p^u - \alpha_i^u - t_i^{v_d*} p_{qu,i}^u - f_i^u}{\beta_i^u - p_{qu,i}^u}$$

For the downstream segment, there exists a similar cutoff price difference for $p_d - p_u$:

$$cutoff = \mathbb{E}[p_d] - \mathbb{E}[p_u] + \sigma_i^v$$

When $p_d - p_u \geq cutoff$, the firm's downstream segment produces at full capacity in time period

3. When $p_d - p_u < cutoff$, the firm's downstream segment selects a production quantity of:

$$q_i^{v_d*} = \frac{p^d - p^u - \alpha_i^d - f_i^d}{\beta_i^d - p_{qd,i}^d}$$

Proof. See Appendix D.3. □

The value of risk mitigation increases the firm's downstream capacity relative to where σ_i^v is 0. Intuitively, the vertical firm would like to expand its downstream capacity in exchange for the role it plays in smoothing expected returns under volatile upstream prices. It can be easily shown that such a firm produces more outputs at every price level relative to a comparable specialized firm.

2.2.4 The Conglomerate Firm

In time period 1, the specialized downstream firm faces the option to expand into a related segment r . Conditional on this choice, this section examines the conglomerate firm's optimal capacity decisions in time period 2 and production quantity in time period 3.

I parameterize the value of risk mitigation for this conglomerate firm as $\sigma_i^c q_i^r > 0$. Unlike vertical integration, conglomeration does not provide the benefit of eliminating the double marginalization issue. As a result, it has to be the case that the firm accounts for a positive $\sigma_i^c q_i^r$ when making its firm boundary decision in period 1.

The expected profit of the conglomerate firm is given by:

$$\begin{aligned} \pi = & \int_{p^u} \int_{p^d} \left[q_i^d(p^d(\cdot) - p^u(\cdot) - \alpha_i^d - \frac{1}{2}\beta_i^d q_i^d) - f_i^d t_i^d \right] dp^d dp^u \\ & + \int_{p^r} \left[q_i^r(p^r(\cdot) - \alpha_i^r - \frac{1}{2}\beta_i^r q_i^r) - f_i^r t_i^r \right] dp^r + \sigma_i^c q_i^r \end{aligned}$$

where $p^r(\cdot)$ represents the realized market price in segment r . Lemma 4 below summarizes the conglomerate firm's optimal decisions.

Lemma 4. *For the conglomerate firm, its optimal ex-ante choices of capacities in time period 2 are:*

$$\begin{aligned} t_i^{cd*} &= \frac{\mathbb{E}[p^d] - \mathbb{E}[p^u] - \alpha_i^d - f_i^d}{\beta_i^d + \mathbb{E}[p_{qd,i}^u] - \mathbb{E}[p_{qd,i}^d]} \\ t_i^{cr*} &= \frac{\mathbb{E}[p^r] - \alpha_i^r - f_i^r + \sigma_i^c}{\beta_i^r - \mathbb{E}[p_{qr,i}^r]} \end{aligned}$$

When realized prices are below cutoff levels $\mathbb{E}[p^d - p^u]$ and $\mathbb{E}[p^r] + \sigma_i^c$, the optimal ex-post choice of production quantities in time period 3 are:

$$\begin{aligned} q_i^{cd*} &= \frac{p^d - p^u - \alpha_i^d - f_i^d}{\beta_i^d + p_{qd,i}^u - p_{qd,i}^d} \\ q_i^{cr*} &= \frac{p^r - \alpha_i^r - f_i^r}{\beta_i^r - p_{qr,i}^r} \end{aligned}$$

When realized prices are above cutoff levels, the optimal production quantities are t_i^{cd*} and t_i^{cr*} , respectively.

Proof. The Lagrangian of the firm's ex-ante capacity choice is

$$\begin{aligned}\mathcal{L} = & \int_{p^u} \int_{p^d} \left[q_i^d(p^d(\cdot) - p^u(\cdot) - a_i^d - \frac{1}{2}\beta_i^d q_i^d) - f_i^d t_i^d \right] dp^d dp^u \\ & + \int_{p^r} \left[q_i^r(p^r(\cdot) - \alpha_i^r - \frac{1}{2}\beta_i^r q_i^r) - f_i^r t_i^r \right] dp^r + \sigma_i^c q_i^r + \lambda_1(t_i^d - q_i^d) + \lambda_2(t_i^r - q_i^r)\end{aligned}$$

where the two constraints following the Lagrange multipliers ensure that both segments of the conglomerate firm do not exceed their production capacities.

Since the firm chooses quantity in each industry based on its expectation on price levels, given the price in industry d , the productivity shifters and the price in industry r do not affect the firm's optimal capacity choice in industry d . Similar arguments apply to industry r . Therefore, solving this Lagrangian is equivalent to solving the optimal decision for two independent specialized firms in industry d and industry r . Results from Appendix D.1 are directly applicable here. $\square$

Note that the value of risk mitigation does not affect the firm's capacity choice in the downstream segment, but leads the firm to expand its capacity in the related subsidiary by $\sigma_i^c / [\beta_i^r - \mathbb{E}[p_{q_r,i}^r]]$. However, conglomeration does not change the firm's optimal production quantity. As a result, the firm experiences fewer capacity constraints in segment r and will leave its capacity idle more frequently. The ability to mitigate return risks when unexpected shocks reduce profits in the firm's downstream segment incentivizes the firm to maintain a larger capacity in the related subsidiary r as a hedge against such profit risks.

Note that with identical productivity parameters, $t_i^{cd*} = t_i^{sd*} \leq t_i^{vd*}$ and $t_i^{cr*} \leq t_i^{vu*}$. In other words, the vertical firm is larger in size compared to the conglomerate firm. This difference is attributed to the resolution of the double marginalization issue by the vertical firm structure.

2.2.5 The Firm's Ex-ante Choice of Type

This section examines the firm's boundary decision in time period 1, where the specialized downstream firm chooses among three options: remain specialized, integrate backward into industry u , or expand into the related industry r . Additionally, this section examines the conditions that determine whether a vertically integrated firm chooses to maintain a capacity surplus or deficit in its downstream segment in time period 2.

Theorem 1. *The firm allocates positive capacity in the downstream industry d , the upstream industry u , and the related subsidiary r when each of the following three inequalities holds respectively*

$$\begin{aligned}\mathbb{E}[p^d] - \mathbb{E}[p^u] &> \alpha^d + f^d \\ \mathbb{E}[p^u] + \sigma_i^v &> \alpha^u + f^u \\ \mathbb{E}[p^r] + \sigma_i^c &> \alpha^r + f^r\end{aligned}$$

The vertical firm allocates capacity surplus in the downstream segment if and only if

$$\frac{\mathbb{E}[p_u] - \alpha_u - f^u}{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_d - f^d} < \frac{\beta_u}{\beta_d - p_{qd}^u}$$

Proof. See Appendix D.4. □

Overall, the specialized firm's time period 1 decision to expand into a new industry depends on its productivity in that industry. The value of risk mitigation incentivizes the firm to enter into industries in which the firm is not as productive. If the firm chooses vertical integration in time period 1, it decides in time period 2 whether to allocate surplus capacity to its downstream segment. This decision is based on comparative advantage and is not affected by concerns of risk mitigation.

2.2.6 A Brief Discussion of the Specialized Upstream Firm

The discussion thus far has centered on the specialized downstream firm. Here, I briefly discuss the symmetric case of the specialized upstream firm and its decisions on firm boundaries, capacity, and production quantity.

I begin by discussing the optimal decisions of the specialized upstream firm. Detailed proof can be found in Appendix D.5. The expected profit of this specialized firm in time period 2 is:

$$\pi = \int_{p_u} \left[q_i \left(p^u(\cdot) - \alpha_i - \frac{1}{2} \beta_i q_i \right) - f_i^u t_i \right] dp_u$$

This gives the firm's optimal ex-ante choice of capacity in time period 2:

$$t_i^{su*} = \frac{\mathbb{E}[p^u] - \alpha_i^u - f_i^u}{\beta_i^u - \mathbb{E}[p_{qu,i}^u]}$$

where $p_{qu,i}^u$ is the partial derivative of upstream price with respect to the upstream supply provided by firm i . This represents the change in the equilibrium market price after firm i increases its quantity by one unit, along with the corresponding reactions of all other firms in the industry.

In Appendix D.5, I show that there also exists a similar cutoff price for the specialized upstream firm. Above the cutoff price $\mathbb{E}[p_u]$, the specialized upstream firm produces at full capacity. Below the cutoff price, the firm produces below full capacity at a quantity of:

$$q_i^{su*} = \frac{p^u - \alpha_i^u - f_i^u}{\beta_i^u - p_{qu,i}^u}$$

Suppose the firm has chosen vertical integration in time period 1. Its optimal decisions on capacity in time period 2 and production quantity in time period 3 follow the analyses in Section 2.2.2 and Section 2.2.3. In the case where the firm chooses to become a conglomerate

and operate a related industry r' , prices in other industries affect production in industry r' only through the price level $p_{r'}$ in industry r' . therefore, the firm's optimal capacity and production choices follow the discussion in Section 2.2.4.

It's obvious that Theorem 1 applies to the firm's boundary decision in time period 1.

2.3 Risk Mitigation Through Integration

In this section, I show that integration lowers volatility that causes realized returns to deviate from expected returns, resulting in non-negative value for the firm.

Note that profit functions used in this section differ slightly from those in Section 2.2. In section 2.2, I assume that integration generates a non-negative risk reduction for the firm, parameterize this value, and incorporate it into the firm's profit function. In this section, I demonstrate that the profit of a vertically integrated firm, without explicitly accounting for the value of risk reduction, is less volatile than that of a specialized firm. This reduced volatility creates value for risk-averse firms or those benefiting from financial market advantages that function as risk-aversion equivalents.

2.3.1 Risk Mitigation under Industry-Specific Supply Shocks

In this section, I show that the specialized downstream firm can backward integrate to reduce the variance in its expected returns caused by industry-specific upstream supply shocks. Theorem 2 summarizes the results.

Theorem 2. *When industry-specific supply shocks cause price fluctuations in the intermediate goods market, the impact on profits for the vertical firm is less pronounced than for the specialized firm:*

$$\left| \frac{\partial \pi_s}{\partial p_u} \right| > \left| \frac{\partial \pi_v}{\partial p_u} \right|$$

Here, π_s and π_v denote the profits of the specialized and vertically integrated firms. When

the profit of the related segment increases in response to increases in the intermediate pricing p_u (i.e., when $\partial\pi_{c_r}/\partial p_u > 0$), then conglomeration also helps mitigate return uncertainties:

$$\left| \frac{\partial\pi_s}{\partial p_u} \right| > \left| \frac{\partial\pi_c}{\partial p_u} \right|$$

Proof. See Appendix E.1 for the detailed proof. □

To examine the impact of an industry-specific supply shock, I take partial derivatives of profits with respect to the intermediate goods price p_u . I demonstrate that in all eight possible scenarios, corresponding to the four scenarios in Section 2.2.2 and four scenarios in Section 2.2.3, the vertical firm's partial derivative of profit with respect to the intermediate goods price is smaller in magnitude than that of the specialized firm. That being said, the profit of the vertically integrated firm is less volatile compared to that of the specialized firm.

Intuitively, when the intermediate goods price goes up, the specialized upstream firm benefits from this change while the specialized downstream firm suffers from this change. The opposite case holds when the intermediate goods price goes down. A vertical merger internalizes such volatility and delivers a smoother income string. When the capacity in the upstream segment and the downstream segment align better, the merged firm is less affected by the supply shock and the corresponding changes in intermediate goods price.

As for the conglomerate firm, assuming price independence between p_r and the intermediate goods price p_u , the conglomerate firm's exposure to supply shocks in segment u is identical to that of a specialized firm. When the profit from the related segment r is increasing in the upstream pricing, then the related segment functions similarly to the upstream segment in hedging against price and profit fluctuations in the downstream segment.

One important caveat is that the partial derivatives derived here represent the magnitude of profit changes. These magnitudes do not account for the fact that the specialized firm is

the smallest in size among the three firm types.

2.3.2 Risk Mitigation under Industry-Specific Demand Shocks

In this section, I analyze the uncertainties in expected returns arising from industry-specific demand shocks. Mathematically, I compare the partial derivatives of profits with respect to changes in final goods market prices across the three firm types. Theorem 3 summarizes the main results.

Theorem 3. *When industry-specific demand shocks cause price uncertainties in the final goods market, the impact on profits for the vertical firm is greater than that of the specialized firm:*

$$\left| \frac{\partial \pi_v}{\partial p_d} \right| > \left| \frac{\partial \pi_s}{\partial p_d} \right|$$

where π_s and π_v denote the profits of the specialized and vertically integrated firms. Let the price relationships among the upstream, downstream, and related subsidiary r be defined as follows: $p_u = g(p_d)$ and $p_r = k(p_d)$. When $g'(p_d) > k'(p_d)$, then the impact on profits for the vertical firm is also greater than the profit of the conglomerate firm π_c :

$$\left| \frac{\partial \pi_v}{\partial p_d} \right| > \left| \frac{\partial \pi_c}{\partial p_d} \right|$$

When $\partial \pi_{c_r} / \partial p_d < 0$, then the impact on profit for the conglomerate firm is less than that for the specialized firm:

$$\left| \frac{\partial \pi_s}{\partial p_d} \right| > \left| \frac{\partial \pi_c}{\partial p_d} \right|$$

Proof. Detailed proof for theorem 3 can be found in Appendix E.2. □

In Theorem 3, I demonstrate that vertical integration is not effective in reducing industry-specific demand shocks that move final goods market pricing. Intuitively, profits in the upstream segment u are influenced by demand shocks in segment d , as a negative shock lowers prices and reduces profitability across the supply chain, while a positive shock has the opposite effect. When upstream suppliers exclusively serve segment d , they are particularly vulnerable to demand shocks in that segment. Likewise, if upstream suppliers are relatively large compared to downstream buyers and already capture most of the supply chain's profits, they are more likely to face substantial profit declines when demand shocks occur.

I also examine whether conglomeration serves as an effective risk mitigation strategy. When $g'(p_d) > k'(p_d)$, meaning that the price in the related segment r is less affected by demand shocks compared to the intermediate goods price, the profit uncertainty for the conglomerate firm is lower than that of the vertically integrated firm.

Furthermore, if $\partial\pi_{c_r}/\partial p_d < 0$, indicating that the profit of the conglomerate firm decreases with downstream pricing p_d , then its profit uncertainty is also lower than that of a specialized firm. In this case, the output from industry r is a substitute for the output from industry d , making conglomeration an effective hedging strategy to reduce profit risk.

2.3.3 A Brief Discussion of the Specialized Upstream Firm and Its Expansion

Sections 2.3.1 and 2.3.2 have focused on the specialized downstream firm's risk concerns. I now briefly discuss, without formal proof, the risk mitigation considerations of the specialized upstream firm. It faces three choices: remains specialized, forward integrates into segment downstream d , and becomes a conglomerate and operates in a related industry r' .

When industry-specific supply shocks hit the upstream industry u , the conclusion of Theorem 2 is applicable. The vertical firm is better at mitigating price uncertainties originating in the upstream of the supply chain. For the conglomerate firm, the impact depends on the

correlation between p_u and $p_{r'}$. If p_u and $p_{r'}$ are positively correlated, the conglomerate firm's additional operation in segment r' introduces greater profit uncertainty compared to the specialized upstream firm. Conversely, if p_u and $p_{r'}$ are negatively correlated, the conglomerate firm's operation in segment r' reduces profit uncertainty relative to the specialized upstream firm, which is similar to a hedging strategy.

When industry-specific demand shocks in segment d cause deviations in the pricing system from the ex-ante expected levels, the vertical firm is not good at mitigating return risks compared to the specialized firm. In Appendix E.1, I decompose $\partial\pi_v/\partial p_d$ into two components: the first represents the change in profits attributable to the downstream segment, while the second represents the change in profits attributable to the upstream segment. I argue that the second component is greater in magnitude than $\partial\pi_s/\partial p_d$. Intuitively, this is because the upstream segment of a vertically integrated firm is larger in size than that of a specialized upstream firm, as discussed in Sections 2.2.2 and 2.2.3.

Regarding the conglomerate firm's profit in segment r' , as long as the demand shock in segment d affects $p_{r'}$ less than p_d , the partial derivative of the conglomerate firm's profits in segment r' will be smaller in magnitude than the first component of $\partial\pi_v/\partial p_d$. For the conglomerate firm to achieve risk mitigation relative to the specialized firm, p_u and $p_{r'}$ must be negatively correlated.

Overall, when uncertainty stems from consumer demand for the final product, conglomeration is more effective for risk mitigation. In contrast, vertical integration is better suited for managing supply chain uncertainties that drive price volatility in the upstream segment.

2.4 Conclusion

The boundaries of firms have long been an important topic in Industrial Organization. Economists have developed a variety of theoretical frameworks to explain firms' integration choices, complemented by numerous empirical studies that examine these theories in

specific industry contexts. This paper proposes and demonstrates an alternative motivation for integration, highlighting the role of integration in reducing return volatility driven by unexpected shocks.

When a firm is either risk-averse or risk-neutral but benefits from financial market advantages that are isomorphic to risk aversion, reducing return volatility creates value for this firm. However, many industries lack effective tools to hedge against industry-specific supply and demand shocks. My model demonstrates that integration can function as a valuable hedging strategy against industry-specific shocks that cause intermediate and final goods prices to deviate from expectations, thereby generating positive value for the firm. As a result, the firm factors in the risk mitigation benefits of integration when making ex-ante decisions about its firm boundary.

Furthermore, my model distinguishes between different types of industry-specific shocks—supply shocks and demand shocks, as well as types of integration—vertical integration and conglomeration. Vertical integration is more effective at reducing supply chain uncertainty, while conglomeration better diversifies product offerings and mitigates profit uncertainty arising from demand shocks.

REFERENCES

- Aguirregabiria, Victor and Chun-Yu Ho**, “A dynamic oligopoly game of the US airline industry: Estimation and policy experiments,” *Journal of Econometrics*, 2012, 168 (1), 156–173.
- Allen, Bruce T**, “Vertical integration and market foreclosure: The case of cement and concrete,” *The Journal of Law and Economics*, 1971, 14 (1), 251–274.
- Almeida, Heitor, Chang-Soo Kim, and Hwanki Brian Kim**, “Internal capital markets in business groups: Evidence from the Asian financial crisis,” *The Journal of Finance*, 2015, 70 (6), 2539–2586.
- Asker, John**, “Diagnosing foreclosure due to exclusive dealing,” *The Journal of Industrial Economics*, 2016, 64 (3), 375–410.
- Atalay, Enghin, Ali Hortaçsu, and Chad Syverson**, “Vertical integration and input flows,” *American Economic Review*, 2014, 104 (4), 1120–1148.
- Baker, George P and Thomas N Hubbard**, “Contractibility and asset ownership: On-board computers and governance in US trucking,” *The Quarterly Journal of Economics*, 2004, 119 (4), 1443–1479.
- Benkard, C Lanier, Aaron Bodoh-Creed, and John Lazarev**, “Simulating the dynamic effects of horizontal mergers: Us airlines,” *Manuscript, Yale University*, 2010.
- Berger, Philip G and Eli Ofek**, “Diversification’s effect on firm value,” *Journal of financial economics*, 1995, 37 (1), 39–65.
- Berry, Steven and Panle Jia**, “Tracing the woes: An empirical analysis of the airline industry,” *American Economic Journal: Microeconomics*, 2010, 2 (3), 1–43.
- , **James Levinsohn, and Ariel Pakes**, “Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at <http://about.jstor.org/terms>,” *Econometrica*, 1995, 63 (4), 841–890.
- Berry, Steven T and Joel Waldfogel**, “Do mergers increase product variety? Evidence from radio broadcasting,” *The Quarterly Journal of Economics*, 2001, 116 (3), 1009–1025.
- Blonigen, Bruce A and Justin R Pierce**, “Evidence for the effects of mergers on market power and efficiency,” 2016.
- Bolton, Patrick and Michael D Whinston**, “Incomplete contracts, vertical integration, and supply assurance,” *The Review of Economic Studies*, 1993, 60 (1), 121–148.
- Borenstein, Severin**, “Hubs and high fares: dominance and market power in the US airline industry,” *The RAND Journal of Economics*, 1989, pp. 344–365.

- , “Airline mergers, airport dominance, and market power,” *The American Economic Review*, 1990, *80* (2), 400–404.
- , “The dominant-firm advantage in multiproduct industries: Evidence from the US airlines,” *The Quarterly Journal of Economics*, 1991, *106* (4), 1237–1266.
- **and Janet Netz**, “Why do all the flights leave at 8 am?: Competition and departure-time differentiation in airline markets,” *International journal of industrial organization*, 1999, *17* (5), 611–640.
- Bork, Robert H.**, *The Antitrust Paradox: A Policy at War with Itself*, New York: Basic Books, 1978.
- Brueckner, Jan K and W Tom Whalen**, “The price effects of international airline alliances,” *The Journal of Law and Economics*, 2000, *43* (2), 503–546.
- Bureau of Transportation Statistics**, “The U.S. Air Carrier Traffic Statistics,” <https://www.transtats.bts.gov/traffic/> 2024. Accessed: 2024-11-11.
- Caillaud, Bernard and Patrick Rey**, “Strategic aspects of vertical delegation,” *European Economic Review*, 1995, *39* (3-4), 421–431.
- Caradonna, Peter, Nathan Miller, and Gloria Sheu**, “Mergers, entry, and consumer welfare,” *Georgetown McDonough School of Business Research Paper*, 2024, (3537135).
- Carlton, Dennis W**, “Revising the horizontal merger guidelines,” *Journal of competition Law and Economics*, 2010, *6* (3), 619–652.
- , “The 2023 Merger Guidelines: A Critical Assessment,” *Review of Industrial Organization*, 2024, pp. 1–17.
- Chandler, Alfred**, “The visible hand: the managerial revolution in American business,” *Cambridge, MA, Harvard University Press*, 1977, *51*, 107–108.
- Chipty, Tasneem**, “Vertical integration, market foreclosure, and consumer welfare in the cable television industry,” *American Economic Review*, 2001, *91* (3), 428–453.
- Ciliberto, Federico and Elie Tamer**, “Market structure and multiple equilibria in airline markets,” *Econometrica*, 2009, *77* (6), 1791–1828.
- **and Jonathan W Williams**, “Limited access to airport facilities and market power in the airline industry,” *The Journal of Law and Economics*, 2010, *53* (3), 467–495.
- **and –** , “Does multimarket contact facilitate tacit collusion? Inference on conduct parameters in the airline industry,” *The RAND journal of economics*, 2014, *45* (4), 764–791.
- , **Charles Murry, and Elie Tamer**, “Market structure and competition in airline markets,” *Journal of Political Economy*, 2021, *129* (11), 2995–3038.

- Coase, Ronald**, “The nature of the firm,” *economica*, 1937, 4, 386–405.
- Cochrane, John H**, *Asset pricing: Revised edition*, Princeton university press, 2009.
- Conlon, Christopher and Julie Holland Mortimer**, “Empirical properties of diversion ratios,” *The RAND Journal of Economics*, 2021, 52 (4), 693–726.
- Craig, Stuart V, Matthew Grennan, and Ashley Swanson**, “Mergers and marginal costs: New evidence on hospital buyer power,” *The RAND Journal of Economics*, 2021, 52 (1), 151–178.
- Crawford, Gregory and Matthew Shum**, “Empirical modeling of endogenous quality choice: the case of cable television,” *Department of Economics, Duke University, working paper*, November, 2001.
- Crawford, Gregory S**, “Endogenous product choice: A progress report,” *International Journal of Industrial Organization*, 2012, 30 (3), 315–320.
- **and Ali Yurukoglu**, “The welfare effects of bundling in multichannel television markets,” *American Economic Review*, 2012, 102 (2), 643–685.
- **, Robin S Lee, Michael D Whinston, and Ali Yurukoglu**, “The welfare effects of vertical integration in multichannel television markets,” *Econometrica*, 2018, 86 (3), 891–954.
- Cuellar, Alison Evans and Paul J Gertler**, “Trends in hospital consolidation: the formation of local systems,” *Health Affairs*, 2003, 22 (6), 77–87.
- Cuesta, José Ignacio, Carlos Noton, and Benjamin Vatter**, “Vertical integration between hospitals and insurers,” *Available at SSRN 3309218*, 2019.
- Das, Somnath**, “Effect of merger on market price and product quality: American and US airways,” *Review of Industrial Organization*, 2019, 55 (3), 339–374.
- Delgado, Juan and Michael Waterson**, “Tyre price dispersion across retail outlets in the UK,” *The Journal of Industrial Economics*, 2003, 51 (4), 491–509.
- Demirer, Mert and Ömer Karaduman**, “Do Mergers and Acquisitions Improve Efficiency? Evidence from Power Plants,” 2024.
- Draganska, Michaela, Michael Mazzeo, and Katja Seim**, “Beyond plain vanilla: Modeling joint pricing and product assortment choices,” *Quantitative Marketing and Economics*, 2009, 7 (2), 105–146.
- Dubois, Pierre and Morten Sæthre**, “On the effect of parallel trade on manufacturers’ and retailers’ profits in the pharmaceutical sector,” *Econometrica*, 2020, 88 (6), 2503–2545.

- , **Ashvin Gandhi**, and **Shoshana Vasserman**, “Bargaining and international reference pricing in the pharmaceutical industry,” Technical Report, National Bureau of Economic Research 2022.
- Dye, Ronald A**, “Earnings management in an overlapping generations model,” *Journal of Accounting research*, 1988, pp. 195–235.
- Ellickson, Paul B, Pianpian Kong, and Mitchell J Lovett**, “Private labels and retailer profitability: Bilateral bargaining in the grocery channel,” *Available at SSRN 3045372*, 2018.
- Fan, Ying**, “Ownership consolidation and product characteristics: A study of the US daily newspaper market,” *American Economic Review*, 2013, *103* (5), 1598–1628.
- and **Chenyu Yang**, “Competition, product proliferation, and welfare: A study of the US smartphone market,” *American Economic Journal: Microeconomics*, 2020, *12* (2), 99–134.
- Farrell, Joseph and Carl Shapiro**, “Antitrust evaluation of horizontal mergers: An economic alternative to market definition,” *The BE Journal of Theoretical Economics*, 2010, *10* (1), 0000102202193517041563.
- Federal Aviation Administration**, “Airport Competition Plan Highlights: Reported Actions to Reduce Barriers to Entry and Enhance Competitive Access,” 2014.
- , “the Economic Impact of U.S. Civil Aviation: 2020,” https://www.faa.gov/sites/faa.gov/files/2022-08/2022-APL-038%202022_economic%20impact_report.pdf 2022. Accessed: 2024-11-11.
- Frontier Group Holdings, Inc.**, “Setting the Record Straight on JetBlue’s Antitrust Arguments,” <https://www.sec.gov/Archives/edgar/data/1498710/000119312522183277/d371870d425.htm> 2022. Filed pursuant to Rule 425 under the Securities Act of 1933 and deemed filed pursuant to Rule 14a-12 under the Securities Exchange Act of 1934.
- Gandhi, Amit, Luke Froeb, Steven Tschantz, and Gregory J Werden**, “Post-merger product repositioning,” *The Journal of Industrial Economics*, 2008, *56* (1), 49–67.
- Gerardi, Kristopher S and Adam Hale Shapiro**, “Does competition reduce price dispersion? New evidence from the airline industry,” *Journal of Political Economy*, 2009, *117* (1), 1–37.
- Goolsbee, Austan and Chad Syverson**, “How do incumbents respond to the threat of entry? Evidence from the major airlines,” *The Quarterly journal of economics*, 2008, *123* (4), 1611–1633.
- Gordon, Robert James and Darryl Jenkins**, *Hub and Network Pricing in the Northwest Airlines Domestic System*, RJ Gordon and D. Jenkins, 1999.

- Gowrisankaran, Gautam, Aviv Nevo, and Robert Town**, “Mergers when prices are negotiated: Evidence from the hospital industry,” *American Economic Review*, 2015, *105* (1), 172–203.
- Gramlich, Jacob**, “Gas prices, fuel efficiency, and endogenous product choice in the US automobile industry,” *Unpublished Working Paper*, 2010.
- Grennan, Matthew**, “Price discrimination and bargaining: Empirical evidence from medical devices,” *American Economic Review*, 2013, *103* (1), 145–177.
- Grossman, Sanford J and Oliver D Hart**, “The costs and benefits of ownership: A theory of vertical and lateral integration,” *Journal of political economy*, 1986, *94* (4), 691–719.
- Grout, Paul A**, “Investment and wages in the absence of binding contracts: A Nash bargaining approach,” *Econometrica: Journal of the Econometric Society*, 1984, pp. 449–460.
- Hart, Oliver**, “Corporate governance: some theory and implications,” *The economic journal*, 1995, *105* (430), 678–689.
- **and John Moore**, “Property Rights and the Nature of the Firm,” *Journal of political economy*, 1990, *98* (6), 1119–1158.
- **, Jean Tirole, Dennis W Carlton, and Oliver E Williamson**, “Vertical integration and market foreclosure,” *Brookings papers on economic activity. Microeconomics*, 1990, *1990*, 205–286.
- Hastings, Justine S and Richard J Gilbert**, “Market power, vertical integration and the wholesale price of gasoline,” *The Journal of Industrial Economics*, 2005, *53* (4), 469–492.
- Hausman, Jerry A**, *Valuation of new goods under perfect and imperfect competition*, National Bureau of Economic Research Cambridge, Mass., USA, 1994.
- Hendricks, Ken and R Preston McAfee**, “A theory of bilateral oligopoly with applications to vertical mergers,” *manuscript, University of Texas, Austin*, 2000.
- Ho, Kate and Robin S Lee**, “Insurer competition in health care markets,” *Econometrica*, 2017, *85* (2), 379–417.
- Ho, Katherine, Justin Ho, and Julie Holland Mortimer**, “The use of full-line forcing contracts in the video rental industry,” *American Economic Review*, 2012, *102* (2), 686–719.
- Holmström, Bengt and John Roberts**, “The boundaries of the firm revisited,” *Journal of Economic perspectives*, 1998, *12* (4), 73–94.
- Hortaçsu, Ali and Chad Syverson**, “Cementing relationships: Vertical integration, foreclosure, productivity, and prices,” *Journal of political economy*, 2007, *115* (2), 250–301.

- , **Olivia R Natan, Hayden Parsley, Timothy Schwieg, and Kevin R Williams**, “Organizational structure and pricing: Evidence from a large us airline,” *The Quarterly Journal of Economics*, 2024, *139* (2), 1149–1199.
- Hüschelrath, Kai and Kathrin Müller**, “Airline Networks, Mergers, and Consumer Welfare,” *Journal of Transport Economics and Policy*, 2014, *48* (3), 385–407.
- Jr, Robert E Lucas**, “Asset prices in an exchange economy,” *Econometrica: journal of the Econometric Society*, 1978, pp. 1429–1445.
- Kim, E Han and Vijay Singal**, “Mergers and market power: Evidence from the airline industry,” *The American Economic Review*, 1993, pp. 549–569.
- Klein, Benjamin, Robert G Crawford, and Armen A Alchian**, “Vertical integration, appropriable rents, and the competitive contracting process,” *The journal of Law and Economics*, 1978, *21* (2), 297–326.
- Klein, Peter G**, “The make-or-buy decision: lessons from empirical studies,” *Handbook of new institutional economics*, 2005, pp. 435–464.
- Kwoka, John and Evgenia Shumilkina**, “The price effect of eliminating potential competition: Evidence from an airline merger,” *The journal of industrial economics*, 2010, *58* (4), 767–793.
- , **Kevin Hearle, and Phillippe Alepin**, “From the fringe to the forefront: Low cost carriers and airline price determination,” *Review of Industrial Organization*, 2016, *48*, 247–268.
- Lambert, Richard A**, “Income smoothing as rational equilibrium behavior,” *Accounting review*, 1984, pp. 604–618.
- Lamont, Owen**, “Cash flow and investment: Evidence from internal capital markets,” *The Journal of Finance*, 1997, *52* (1), 83–109.
- Lazarev, John**, “The welfare effects of intertemporal price discrimination: an empirical analysis of airline pricing in US monopoly markets,” *New York University*, 2013.
- Lederman, Mara**, “Do enhancements to loyalty programs affect demand? The impact of international frequent flyer partnerships on domestic airline demand,” *The RAND Journal of Economics*, 2007, *38* (4), 1134–1158.
- , “Are frequent-flyer programs a cause of the “hub premium”?,” *Journal of Economics & Management Strategy*, 2008, *17* (1), 35–66.
- Lee, Darin and Maria José Luengo-Prado**, “The impact of passenger mix on reported “hub premiums” in the US airline industry,” *Southern Economic Journal*, 2005, *72* (2), 372–394.

- Lee, Jinkook**, “Endogenous product characteristics in merger simulation: A study of the us airline industry,” *Unpublished manuscript*, 2013.
- Lee, Robin S and Ariel Pakes**, “Multiple equilibria and selection by learning in an applied setting,” *Economics Letters*, 2009, *104* (1), 13–16.
- , **Michael D Whinston**, and **Ali Yurukoglu**, “Structural empirical analysis of contracting in vertical markets,” in “Handbook of Industrial Organization,” Vol. 4, Elsevier, 2021, pp. 673–742.
- Lewellen, Wilbur G**, “A pure financial rationale for the conglomerate merger,” *The journal of Finance*, 1971, *26* (2), 521–537.
- Li, Sophia Ying, Joe Mazur, Yongjoon Park, James W Roberts, Andrew Sweeting, and Jun Zhang**, “Endogenous and selective service choices after airline mergers,” 2018.
- Majd, Saman and Stewart C. Myers**, “Tax Asymmetries and Corporate Tax Reform,” in “The Effects of Taxation on Capital Accumulation,” University of Chicago Press, 1987, pp. 343–376.
- Maksimovic, Vojislav and Gordon Phillips**, “Do conglomerate firms allocate resources inefficiently across industries? Theory and evidence,” *The Journal of Finance*, 2002, *57* (2), 721–767.
- Manuszak, Mark D and Charles C Moul**, “Prices and endogenous market structure in office supply superstores,” *The Journal of Industrial Economics*, 2008, *56* (1), 94–112.
- Matvos, Gregor and Amit Seru**, “Resource allocation within firms and financial market dislocation: Evidence from diversified conglomerates,” *The Review of Financial Studies*, 2014, *27* (4), 1143–1189.
- Mazzeo, Michael J**, “Product choice and oligopoly market structure,” *RAND Journal of Economics*, 2002, pp. 221–242.
- McAfee, R Preston**, “The effects of vertical integration on competing input suppliers,” *Economic Review-Federal Reserve Bank of Cleveland*, 1999, *35*, 2–8.
- Meza, David De and Ben Lockwood**, “Does asset ownership always motivate managers? Outside options and the property rights theory of the firm,” *The Quarterly Journal of Economics*, 1998, *113* (2), 361–386.
- Milgrom, Paul and John Roberts**, “An economic approach to influence activities in organizations,” *American Journal of sociology*, 1988, *94*, S154–S179.
- Miller, Nathan and Matthew Weinberg**, “The market power effects of a merger: Evidence from the us brewing industry,” *Econometrica*, 2016.

- Morrison, Steven A**, “Actual, adjacent, and potential competition estimating the full effect of Southwest Airlines,” *Journal of Transport Economics and Policy (JTEP)*, 2001, 35 (2), 239–256.
- Mortimer, Julie H**, “Vertical contracts in the video rental industry,” *The Review of Economic Studies*, 2008, 75 (1), 165–199.
- Nevo, Aviv**, “Measuring market power in the ready-to-eat cereal industry,” *Econometrica*, 2001, 69 (2), 307–342.
- Ordover, Janusz A, Garth Saloner, and Steven C Salop**, “Equilibrium vertical foreclosure,” *The American Economic Review*, 1990, pp. 127–142.
- Park, Yongjoon**, “Structural remedies in network industries: An assessment of slot divestitures in the American Airlines/US Airways merger,” *US Airways Merger (October 12, 2020)*, 2020.
- Peters, Craig**, “Evaluating the performance of merger simulation: Evidence from the US airline industry,” *The Journal of law and economics*, 2006, 49 (2), 627–649.
- Posner, Richard**, “Antitrust Law: An Economic Perspective,” 1976.
- Prince, Jeffrey T and Daniel H Simon**, “The impact of mergers on quality provision: Evidence from the airline industry,” *The Journal of Industrial Economics*, 2017, 65 (2), 336–362.
- Qiu, Ziyi**, “Merger analysis with endogenous prices and product characteristics: Generalized theorem and application to the US airline industry,” *Available at SSRN 2992875*, 2018.
- Rajan, Raghuram G and Luigi Zingales**, “Power in a Theory of the Firm,” *The Quarterly Journal of Economics*, 1998, 113 (2), 387–432.
- Rajan, Raghuram, Henri Servaes, and Luigi Zingales**, “The cost of diversity: The diversification discount and inefficient investment,” *The journal of Finance*, 2000, 55 (1), 35–80.
- Reiss, Peter C and Pablo T Spiller**, “Competition and entry in small airline markets,” *The Journal of Law and Economics*, 1989, 32 (2, Part 2), S179–S202.
- Richard, Oliver**, “Flight frequency and mergers in airline markets,” *international Journal of industrial organization*, 2003, 21 (6), 907–922.
- Riordan, Michael H and Oliver E Williamson**, “Asset specificity and economic organization,” *International Journal of Industrial Organization*, 1985, 3 (4), 365–378.
- **and Steven C Salop**, “Evaluating vertical mergers: A post-Chicago approach,” *Antitrust LJ*, 1994, 63, 513.

- Ronen, J**, “Smoothing income numbers: Objectives, means, and implications,” 1981.
- Salinger, Michael A**, “Vertical mergers and market foreclosure,” *The Quarterly Journal of Economics*, 1988, *103* (2), 345–356.
- Salop, Steven C and David T Scheffman**, “Cost-raising strategies,” *The Journal of Industrial Economics*, 1987, pp. 19–34.
- Seim, Katja**, “An empirical model of firm entry with endogenous product-type choices,” *The RAND Journal of Economics*, 2006, *37* (3), 619–640.
- Shin, Hyun-Han and René M Stulz**, “Are internal capital markets efficient?,” *The Quarterly Journal of Economics*, 1998, *113* (2), 531–552.
- Small, Kenneth A and Harvey S Rosen**, “Applied welfare economics with discrete choice models,” *Econometrica: Journal of the Econometric Society*, 1981, pp. 105–130.
- Spengler, Joseph J**, “Vertical integration and antitrust policy,” *Journal of political economy*, 1950, *58* (4), 347–352.
- Stein, Jeremy C**, “Internal capital markets and the competition for corporate resources,” *The journal of finance*, 1997, *52* (1), 111–133.
- Stulz, RenéM**, “Managerial discretion and optimal financing policies,” *Journal of financial Economics*, 1990, *26* (1), 3–27.
- Sweeting, Andrew**, “The effects of mergers on product positioning: evidence from the music radio industry,” *The RAND Journal of Economics*, 2010, *41* (2), 372–397.
- , “Dynamic product positioning in differentiated product markets: The effect of fees for musical performance rights on the commercial radio industry,” *Econometrica*, 2013, *81* (5), 1763–1803.
- Tesler, Michael**, “Priming predispositions and changing policy positions: An account of when mass opinion is primed or changed,” *American Journal of Political Science*, 2015, *59* (4), 806–824.
- Tirole, Jean**, *The theory of industrial organization*, MIT press, 1988.
- Trueman, Brett and Sheridan Titman**, “An explanation for accounting income smoothing,” *Journal of accounting research*, 1988, pp. 127–139.
- United States District Court for the District of Massachusetts**, “United States v. JetBlue Airways Corp. and Spirit Airlines, Inc., Findings of Fact and Conclusions of Law,” 2024. No. 23-10511-WGY, D. Mass. Jan. 16, 2024.
- U.S. Department of Justice and Federal Trade Commission**, *Merger Guidelines* 2010.
- and – , *Merger Guidelines* 2023.

- Villas-Boas, Sofia Berto**, “An empirical investigation of the welfare effects of banning wholesale price discrimination,” *The RAND Journal of Economics*, 2009, 40 (1), 20–46.
- Vinod, Ben**, *Evolution of Yield Management in the Airline Industry*, Springer, 2021.
- Wang, Zhemin and Thomas H Williams**, “Accounting income smoothing and stockholder wealth,” *Journal of Applied Business Research*, 1994, 10 (3), 96.
- Waterman, David and Andrew A Weiss**, “The effects of vertical integration between cable television systems and pay cable networks,” *Journal of Econometrics*, 1996, 72 (1-2), 357–395.
- Weston, J Fred**, “The nature and significance of conglomerate firms,” . *John’s L. Rev.*, 1969, 44, 66.
- Williamson, Oliver E.**, “Economies as an Antitrust Defense: The Welfare Tradeoffs,” *The American Economic Review*, 1968, 58 (1), 18–36.
- Williamson, Oliver E**, “The vertical integration of production: market failure considerations,” *The American economic review*, 1971, 61 (2), 112–123.
- , “Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization,” *University of Illinois at Urbana-Champaign’s Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship*, 1975.
- , “The modern corporation: origins, evolution, attributes,” *Journal of economic literature*, 1981, 19 (4), 1537–1568.
- , “Transaction cost economics: The natural progression,” *American Economic Review*, 2010, 100 (3), 673–690.
- Wollmann, Thomas G**, “Trucks without bailouts: Equilibrium product characteristics for commercial vehicles,” *American Economic Review*, 2018, 108 (6), 1364–1406.
- Yang, Chenyu**, “Vertical structure and innovation: A study of the SoC and smartphone industries,” *The RAND Journal of Economics*, 2020, 51 (3), 739–785.
- Yuan, Zhe and Panle Jia Barwick**, “Network Competition in the Airline Industry: An Empirical Framework,” Technical Report, National Bureau of Economic Research 2024.

APPENDIX

A Figures and Tables: Chapter 1

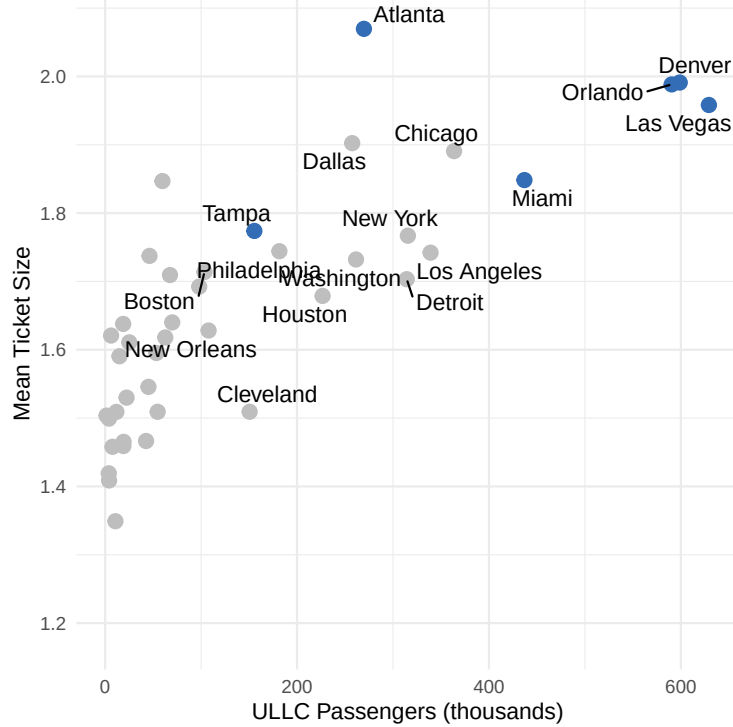


Figure A.1: Total ULCC Passengers v. Mean Ticket Size

Notes: This figure plots the total number of passengers flying with Spirit and Frontier against the average ticket size, with both metrics aggregated at the city level. Only city names with more than 100,000 ultra-low-cost travelers are displayed. Cities without ultra-low-cost travelers are omitted. Blue dots represent the six selected leisure destination cities.

In Figure A.1, I introduce two proxies to assess how "leisure-oriented" a city is. The first proxy is the total number of passengers flying with ultra-low-cost carriers. Frontier and Spirit primarily attract leisure travelers and thus serve as a good indicator of leisure destinations. According to this metric, Denver, Orlando, and Las Vegas are the most leisure-oriented destinations. However, a limitation of this measure is that ultra-low-cost carriers also operate between major cities, appealing to the most price-sensitive travelers on these routes.

The second proxy is the average ticket size. The DB1B dataset includes information on the number of passengers booked under each reservation record. Larger group reservations

are more likely to be associated with family and leisure travel. According to this measure, Atlanta stands out as the most "leisure-oriented" destination.

I also include the two Florida cities, Miami and Tampa, as top leisure destinations. This is consistent with the approach of Berry and Jia (2010). Both cities rank high in the two leisure proxies used here. Although Tampa's total number of ULCC passengers is not exceptionally high, it attracts a comparable number of ULCC travelers to larger cities like Washington DC, and Houston, despite being a much smaller city.

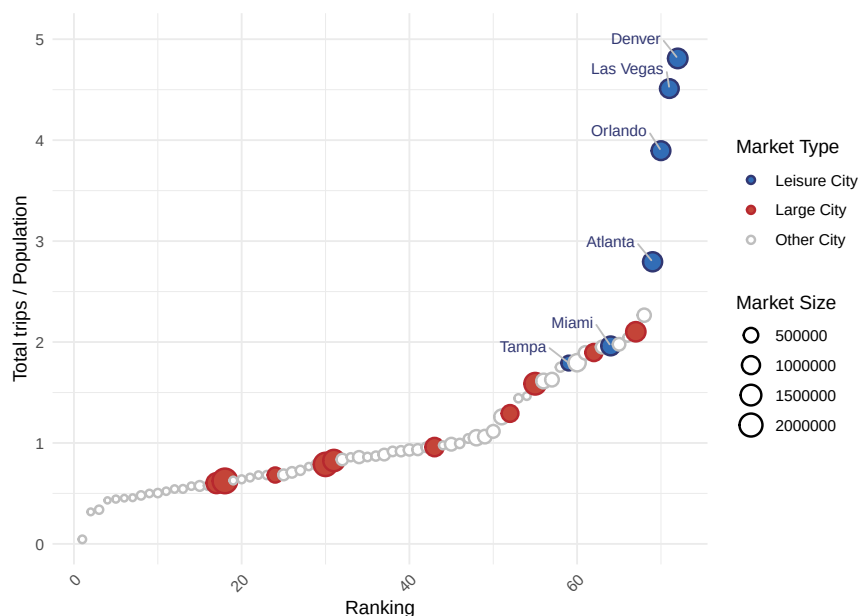


Figure A.2: Travel Intensity by City

Notes: This figure ranks the travel intensity of each city in the data sample. Travel intensity is measured as the annual total number of air trips per capita. The x-axis displays cities ranked by travel intensity, from the lowest to the highest intensity values. The six leisure cities are represented in blue, while the 12 largest cities (excluding Miami and Atlanta) are represented in red. The size of each dot corresponds to the annual number of air travelers in the DB1B dataset.

Directly comparing total air travel volume across cities may lead to a bias favoring larger cities. For instance, while New York City sees more air traffic than Orlando, this does not necessarily indicate that a greater proportion of people from the middle of the income distribution are traveling in New York compared to Orlando. To address this bias, I use the ratio of total air trips to population as a measure of travel intensity. Figure A.2 shows that

the six leisure destinations are more heavily traveled, attracting more leisure travelers from the middle of the income distribution.

Figure A.3 presents the average ticket prices across cities. Leisure destinations generally have lower ticket fares compared to other cities. It is important to note that differences in average travel distances—longer in some cities and shorter in others—can influence prices through cost variations. Additionally, competition is another factor affecting prices but is not captured in this plot.

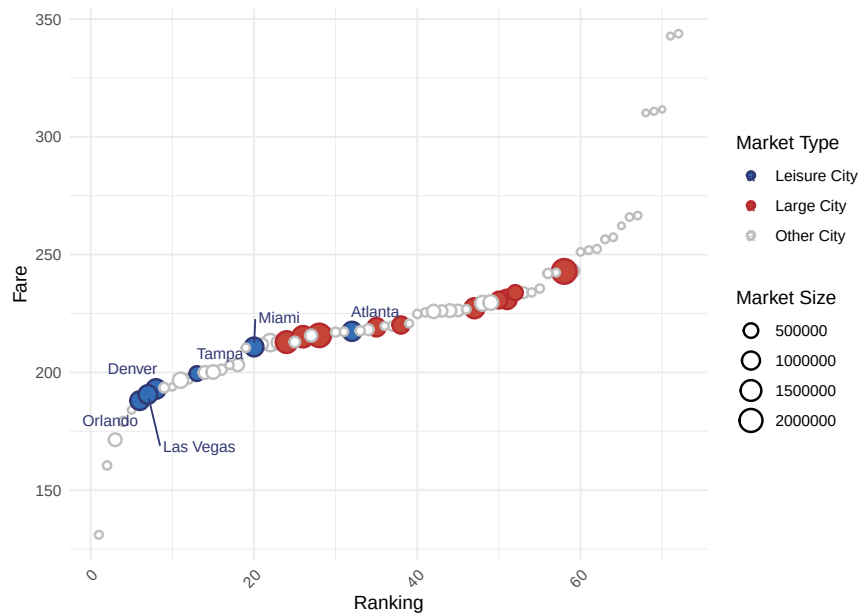


Figure A.3: Mean Fare by City

Notes: This figure ranks each city by its average fare, with the x-axis displaying cities ordered by mean fare. Notice that this ranking differs from the ranking presented in Figure A.2. The six leisure cities are represented in blue, while the 12 largest cities (excluding Miami and Atlanta) are represented in red. The size of each dot corresponds to the annual number of air travelers in the DB1B dataset.

Table A.1: Marginal Cost Estimation per Standardized Seat, Assuming a \$10.00 Marginal Cost per Passenger

Parameters	Estimate	Standard error
Takeoff and landing	48.944	3.417
Distance $\times$ legacy	0.051	0.012
Distance $\times$ hybrid	0.050	0.003
Distance $\times$ Southwest	0.049	0.003
Distance $\times$ ultra-low-cost	0.042	0.003
American	35.261	3.638
United	37.958	3.706
Delta	37.060	8.636
Alaska	-1.156	5.158
JetBlue	1.665	4.980
Southwest	11.783	3.417
Spirit	-3.302	0.546
Observations	83,654	

Notes: This table presents the marginal cost estimates for a "standard seat," assuming a per-passenger marginal cost of \$10.00, which includes expenses such as catering and additional fuel for this passenger. To ensure comparability across carriers, I standardized seating capacity by adjusting legroom to a uniform benchmark of 31.83 inches, the average legroom in the sample. To calculate the actual cost of operating a flight, these per-seat estimates should be adjusted by the ratio of the actual legroom to the "standard" 31.83 inches and then multiplied by the total number of seats on the aircraft. Observations with negative predicted marginal costs using demand estimates (153 in total) are excluded from the regression sample.

Table A.2: Cost Per Available Seat Mile: Estimation vs. Financial Statement

Carrier	Financial Statement	Estimate
American	14.98	14.55
United	13.67	13.59
Delta	14.67	14.85
Southwest	12.66	12.61
Alaska	11.58	10.27
JetBlue	11.43	10.30
Spirit	8.36	8.38
Frontier	8.27	9.07

Notes: This table compares the estimated Cost per Available Seat Mile (CASM) with the actual CASM values reported by airlines in their 10-K financial statements for the fiscal year ending December 2019. It provides the data used to generate Figure 1.2.

Table A.3: Markup and Marginal Costs by Carrier and Distance

Carrier	Distance group	Average fare	Estimated MC	Estimated markup
American	< 500	214.67	141.10	73.57
	500 ~1000	225.27	160.46	64.81
	1000 ~ 1500	255.11	182.78	72.33
	1500 ~ 2000	279.61	209.62	69.99
	> 2000	344.06	242.04	102.03
United	< 500	209.41	143.58	65.83
	500 ~1000	219.74	161.94	57.80
	1000 ~ 1500	258.95	184.52	74.43
	1500 ~ 2000	289.07	211.46	77.60
	> 2000	348.63	253.81	94.83
Delta	< 500	210.28	141.60	68.69
	500 ~1000	217.96	157.77	60.19
	1000 ~ 1500	228.56	180.03	48.54
	1500 ~ 2000	312.52	207.23	105.29
	> 2000	350.22	252.90	97.32
Southwest	< 500	153.93	112.06	41.87
	500 ~1000	179.66	127.09	52.57
	1000 ~ 1500	202.81	148.77	54.04
	1500 ~ 2000	232.80	172.43	60.37
	> 2000	259.48	196.81	62.67
Alaska	< 500	122.93	95.40	27.53
	500 ~1000	174.14	119.17	54.97
	1000 ~ 1500	185.56	131.98	53.58
	1500 ~ 2000	236.79	173.03	63.75
	> 2000	284.80	210.99	73.81
JetBlue	< 500	149.54	106.87	42.67
	500 ~1000	171.98	128.63	43.34
	1000 ~ 1500	201.08	147.49	53.58
	1500 ~ 2000	209.33	186.19	23.14
	> 2000	322.76	219.45	103.31
Spirit	< 500	99.94	79.10	20.85
	500 ~1000	126.53	92.53	34.00
	1000 ~ 1500	151.27	107.40	43.87
	1500 ~ 2000	180.07	131.11	48.95
	> 2000	206.76	151.55	55.21
Frontier	< 500	99.12	83.82	15.30
	500 ~1000	141.64	97.57	44.07
	1000 ~ 1500	162.21	117.21	45.00
	1500 ~ 2000	174.90	136.12	38.79
	> 2000	202.54	155.05	47.49

Notes: This table presents the average ticket fare, estimated marginal cost, and estimated markup for each carrier, segmented by travel distance, and weighted by passenger volume. Distance is measured in total miles traveled. The median and mean ratios of the estimated markup to the average fare are 0.249 and 0.246, respectively, which roughly correspond to the median own-price elasticity of -3.92.

B Model Supplements: Chapter 1

B.1 Derivations for Optimal Pricing

In this appendix section, I derive the markup equation based on the optimal condition given by equation 1.4. For a product l in any market m' that shares a flight segment with product j in market m ,

$$\begin{aligned}
 c_{lm'}p_{jm} &= p_{jm} \sum_{s \in S_j \cap S_l} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_{fs}} + X_s^2 \gamma_2 \right) \\
 &= \sum_{s \in S_j \cap S_l} \left(X_{fs}^1 \gamma_1 p_{jm} \frac{C_{fs}}{Q_{fs}} \right) \\
 &= - \sum_{s \in S_j \cap S_l} \left(X_{fs}^1 \gamma_1 \frac{1}{Q_{fs}} \frac{C_{fs}}{Q_{fs}} \sum_{k \in \mathcal{J}(s)} Q_{fs} p_{jm} \right) \\
 &= - \sum_{s \in S_j \cap S_l} \left(X_{fs}^1 \gamma_1 \frac{1}{Q_{fs}} \frac{C_{fs}}{Q_{fs}} \sum_{k \in \mathcal{J}(s)} q_{km} p_{jm} \right) \\
 &= - \sum_{s \in S_j \cap S_l} \left(X_{fs}^1 \gamma_1 \frac{1}{Q_{fs}} \frac{C_{fs}}{Q_{fs}} q_{jm} p_{jm} \right)
 \end{aligned}$$

In the first and second equations, the summation is the sum across the flight segments shared by product j and product l . In the earlier example, this is either LAX - ORD or ORD - LGA, depending on product l . The third equation is a simple expansion of the second equation. The second summation in the third equation is the sum across all products that share the flight segment s . However, note that the price of product j only has a direct effect on its own quantity. Products in the same market with product j will not share any flight segments with product j by definition. Thus, $\partial q_{km} / \partial p_{jm}$ is zero for all other products. This gives equation four. Notice that $q_{jm} p_{jm} < 0$, so $c_{lm'} p_{jm} > 0$. When the price of product j goes up, demand for product j goes down, and so does the load factor on flight segments associated with product j . This increases the cost for product j . Product l in other market m' that shares the flight segment with product j also faces the same increase in cost.

Therefore,

$$\begin{aligned}
\sum_{l \in \mathcal{J}(S_j)} c_{lm'} p_{jm} q_l &= - \sum_{l \in \mathcal{J}(S_j)} \left(\sum_{s \in S_j \cap S_l} \left(X_{fs}^1 \gamma_1 \frac{1}{Q_{fs}} \frac{C_{fs}}{Q_{fs}} q_{jm} p_{jm} \right) q_l \right) \\
&= - \sum_{s \in S_j} \left(\sum_{l \in \mathcal{J}(s)} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_{fs}} q_{jm} p_{jm} \right) \frac{1}{Q_{fs}} q_l \right) \\
&= - \sum_{s \in S_j} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_{fs}} q_{jm} p_{jm} \frac{\sum_{l \in \mathcal{J}(s) \setminus j} q_l}{Q_{fs}} \right)
\end{aligned}$$

In the first line, the first summation is the sum across all products in other markets that share a flight segment with product j , denoted by l . The second summation is the sum of flight segment(s) that is shared by product l and j . In the earlier example, this is either LAX – ORD or ORD – LGA. This is equivalent to first summing across the two flight segments used by product j , and then summing across all other products that involve one of the two flight segments. The last term of the third equation, $\sum_{l \in \mathcal{J}(s)} q_l / Q_{fs}$, is simply the ratio of passengers on flight segment s that is not under product j . Suppose the flight segment s is ORD – LGA. Passengers not under product j include direct flight passengers and other connecting passengers on board.

Plugging in, the first order condition can be written as

$$\frac{d VP_f}{d p_{jm}} = q_{jm} + \sum_{k \in J_{fm}} (p_{km} - c_{km}) q_{km} p_{jm} + \sum_{s \in S_j} \left(X_{fs}^1 \gamma_1 \frac{C_{fs}}{Q_{fs}} \frac{\sum_{l \in \mathcal{J}(s) \setminus j} q_l}{Q_{fs}} \right) q_{jm} p_{jm} = 0$$

C Counterfactual Supplements: Chapter 1

The counterfactual baseline is established by inputting the observed market data into the full model, which allows for endogenous product positioning, and then executing the iterative best response algorithm. Assuming the current market is in equilibrium, the counterfactual baseline should closely mirror the observed data. Tables C.1 and C.2 illustrate the gap between the observed data and the simulated counterfactual baseline.

Table C.1: Observed Data vs. Simulated Counterfactual Baseline:
Market Conditions

	Group	Observed data	Counterfactual baseline
<i>Average price</i>	All markets	215.54	212.68
	Large city markets	244.77	253.74
	Leisure markets	197.54	187.43
<i>Total passengers (thousands)</i>	All markets	963.69	976.64
	Large city markets	259.68	255.45
	Leisure markets	409.51	410.28
<i>Total departures</i>	All markets	7789	7971
	Large city markets	1851	1859
	Leisure markets	3302	3264

Table C.1 compares the counterfactual baseline with observed data, focusing on markets relevant to JetBlue and Spirit. These markets encompass those where either JetBlue or Spirit currently operates, as well as those operated by these two carriers in the counterfactual baseline.¹⁰ The comparison of weighted average prices, total passenger volumes, and total departures shows that the counterfactual baseline closely matches the observed data across all market types.

Table C.2 compares observed data with model predictions in the counterfactual baseline, where each number under "counterfactual baseline" represents changes in market conditions relative to the observed data. These modest changes indicate that while there are some shifts in market conditions, the counterfactual baseline predictions stay largely consistent with the observed data.

10. In the simulation, other carriers can reallocate their airplanes between markets served by JetBlue and Spirit and all other markets. To illustrate the merger's impact, I report data exclusively on markets where these two merging carriers operate.

Table C.2: Observed Data vs. Simulated Counterfactual Baseline:
Product Changes

	Observed data	Changes in counterfactual baseline			
	Total products	New products	Dropped products	Increased departure	Decreased departure
All markets	1871	270	44	250	68
Large city markets	359	18	10	48	40
Leisure markets	1148	104	25	51	89

D Proofs for Section 2.2

D.1 Proof for Lemma 1

Proof. In this proof, I first show that the specialized downstream firm will not choose a capacity such that it always has spare capacity under all price levels. Next, I show that the specialized downstream firm will not choose a capacity such that it always produces at full capacity. Finally, I show that the cutoff upstream-downstream price difference is given by $\mathbb{E}[p_d] - \mathbb{E}[p_u]$.

First, I show that the specialized downstream firm will not produce at full capacity under all price levels. The firm always has an incentive to increase its capacity in this case. By choosing an capacity increase $\epsilon > 0$ such that $q_d^* > t_d + \epsilon$, all capacity are still used after the increase in capacity. Thus, the change in the firm's profit is given by

$$\epsilon \left[\mathbb{E}[p_d - p_u] - \alpha_d - \frac{1}{2}\beta_d t_d^* - f^d \right]$$

which is strictly positive because $\alpha_d + \frac{1}{2}\beta_d t_d + f^d$ is just the cost of production and the firm will not produce if this condition fails.

In the extreme case, the firm's optimal choice of production is equal to its capacity under the lowest upstream-downstream price difference $\underline{p_d - p_u}$. When the firm increases its capacity by ϵ , with a probability of $Pr\{p_d - p_u < p_d(t_d^* + \epsilon) - p_u(t_d^* + \epsilon)\}$, the firm is producing below full capacity. When ϵ is small, this probability tends to 0. In this case, the change in the firm's profit is given by

$$\begin{aligned} & Pr\{p_d - p_u < p_d(t_d^* + \epsilon) - p_u(t_d^* + \epsilon)\}(q_d - t_d^*) \left[\mathbb{E}[p_d - p_u] - \alpha_d - \frac{1}{2}\beta_d t_d^* - f^d \right] \\ & + Pr\{p_d - p_u > p_d(t_d^* + \epsilon) - p_u(t_d^* + \epsilon)\} \epsilon \left[\mathbb{E}[p_d - p_u] - \alpha_d - \frac{1}{2}\beta_d t_d^* - f^d \right] - f^u \epsilon \end{aligned}$$

where $\epsilon > q_d - t_d^* > 0$. When ϵ is small, this equation tends to

$$\mathbb{E}[p_d - p_u] - \alpha_d - \frac{1}{2}\beta_d t_d^* - f^d$$

so the firm has the incentive to increase its capacity by ϵ to increase its profits.

Next, I show that the firm will not choose a capacity at which it produces below full capacity under all price levels. Suppose this is the case. By choosing a capacity decrease by $\epsilon > 0$ such that $q_d^* < t_d^* - \epsilon$, not all capacity are utilized even after the ϵ decrease in capacity.

Thus, the increase in the firm's profit is given by

$$\epsilon \left[\frac{1}{2} q_d \beta_d + f^d \right] > 0$$

Therefore, it is always profitable to decrease the capacity when $q_u^* < t_u - \epsilon$ under all price levels. I can continue reducing the capacity t_d until the specific capacity where the firm produces below full capacity at $\hat{p}_d - \underline{p}_u$. Here, when the firm decreases its capacity by ϵ , with a probability $Pr\{p_d - p_u > p_d(t_d^* - \epsilon) - p_u(t_d^* - \epsilon)\}$, the firm is producing at full capacity. Since ϵ is small, this probability tends to 0. In this case, the change in the firm's profit is given by:

$$\begin{aligned} & Pr\{p_d - p_u > p_d(t_d^* - \epsilon) - p_u(t_d^* - \epsilon)\} \left[(t_d^* - \epsilon - q_d)[p_d - p_u - \alpha_d] + \frac{1}{2} \beta_d [q_d t_d - (t_d - \epsilon)^2] \right] + f^d \\ & + Pr\{p_d - p_u < p_d(t_d^* - \epsilon) - p_u(t_d^* - \epsilon)\} \epsilon \left[\frac{1}{2} q_d \beta_d \right] + \epsilon \end{aligned}$$

where $t_d^* - \epsilon - q_d < 0$. When ϵ is small, this degenerates to the earlier case. Therefore, I can always improve the firm's profits by cutting the firm's upstream capacity by $\epsilon > 0$.

Since production is monotonically increasing in price, there must exist a cutoff price tuples $(\hat{p}_u, \hat{p}_d) : \{\bar{p}_d - \underline{p}_u > \hat{p}_d - \hat{p}_u > 0\}$ such that the firm produces at full capacity when $p_d - p_u > \hat{p}_d - \hat{p}_u$. Therefore, the optimal choice of capacity conditioning on $p_u > \hat{p}_u$ is given by

$$t_d^* = \int_{\underline{p}_u}^{\bar{p}_u} \int_{\hat{p}_d - \hat{p}_u}^{\bar{p}_d} \frac{p_d - p_u - \alpha_d - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d} dp_d dp_u$$

and the optimal choice of upstream output conditioning on price level $p_d - p_u < |\hat{p}_d - \hat{p}_u|$ is given by solving the Lagrangian:

$$\mathcal{L} = q_d \left(p_d \left(\sum_i q_{d_i} \right) - \alpha_0 - p_u \left(\sum_i q_{d_j}^{nv}, \sum_j q_{d_j}^{nv} \right) - \frac{1}{2} b t_d \right) - f^d t_d + \lambda (t_d - q)$$

which gives

$$q_d^* = \frac{p_d - p_u - \alpha_d - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

The first-order condition of the Lagrangian states that at optimality, the capacity is equal

to the output. Therefore, the optimal choice of capacity is given by

$$Pr\{(p_d - p_u) > \hat{p}_d - \hat{p}_u\} \int_{\underline{p}_u}^{\bar{p}_u} \int_{\hat{p}_d - \hat{p}_u}^{\bar{p}_d} \frac{p_d - p_u - \alpha_d - f^d}{\beta_d + p_{qd}^u - p_{qd}^d} dp_d dp_u$$

$$Pr\{(p_d - p_u) < \hat{p}_d - \hat{p}_u\} \int_{\underline{p}_u}^{\bar{p}_u} \int_{\underline{p}_d}^{\hat{p}_d - \hat{p}_u} \frac{p_d - p_u - \alpha_d - f^d}{\beta_d + p_{qd}^u - p_{qd}^d} dp_d dp_u$$

This should be equivalent to the optimal capacity choice t_d^* derived from the Lagrangian, which would require $\hat{p}_d - \hat{p}_u = \mathbb{E}[p_d - p_u]$. To see this, since the Lagrangian requires capacity equals to expected output at optimality, the inner integral with respect to the upstream price can simply be treated as an expectation operation. Thus, the integral of the upstream price reduces to $\mathbb{E}[p_u]$ and the integral of the upstream quantity reduces to the optimal choice of upstream capacity t_u^* . As a result, I can rewrite the equation above as

$$Pr\{(p_d - p_u) > \mathbb{E}[p_d - p_u]\} \int_{\mathbb{E}[p_d - p_u]}^{\bar{p}_d} \frac{p_d - \mathbb{E}[p_u] - \alpha_d - f^d}{\beta_d + \mathbb{E}[p_{qd}^u] - p_{qd}^d} dp_d$$

$$+ Pr\{(p_d - p_u) < \mathbb{E}[p_d - p_u]\} \int_{\underline{p}_d}^{\mathbb{E}[p_d - p_u]} \frac{p_d - \mathbb{E}[p_u] - \alpha_d - f^d}{\beta_d + \mathbb{E}[p_{qd}^u] - p_{qd}^d} dp_d$$

which can be further simplified into

$$\frac{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_d - f^d}{\beta_d + \mathbb{E}[p_{qd}^u] - \mathbb{E}[p_{qd}^d]}$$

Therefore, the cutoff price tuple is given by the expected price level $\mathbb{E}[p_d - p_u]$. $\square$

D.2 Proof for Lemma 2

Proof. In this proof, I first establish the existence of analogous cutoff price concepts for vertically integrated firms. I then analyze the four cases outlined at the beginning of Section 2.2.2. For each case, I construct the corresponding Lagrangian and derive the ex-ante optimal capacity choice in time period 2 and the ex-post optimal production decision in time period 3. Finally, I consolidate the results from these four cases by examining their respective domains of applicable price levels and derive the firm's overall optimal decisions.

The cutoff prices

The proof will be analogous to that for specialized firms, which are detailed in Appendix D.1. Separate proofs are needed for each of the four cases outlined. Using similar strategies, I can show that both the upstream segment and the downstream segment of the vertically integrated firm will not choose a capacity at which it always produces below capacity or at full capacity. Therefore, there must exist some cutoff price $\hat{p}_u$ for the upstream production and some cutoff price tuples $(\hat{p}_u, \hat{p}_d)$ for the downstream production.

Detailed proof for the cutoff prices can be found after my discussion of the four cases below, at the end of Section D.2.

Case 1: upstream at capacity, downstream below capacity

In this case, I discuss the scenario where the firm's upstream produces at capacity and the downstream produces below capacity constraint. The Lagrangian of this case is

$$\begin{aligned} \mathcal{L} = \int_{p_d} \int_{p_u} & \left[t_u \left[p_d - \alpha_d - \alpha_u - \frac{1}{2} \beta_u t_u - \frac{1}{2} \beta_d q_d \right] + (q_d - t_u) \left[p_d - p_u - \alpha_d - \frac{1}{2} \beta_d q_d \right] \right. \\ & \left. - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma^v t_u + \lambda(t_d - q_d) \end{aligned}$$

Solving the Lagrangian gives

$$t_u^* = \int_{p_u} \frac{p_u - \alpha_u - f^u + \sigma^v}{\beta_u} dp_u$$

Because I only consider the situation where the upstream production hits the capacity, t_u^* is the integration between the cutoff upstream price where the optimal choice of production is equal to the capacity and the maximal upstream price level. Note that the optimal choice of upstream capacity, in this case, does not depend on the downstream price p_d or capacity t_d .

As for the downstream capacity, if assuming the downstream capacity always satisfies the need for its downstream production, the downstream capacity should satisfy

$$t_d \geq \frac{\bar{p}_d - \underline{p}_u - \alpha_d + t_u p_{q_d}^u - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

However, as previously discussed, the firm will not select a downstream capacity that meets its production demand across all price levels. Consequently, this inequality is not a critical

consideration.

The objective function when the firm observes the realized price levels is

$$t_u[p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d q_d] + (q_d - t_u)[p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_d] - f^u t_u - f^d t_d$$

Setting up the Lagrangian, the first-order condition with respect to q_d gives the optimal choice of downstream production:

$$q_d^* = \frac{p_d - p_u - \alpha_d + t_u p_{q_d}^u - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

It's important to note that the optimal choice of downstream when the downstream capacity is abundant depends on both upstream and downstream prices, the upstream capacity, the partial derivatives of downstream quantity with respect to prices in the intermediate goods market, and the final goods market.

Case 2: upstream below capacity, downstream below capacity

In this case, I discuss the scenario where both the firm's upstream and downstream segments are producing below capacity. The Lagrangian is

$$\begin{aligned} \mathcal{L} = \int_{p_d} \int_{p_u} & \left[q_u[p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u q_u - \frac{1}{2}\beta_d q_d] + (q_d - q_u)[p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_d] \right. \\ & \left. - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma^v q_u + \lambda_1(t_u - p_u) + \lambda_2(t_d - p_d) \end{aligned}$$

The first-order conditions with respect to t_u and t_d give the optimal choice of capacities:

$$\begin{aligned} t_u & \geq \frac{\hat{p}_u - \alpha_u - f^u + \sigma^v}{\beta_u} \\ t_d & \geq \frac{\bar{p}_d - \underline{p}_u - \alpha_d + q_u^* p_{q_d}^u - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d} \end{aligned}$$

The optimal upstream capacity depends solely on the upstream price, while the optimal downstream quantity is influenced by the upstream price, downstream price, and the upstream quantity. Intuitively, the optimal downstream choice increases with the firm's upstream output because utilizing in-house production is more cost-effective than outsourcing. Furthermore, since the firm will not select a downstream capacity that consistently exceeds

its optimal production level, the downstream capacity choice in this context, similar to the upstream case, becomes irrelevant.

Given the assumption in Case 2, the firm will not select an upstream capacity that consistently exceeds its optimal production level, making the capacity choice irrelevant in this context. A similar rationale applies to the downstream segment.

The objective function when the firm observes the realized price levels is

$$q_u [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u q_u - \frac{1}{2}\beta_d q_d] + (q_d - q_u) [p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_d] - f^u t_u - f^d t_d \\ + \lambda_1(t_u - p_u) + \lambda_2(t_d - p_d)$$

Setting up the Lagrangian, the first-order condition with respect to q_u and q_d give the optimal choice of production quantities

$$q_u^* = \frac{p_u - \alpha_u - f^u}{\beta_u} \\ q_d^* = \frac{p_d - p_u - \alpha_d + q_u p_{q_d}^u - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

Case 3: upstream at capacity, downstream at capacity

In this case, I discuss the scenario where both the firm's upstream and downstream are producing at capacity. This would happen when price levels in both markets are high. Under this scenario, the objective function of the firm is

$$\int_{p_d} \int_{p_u} \left[t_u [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d t_d] \right. \\ \left. + (t_d - t_u) [p_d - p_u - \alpha_d - \frac{1}{2}\beta_d t_d] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma^v t_u$$

The first-order conditions with respect to t_u and t_d solve the optimal choice of upstream and downstream capacity:

$$t_u^* = \int_{p_u} \frac{p_u - \alpha_u - f^u + \sigma^v}{\beta_u} dp_u \\ t_d^* = \int_{p_d} \int_{p_u} \frac{p_d - p_u - \alpha_d + t_u p_{t_d}^u - f^d}{\beta_d + p_{t_d}^u - p_{t_d}^d} dp_u dp_d$$

As previously discussed, when the firm's upstream production is at capacity, the optimal

upstream capacity depends solely on the productivity shifters. In this case, the integration is performed between the cutoff upstream price, where optimal production equals capacity, and the maximum upstream price level.

Conditional on the downstream segment producing at capacity, the downstream production depends on both the downstream productivity and the upstream capacity (or, in this case, upstream production). The inner integral is evaluated over the same range as that for t_u^* , while the outer integral is evaluated over a similar range—between the cutoff downstream price, where the optimal production equals capacity, and the maximum downstream price level.

Case 4: upstream below capacity, downstream at capacity

In this case, I analyze the scenario where the upstream operates below capacity while the downstream produces at full capacity. Although this may seem implausible, it can occur in rare situations where the upstream price is exceptionally low, and the downstream price is high.

The Lagrangian of the objective function is :

$$\begin{aligned} \mathcal{L} = \int_{p_d} \int_{p_u} & \left[q_u [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u q_u - \frac{1}{2}\beta_d t_d] + (t_d - q_u) [p_d - p_u - \alpha_d - \frac{1}{2}\beta_d t_d] \right. \\ & \left. - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma^v q_u + \lambda(t_u - p_u) \end{aligned}$$

The first-order conditions with respect to t_u and t_d give

$$\begin{aligned} t_u & \geq \frac{\hat{p}_u - \alpha_u - f^u + \sigma^v}{\beta_u} \\ t_d^* & = \int_{p_d} \int_{p_u} \frac{p_d - p_u - \alpha_d + t_u p_{t_d}^u - f^d}{\beta_d + p_{t_d}^u - p_{t_d}^d} dp_u dp_d \end{aligned}$$

As noted in Case 2, the firm will never select an upstream capacity that always exceeds its optimal production level. Consequently, the capacity choice in this scenario is trivial.

For t_d^* , the inner integral is taken on prices where the firm's upstream is producing below the capacity constraint. In particular, it will be between the minimal price $\underline{p}_u$ and the cutoff price $\hat{p}$ where the firm produces at the chosen capacity. Since I assume the downstream produce at capacity, in this case, the outer integral is taken from the cutoff downstream price to the maximal downstream price. The downstream cutoff price is the price under

which the downstream, taking the expected upstream price as given, produces at capacity.

The objective function after the firm observes realized prices is

$$q_u [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u q_u - \frac{1}{2}\beta_d t_d] + (t_d - q_u)[p_d - p_u - \alpha_d - \frac{1}{2}\beta_d t_d] - f^u t_u - f^d t_d \lambda(t_u - p_u)$$

The first-order condition with respect to q_u gives

$$q_u^* = \frac{p_u - \alpha_u - f^u}{\beta_u}$$

Ex-ante choice of capacity: vertical firm with surplus downstream capacity

As shown by case 1 - 4, the firm will choose a capacity such that both the firm's upstream and downstream will produce at capacity when the price is high, and produce below capacity when the price is low. The optimal choice of upstream capacity conditioning on $p_u > \hat{p}_u$ is

$$t_u^* = \int_{\hat{p}_u}^{\bar{p}_u} \frac{p_u - \alpha_u - f^u + \sigma^v}{\beta_u} dp_u$$

and the optimal choice of downstream capacity conditional on the price difference between p_d and p_u is greater than the cutoff value is

$$t_d^* = \int_{\underline{p}_u}^{\bar{p}_u} \int_{\text{cutoff}}^{\bar{p}_d} \frac{p_d - p_u - \alpha_d + t_u^* p_{t_d}^u - f^d}{\beta_d + p_{t_d}^u - p_{t_d}^d} dp_d dp_u$$

where cutoff represents the cutoff price difference between p_d and p_u .

The optimal choice of upstream output conditioning on $p_u < \hat{p}_u$ is

$$q_u^* = \frac{p_u - \alpha_u - f^u}{\beta_u}$$

The optimal choice of downstream output conditioning on the price tuple $(p_d - p_u) < \hat{\text{cutoff}}$ is

$$q_d^* = \frac{p_d - p_u - \alpha_d + q_u p_{q_d}^u - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

Conditional on the fact that $p_u < \hat{p}_u$ and $(p_d - p_u) < \hat{\text{cutoff}}$, the optimal choice of capacity will be calculated by the expectation taken among the corresponding price range.

Therefore, the optimal choice of upstream capacity is given by

$$t_u^* = Pr\{p_u > \hat{p}_u\} \int_{\hat{p}_u}^{\bar{p}_u} \frac{(p_u - \alpha_u) - f^u}{\beta_u} dp_u + Pr\{p_u \leq \hat{p}_u\} \int_{\underline{p}_u}^{\hat{p}_u} \frac{p_u - \alpha_u - f^u}{\beta_u} dp_u$$

The equation above can be simplified into

$$\frac{(\hat{p}_u - \alpha_u) - f^u}{\beta_u}$$

When directly solving the firm's ex-ante Lagrangian in time period 2, the optimal choice of upstream capacity is given by

$$\frac{(\mathbb{E}[p_u] - \alpha_u + \sigma^v) - f^u}{\beta_u}$$

It is obvious that $\hat{p}_u = \mathbb{E}[p_u] + \sigma^v$.

It's important to note that the optimal choice of ex-ante upstream capacity in time period 2 depends on the expected upstream price, the industry-wide fixed cost f^u , firm-specific productivity shifters α_u and β_u , as well as the firm's valuation on risk reduction.

The optimal downstream capacity choice depends on additional factors including both the upstream capacity and the ex-ante uncertain upstream price. Since the Lagrangian requires the capacity to equal the expected output at optimality, the inner integral with respect to the upstream price can be simplified as an expectation operation. As a result, the integral over the upstream price reduces to $\mathbb{E}[p_u]$, and the integral over the upstream quantity reduces to the optimal upstream capacity, t_u^* . Consequently, the equation above can be rewritten as

$$\begin{aligned} t_d^* &= Pr\{(p_d - p_u) > \text{cutoff}\} \int_{\text{cutoff}}^{\max(p_d - p_u)} \frac{p_d - \mathbb{E}[p_u] - \alpha_d + t_u^* \mathbb{E}[p_{qd}^u] - f^d}{\beta_d + \mathbb{E}[p_{qd}^u] - p_{qd}^d} dp_d \\ &\quad + Pr\{(p_d - p_u) < \text{cutoff}\} \int_{\min(p_d - p_u)}^{\text{cutoff}} \frac{p_d - \mathbb{E}[p_u] - \alpha_d + t_u^* \mathbb{E}[p_{qd}^u] - f^d}{\beta_d + \mathbb{E}[p_{qd}^u] - p_{qd}^d} dp_d \\ &= \frac{\text{cutoff} - \alpha_d + t_u^* \mathbb{E}[p_{qd}^u] - f^d}{\beta_d + \mathbb{E}[p_{qd}^u] - \mathbb{E}[p_{qd}^d]} \end{aligned}$$

Directly solving the ex-ante Lagrangian of the downstream segment gives the optimal ca-

capacity

$$t_d^* = \frac{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_d + t_u^* \mathbb{E}[p_{q_d}^u] - f^d + \mathbb{E}[p_{q_d}^u] \sigma^v}{\beta_d + \mathbb{E}[p_{q_d}^u] - \mathbb{E}[p_{q_d}^d]}$$

Therefore, the cutoff price difference at which the downstream produces at full capacity is

$$\text{cutoff} = \mathbb{E}[p_d] - \mathbb{E}[p_u] + \mathbb{E}[p_{q_d}^u] \sigma^v$$

□

D.3 Proof for Lemma 3

Proof. In this proof, I analyze the four scenarios outlined at the beginning of Section 2.2.3. For each scenario, I construct the Lagrangian and derive both the ex-ante optimal capacity choice in time period 2 and the ex-post optimal production decision in time period 3. Finally, I consolidate the results from these four cases based on their domain of applicable price levels and derive the firm's overall optimal decision.

I apply the findings regarding the existence of cutoff prices as demonstrated in Appendix D.2. Specifically, when the price of intermediate goods is high, the upstream segment is likely to operate at full capacity. Similarly, when the price of final goods is high, the downstream segment tends to produce at full capacity. The discussion of the cutoff prices can be found towards the end of this proof.

In the following four subsections, I derive the firm's optimal choices in each of the four cases:

Case 1: Upstream at capacity, downstream below capacity

In this scenario, I study the case where the firm's upstream produces at full capacity and the downstream produces below full capacity. The corresponding Lagrangian is

$$\begin{aligned} \mathcal{L} = \int_{p_d} \int_{p_u} & \left[q_d [p_d - \alpha_0 - \alpha_u - \frac{1}{2} \beta_u t_u - \frac{1}{2} \beta_d q_d] + (t_u - q_d) [p_u - \alpha_u - \frac{1}{2} \beta_u t_u] \right. \\ & \left. - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma^v q_d + \lambda (t_d - q_d) \end{aligned}$$

The first-order condition with respect to t_u gives the optimal choice of

$$t_u^* = \int_{p_d} \int_{p_u} \frac{p_u - \alpha_u - q_d^*(p_u, p_d) p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u} dp_u dp_d$$

Because this case only concerns the situation where the upstream production hits the capacity constraint, the integration is only taken between the cutoff upstream price and the maximal upstream price level $\bar{p}_u$. Note that the optimal choice of upstream capacity, in this case, does not depend on the downstream price p_d or capacity t_d .

The first-order condition with respect to t_d gives the optimal choice for downstream capacity

$$t_d \geq \frac{\bar{p}_d - \underline{p}_u - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{q_d}^d}$$

Similar to Case 1 in the proof of Lemma D.2, if I assume that downstream capacity always satisfies the production requirements of the downstream segment, then the downstream capacity must exceed the optimal production quantity even at the highest downstream price, $\bar{p}_d$. However, as discussed earlier, the firm will not select a downstream capacity that meets production demand across all price levels. Therefore, this inequality is trivial.

The ex-post objective function from time period 3 is

$$q_d[p_d - \alpha_0 - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d q_d] + (t_u - q_d)[p_u - \alpha_u - \frac{1}{2}\beta_u t_u] - f^u t_u - f^d t_d$$

Setting up the Lagrangian and solving the first-order condition with respect to q_d gives the optimal choice of downstream production

$$q_d^* = \frac{p_d - p_u - \alpha_0 - f^d}{\beta_d - p_{q_d}^d}$$

Note that the optimal downstream production choice is independent of upstream capacity or production. It also does not depend on the partial derivatives of downstream quantity with respect to prices in the intermediate goods market. This is because, in this setup, the downstream segment receives its entire supply of intermediate goods from the upstream segment, meaning it does not participate in the intermediate goods market and is not constrained by the upstream's production levels. If the upstream segment is unable to fully supply the downstream's needs, the scenario reverts to Case 1 in the proof of Lemma D.2.

Case 2: upstream below capacity, downstream below capacity

In this case, I discuss the scenario where the firm's upstream and downstream both produce below capacity. The Lagrangian is

$$\begin{aligned} \mathcal{L} = \int_{p_d} \int_{p_u} & \left[q_d \left[p_d - \alpha_0 - \alpha_u - \frac{1}{2} \beta_u q_u - \frac{1}{2} \beta_d q_d \right] + (q_u - q_d) \left[p_u - \alpha_u - \frac{1}{2} \beta_u q_u \right] \right. \\ & \left. - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma^v q_d + \lambda_1 (t_u - p_u) + \lambda_2 (t_d - p_d) \end{aligned}$$

The first-order condition with respect to t_u and t_d gives the optimal choice of capacities:

$$\begin{aligned} t_u^* & \geq \frac{\bar{p}_u - \alpha_u - t_d^* p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u} \\ t_d & \geq \frac{\bar{p}_d - \underline{p}_u - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{q_d}^d} \end{aligned}$$

Since the firm never chooses an upstream capacity that is always higher than its optimal production choice, as discussed before, the capacity choice is trivial in this case. Similar arguments apply to the downstream segment.

The objective function when the firm observes the realized price levels is

$$q_d \left[p_d - \alpha_0 - \alpha_u - \frac{1}{2} \beta_u q_u - \frac{1}{2} \beta_d q_d \right] + (q_u - q_d) \left[p_u - \alpha_u - \frac{1}{2} \beta_u q_u \right] - f^u t_u - f^d t_d$$

Setting up the Lagrangian and solving the first-order conditions with respect to q_u and q_d give the optimal choice of downstream production:

$$\begin{aligned} q_u^* & = \frac{p_u - \alpha_u - q_d^* p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u} \\ q_d^* & = \frac{p_d - p_u - \alpha_0 - f^d}{\beta_d - p_{q_d}^d} \end{aligned}$$

The optimal upstream quantity depends solely on the upstream price and not on the downstream price. However, it does depend on the downstream quantity, as this case assumes that upstream production can always satisfy the demand of the downstream segment. Conversely, the optimal downstream quantity depends on both the upstream and downstream prices but, unlike in Case 2 in the proof of Lemma 2, is independent of the upstream quantity. It is worth noting that downstream production depends only on the firm's productivity, while

upstream production is influenced by the downstream production choice. Intuitively, the optimal upstream quantity increases with the firm's downstream output because utilizing in-house production is more cost-effective than outsourcing.

Case 3: upstream at capacity, downstream at capacity

In this case, I discuss the scenario where both the firm's upstream and downstream are producing at capacity. This would happen when the price level in both markets is high.

The objective function is

$$\int_{p_d} \int_{p_u} \left[t_d [p_d - \alpha_0 - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d t_d] + (t_u - t_d) [p_u - \alpha_u - \frac{1}{2}\beta_u t_u] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma^v t_d$$

The first-order conditions with respect to t_u and t_d give the following optimal choice of upstream and downstream capacity:

$$t_u^* = \int_{p_u} \frac{p_u - \alpha_u - t_d p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u} dp_u$$

$$t_d^* = \int_{p_d} \int_{p_u} \frac{p_d - p_u - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{q_d}^d} dp_u dp_d$$

Since this case assumes that the upstream segment is operating at full capacity, the integration is taken between the cutoff upstream price where the optimal choice of production is equal to the capacity and the maximal upstream price level.

Conditional on the downstream producing at capacity, the downstream does not depend on the upstream production. The inner integral is taken on the same range as the integral for t_u^* , and the outer integral is taken on a similar range: between the cutoff downstream price where the optimal choice of production is equal to the capacity and the maximal downstream price level.

Case 4: upstream below capacity, downstream at capacity

In this case, I study the scenario where the upstream produces below capacity but the downstream segment produces at full capacity. The Lagrangian of the objective function is

$$\mathcal{L} = \int_{p_d} \int_{p_u} \left[t_d [p_d - \alpha_0 - \alpha_u - \frac{1}{2}\beta_u q_u - \frac{1}{2}\beta_d t_d] + (q_u - t_d) [p_u - \alpha_u - \frac{1}{2}\beta_u q_u] - f^u t_u - f^d t_d \right] dp_u dp_d + \sigma^v t_d + \lambda(t_u - q_u)$$

The first-order condition with respect to t_u and t_d give

$$t_u^* \geq \frac{\bar{p}_u - \alpha_u - t_d p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u}$$

$$t_d^* = \int_{p_d} \int_{p_u} \frac{p_d - p_u - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{q_d}^d} dp_u dp_d$$

Note that since the firm will never choose an upstream capacity that is always higher than its optimal production choice, as discussed in case 2, the capacity choice is trivial in this case. As for the downstream capacity, note that the inner integral is taken on prices where the firm's upstream is producing below the capacity constraint. In particular, it will be between the minimal price $\underline{p}_u$ and the cutoff price where the firm produces at the chosen capacity. Since I assume the downstream produces at capacity in this case, the outer integral is taken from the cutoff downstream price to the maximal downstream price. The downstream cutoff price is the price under which the downstream produces at capacity, taken the expected upstream price as given.

The objective function when the firm observes the realized price levels is

$$t_d [p_d - \alpha_0 - \alpha_u - \frac{1}{2}\beta_u q_u - \frac{1}{2}\beta_d t_d] + (q_u - t_d) [p_u - \alpha_u - \frac{1}{2}\beta_u q_u] - f^u t_u - f^d t_d^*$$

Setting up the Lagrangian and solving for the first-order condition with respect to q_u gives

$$q_u^* = \frac{p_u - \alpha_u - t_d p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u}$$

Ex-ante choice of capacity, excessive upstream supply

Denote the cutoff price difference between the downstream and upstream price with cutoff. Based on the analysis from Case 1 to 4, the optimal choice of downstream capacity conditioning on the price tuple $(p_d - p_u) > \hat{\text{cutoff}}$ is

$$t_d^* = \int_{\underline{p}_u}^{\bar{p}_u} \int_{\hat{\text{cutoff}}}^{\bar{p}_d} \frac{p_d - p_u - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{t_d}^d} dp_d dp_u$$

and the optimal choice of upstream capacity conditioning on $p_u > \hat{p}_u$ is

$$t_u^* = \int_{\hat{p}_u}^{\bar{p}_u} \frac{p_u - \alpha_u - t_d^* p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u} dp_u$$

The optimal choice of downstream output conditioning on the price tuple $(p_d - p_u) < \hat{\text{cutoff}}$ is

$$q_d^* = \frac{p_d - p_u - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{q_d}^d}$$

and $q_d^* = t_d^*$ when $(p_d - p_u) \geq \hat{\text{cutoff}}$.

Given the downstream optimal production q_d^* , the optimal choice of upstream output conditioning on $p_u < \hat{p}_u$ is

$$q_u^* = \frac{p_u - \alpha_u - q_d^* p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u}$$

and $q_u^* = t_u^*$ when $p_u \geq \hat{p}_u$. Conditioning on the fact that $p_u < \hat{p}_u$ and $(p_d - p_u) < \hat{\text{cutoff}}$, the optimal choice of capacity will be calculated by the expectation taken among the corresponding price range.

Therefore, the optimal choice of downstream capacity is given by:

$$\begin{aligned} t_d^* = & Pr\{(p_d - p_u) > \hat{\text{cutoff}}\} \int_{\underline{p}_u}^{\bar{p}_u} \int_{\hat{\text{cutoff}}}^{\bar{p}_d} \frac{p_d - p_u - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{q_d}^d} dp_d dp_u \\ & + Pr\{(p_d - p_u) < \hat{\text{cutoff}}\} \int_{\underline{p}_u}^{\bar{p}_u} \int_{\underline{p}_d}^{\hat{\text{cutoff}}} \frac{p_d - p_u - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{q_d}^d} dp_d dp_u \end{aligned}$$

Since the Lagrangian requires capacity equal to the expected output at optimality, the inner integral with respect to the upstream price can simply be treated as an expectation

operation. Thus, the integral of the upstream price reduces to $\mathbb{E}[p_u]$ and the integral of the upstream quantity reduces to the optimal choice of upstream capacity t_u^* . Therefore, I can rewrite the equation above as

$$\begin{aligned} t_d^* &= Pr\{(p_d - p_u) > \text{cutoff}\} \int_{\text{cutoff}}^{\bar{p}_d} \frac{p_d - \mathbb{E}[p_u] - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{q_d}^d} dp_d \\ &\quad + Pr\{(p_d - p_u) < \text{cutoff}\} \int_{\underline{p}_d}^{\text{cutoff}} \frac{p_d - \mathbb{E}[p_u] - \alpha_0 - f^d + \sigma^v}{\beta_d - p_{q_d}^d} dp_d \\ &= \frac{\text{cutoff} - \alpha_0 - f^d + \sigma^v}{\beta_d - \mathbb{E}[p_{q_d}^d]} \end{aligned}$$

When directly solving the firm's ex-ante Lagrangian from time period 2, the optimal choice of capacity is

$$\frac{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_0 - f^d + \sigma^v}{\beta_d - \mathbb{E}[p_{q_d}^d]}$$

Therefore, the cutoff price difference in this case is

$$\text{cutoff} = \mathbb{E}[p_d] - \mathbb{E}[p_u] + \sigma^v$$

Given the ex-ante optimal choice of downstream capacity, the ex-ante optimal choice of upstream capacity is given by

$$\begin{aligned} t_u^* &= Pr\{p_u > \hat{p}_u\} \int_{\hat{p}_u}^{\bar{p}_u} \frac{p_u - \alpha_u - t_d^* p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u} dp_u + Pr\{p_u \leq \hat{p}_u\} \int_{\underline{p}_u}^{\hat{p}_u} \frac{p_u - \alpha_u - t_d^* p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u} dp_u \\ &= \frac{\hat{p}_u - \alpha_u - t_d^* \mathbb{E}[p_{q_u}^u] - f^u}{\beta_u - \mathbb{E}[p_{q_u}^u]} \end{aligned}$$

In addition to productivity shifters and expected intermediate goods price level, the optimal ex-ante choice of upstream capacity also depends on the optimal choice of downstream capacity.

When directly solving for the firm's ex-ante Lagrangian, the optimal choice of capacity is

$$\frac{\mathbb{E}[p_u] - \alpha_u - t_d^* \mathbb{E}[p_{q_u}^u] - f^u - \mathbb{E}[p_{q_u}^u] \sigma^v}{\beta_u - \mathbb{E}[p_{q_u}^u]}$$

Therefore, the cutoff value is

$$\hat{p}_u = \mathbb{E}[p_u] - \mathbb{E}[p_{q_u}^u] \sigma^v$$

□

D.4 Proof for Theorem 1

Proof. According to Lemma 1, 2, 3, and 4, the firm's productivity in one segment determines its ex-ante capacity choice in this segment in time period 2. The firm only expands into segments where it finds itself productive. Mathematically, the firm produces in one industry when $t^* > 0$, become vertically integrated if $t_d^* > 0$ and $t_u^* > 0$, and becomes a conglomerate firm when $t_d^* > 0$ and $t_r^* > 0$.

When the firm decides to stay specialized, it must be that $t_u^* < 0$, $t_r^* < 0$, and $t_d^* > 0$. Thus, I solve

$$\begin{aligned} t_i^{s_d*} &= \frac{\mathbb{E}[p^d] - \mathbb{E}[p^u] - \alpha_i^d - f_i^d}{\beta_i^d + \mathbb{E}[p_{q_d,i}^u] - \mathbb{E}[p_{q_d,i}^d]} > 0 \\ t_i^{v_u*} &= \frac{\mathbb{E}[p^u] - \alpha_i^u - f_i^u + \sigma_i^v}{\beta_i^u} < 0 \\ t_i^{c_r*} &= \frac{\mathbb{E}[p^r] - \alpha_i^r - f_i^r + \sigma_i^c}{\beta_i^r - \mathbb{E}[p_{q_r,i}^r]} < 0 \end{aligned}$$

which gives

$$\begin{aligned} \mathbb{E}[p^d] - \mathbb{E}[p^u] &> \alpha_i^d + f_i^d \\ \mathbb{E}[p^u] + \sigma_i^v &< \alpha_i^u + f_i^u \\ \mathbb{E}[p^r] + \sigma_i^c &< \alpha_i^r + f_i^r \end{aligned}$$

In other words, the specialized firm in the downstream industry d continues to focus on industry d when its ex-ante expected revenue $\mathbb{E}[p^d] - \mathbb{E}[p^u]$ exceeds some functions of downstream production costs $\alpha_i^d - f_i^d$. It does not enter the upstream industry u or the related industry r when its ex-ante expected revenue plus the benefits of risk mitigation still cannot cover the costs. Flipping the inequality signs in the last two equations indicates the firm operates in industry u and industry r .

Next, I show the conditions under which the vertical firm chooses to maintain a capacity surplus in the downstream segment. This is equivalent to $t_d^* > t_u^*$. Note that when a company chooses to go vertical, it captures the value of risk mitigation from the overlapping capacity between the upstream and the downstream segments, regardless of whether it allocates greater capacity to the upstream or downstream. Thus, I drop the value of risk mitigation

σ_i^v in both sides of the inequality below.

In the case where the firm has surplus capacity in the downstream ,

$$t_i^{v_d*} = \frac{\mathbb{E}[p^d] - \mathbb{E}[p^u] - \alpha_i^d + t_i^{v_u*} \mathbb{E}[p_{q_d,i}^u] - f_i^d}{\beta_i^d + \mathbb{E}[p_{q_d,i}^u] - \mathbb{E}[p_{q_d,i}^d]} > \frac{\mathbb{E}[p^u] - \alpha_i^u - f_i^u}{\beta_i^u} = t_i^{\tilde{v}_u*}$$

where $t_i^{\tilde{v}_u*}$ denotes the firm's choice of upstream capacity when there's no value for risk mitigation. This inequality can be simplified into

$$\frac{\mathbb{E}[p_u] - \alpha_u - f^u}{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_d - f^d} < \frac{\beta_u}{\beta_d - p_{q_d}^u}$$

Intuitively, the firm's decision to maintain capacity surplus in the downstream depends on the firm's comparative advantage in the two industries. The vertical firm chooses surplus capacity in the downstream when it is "relatively" more productive in the downstream.

In the case where the firm has a capacity deficit in the downstream,

$$t_i^{v_u*} = \frac{\mathbb{E}[p^u] - \alpha_i^u - t_i^{v_d*} \mathbb{E}[p_{q_u,i}^u] - f_i^u}{\beta_i^u - \mathbb{E}[p_{q_u,i}^u]} > \frac{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_i^d - f_i^d}{\beta_i^d - \mathbb{E}[p_{q_d,i}^d]} = t_i^{\tilde{v}_d*}$$

where $t_i^{\tilde{v}_d*}$ denotes the firm's choice of downstream capacity absent of the value of risk mitigation. This inequality can be simplified into

$$\frac{\mathbb{E}[p_u] - \alpha_u - f^u}{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_d - f^d} > \frac{\beta_u}{\beta_d - p_{q_d}^u}$$

which is the opposite of the case where there is a capacity surplus in the downstream. $\square$

D.5 Proof for the Discussion of the Specialized Upstream Firm

Proof. I want to show that for a specialized firm operating in the upstream segment u , there exists a cutoff price $\hat{p}_u = \mathbb{E}[p_u]$, above which the firm operates at full capacity. To do so, I will first establish that the specialized upstream firm will not select a capacity under which it operates at full capacity across all price levels. Next, I will show that the firm will not choose a capacity under which it consistently operates below full capacity for all price levels. Finally, I will prove that the firm chooses a capacity such that $\hat{p}_u = \mathbb{E}[p_u]$ serves as the cutoff price. Overall, the proof is very similar to the one in Appendix D.1.

First, I demonstrate that the specialized upstream firm will not operate at full capacity

across all upstream price levels, as the firm always has an incentive to increase its capacity in such a scenario. When the firm operates at full capacity, its optimal upstream production, q_u^* , under a binding constraint, exceeds its current capacity. By increasing its capacity by a small amount $\epsilon > 0$ such that $q_u^* > t_u + \epsilon$, the firm fully utilizes the additional capacity. The resulting change in the firm's profit is then given by:

$$\epsilon \left[\mathbb{E}[p_u] - \alpha_u - \frac{1}{2}\beta_u t_u^* - f^u \right]$$

which is strictly positive because $\alpha_u + \frac{1}{2}\beta_u t_u + f^u$ is just the cost of production and the firm will not produce if this condition fails.

In the extreme case, the firm's optimal choice of production is equal to its capacity under the minimal price $\underline{p_u}$. When the firm increases the upstream capacity by ϵ , with a probability of $Pr\{p_u < p_u(t_u^* + \epsilon)\}$, the firm's upstream is producing below full capacity. When ϵ is small, this probability tends to 0. In this case, the change in the firm's profit is given by

$$Pr\{p_u > p_u(t_u^* + \epsilon)\} \epsilon \left[\mathbb{E}[p_u] - \alpha_u - \frac{1}{2}\beta_u t_u^* \right] + Pr\{p_u < p_u(t_u^* + \epsilon)\} (q_u - t_u^*) \left[\mathbb{E}[p_u] - \alpha_u - \frac{1}{2}\beta_u t_u^* \right] - f^u \epsilon$$

where $\epsilon > q_u - t_u^* > 0$. When ϵ is small, this equation tends to

$$\mathbb{E}[p_u] - \alpha_u - \frac{1}{2}\beta_u t_u^* - f^u$$

so the firm has the incentive to increase its capacity by ϵ to increase its profits.

Next, I show that the firm will not choose a capacity at which it always produces below full capacity. Suppose the firm's upstream is not producing at full capacity under all possible upstream price levels. By choosing a capacity decrease by $\epsilon > 0$ such that $q_u^* < t_u - \epsilon$, not all upstream capacity is utilized even after the ϵ decrease in capacity. The change in the firm's profit is given by

$$\epsilon \left[\frac{1}{2} q_u \beta_u + f^u \right] > 0$$

Therefore, it is always profitable to decrease the upstream capacity when $q_u^* < t_u - \epsilon$ under all price levels. In the scenario when the firm is producing at all capacity when the intermediate good price is at its highest level, when the firm decreases its upstream capacity by ϵ , with a probability $Pr\{p_u > p_u(t_u^* - \epsilon)\}$, the firm's upstream is producing at full capacity. Since ϵ

is small, this probability tends to 0. In this case, the change in the firm's profit is given by:

$$\begin{aligned} &Pr\{p_u > p_u(t_u^* - \epsilon)\} \left[(t_u^* - \epsilon - q_u)[p_u - \alpha_u] + \frac{1}{2}\beta_u[q_u t_u - (t_u - \epsilon)^2] \right] + f^u \\ &Pr\{p_u < p_u(t_u^* - \epsilon)\} \epsilon \left[\frac{1}{2}q_u\beta_u \right] + \epsilon \end{aligned}$$

where $t_u^* - \epsilon - q_u < 0$. When ϵ is small, this degenerates to the earlier case. Therefore, I can always improve the firm's profits by cutting the firm's upstream capacity by $\epsilon > 0$.

Since production is monotonically increasing in price, there must exist a cutoff price $\bar{p}_u > \hat{p}_u > \underline{p}_u$ such that the firm produces at full capacity when $p > \hat{p}_u$. Therefore, the optimal choice of capacity conditioning on $p_u > \hat{p}_u$ is given by

$$t_u = \int_{\hat{p}_u}^{\bar{p}_u} \frac{(p_u - \alpha_u) - f^u}{\beta_u - p_{q_u}^u} dp_u$$

and the optimal choice of upstream output conditioning on price level $p_u < \hat{p}_u$ is given by solving the Lagrangian:

$$\mathcal{L} = q(p_u - \alpha - \frac{1}{2}bt_u) - f^u t + \lambda(t_u - q)$$

which gives

$$q_u^* = \frac{p_u - \alpha_u - f_u}{\beta_u - p_{q_u}^u}$$

The first-order condition of the Lagrangian states that at optimality, the capacity is equal to the output. Therefore, the optimal choice of upstream capacity is given by

$$Pr\{p_u > \hat{p}_u\} \int_{\hat{p}_u}^{\bar{p}_u} \frac{(p_u - \alpha_u) - f^u}{\beta_u - p_{q_u}^u} dp_u + Pr\{p_u \leq \hat{p}_u\} \int_{\underline{p}_u}^{\hat{p}_u} \frac{p_u - \alpha_u - f^u}{\beta_u - p_{q_u}^u}$$

To equate this expression with the optimal choice of capacity t_{*u} , I must let $\hat{p}_u = \mathbb{E}[p_u]$. Therefore, the cutoff price $\hat{p}_u$ is given by the expected price level $\mathbb{E}[p_u]$.

□

E Proofs for Section 2.3

E.1 Proof for Theorem 2

Proof. I will show that the partial derivative of a vertically integrated firm's profit with respect to the intermediate goods price, p_u , is smaller in magnitude than that of specialized firms and conglomerate firms. To establish this, I first compare the partial derivatives of the vertically integrated firm and the specialized firm. To complete the proof, I analyze the partial derivatives of the specialized firm and the vertically integrated firm across all eight cases: four cases where the vertically integrated firm has greater downstream capacity and four cases where it has greater upstream capacity. Finally, I briefly examine the partial derivatives of the conglomerate firm.

The specialized downstream firm

The expected profit of the specialized downstream firm given prices p_u and p_d is

$$\pi = \min\{q_d^*, t_d^*\} (p_d - a_0 - p_u - \frac{1}{2}b \min\{q_d^*, t_d^*\}) - f^d t_d$$

where q_d^* and t_d^* are given by the equations listed earlier in this section

$$q_{d_s}^* = \frac{p_d - p_u - \alpha_0 - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d} \quad t_{d_s}^* = \frac{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_0 - f^d}{\beta_d + \mathbb{E}[p_{q_d}^u] - \mathbb{E}[p_{q_d}^d]}$$

Thus, I have

$$q_d^* p_u = -\frac{1}{\beta_d + p_{q_d}^u - p_{q_d}^d} \quad t_u^* p_u = 0$$

When the specialized downstream firm is producing below capacity, the first derivative of its profit with respect to p_u is

$$\pi_s p_u = -\frac{2p_d - 2p_u - 2\alpha_0 - f^d - \frac{1}{2}\beta_d q_d^*}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

When the specialized downstream firm is producing at capacity, the first derivative is

$$\pi_s p_u = -t_d^*$$

which states that the firm does not change its production quantity.

Specialized upstream firm

The expected profit function of the specialized upstream firm given price p_u is

$$\pi = \min\{q_u^*, t_u^*\} \left(p_u - \alpha_u - \frac{1}{2}b \min\{q_u^*, t_u^*\} \right) - f^u t_u^*$$

where q_u^* and t_u^* are given by the equations listed earlier in this section

$$q_u^* = \frac{p_u - \alpha_u - f^u}{\beta_u - p_{q_u}^u} \quad t_u^* = \frac{\mathbb{E}[p_u] - \alpha_u - f^u}{\beta_u - \mathbb{E}[p_{q_u}^u]}$$

Note that

$$q_u^* p_u = \frac{1}{\beta_u - p_{q_u}^u} \quad t_u^* p_u = 0$$

Therefore, when the specialized upstream firm is producing below capacity,

$$\pi_u p_u = \frac{2p_u - 2\alpha_u - f^u - \frac{1}{2}\beta_u t_u^*}{\beta_u - p_{q_u}^u}$$

When the specialized upstream firm is producing at capacity,

$$\pi_u p_u = t_u^*$$

which simply implies that the firm does not change its production quantity.

The vertically integrated firm

For vertical firms with surplus downstream capacity (case 1.a to 4.a below), the optimal choice of upstream quantity, when the upstream is producing below full capacity, is

$$q_{u_v}^* = \frac{p_u - \alpha_u - f^u}{\beta_u}$$

and the optimal choice of downstream quantity when $p_d - p_u < \mathbb{E}[p_d] - \mathbb{E}[p_u]$ is

$$q_{d_v}^* = \frac{p_d - p_u - \alpha_0 + q_u^* p_{q_d}^u - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

The first derivatives of q_{uv}^* and q_{dv}^* with respect to p_u are

$$q_{uv}^* p_u = \frac{1}{\beta_u}$$

$$q_{dv}^* p_u = \frac{-\beta_u + p_{qd}^u}{\beta_u(\beta_d + p_{qd}^u - p_{qd}^d)}$$

For vertical firms with deficit downstream capacity (case 1.b to 4.b below), the optimal choice of downstream quantity when the downstream is producing below full capacity is

$$q_{dv}^* = \frac{p_d - p_u - \alpha_0 - f^d}{\beta_d - p_{qd}^d}$$

and the optimal choice of upstream quantity when the upstream is producing below full capacity is

$$q_{uv}^* = \frac{p_u - \alpha_u - q_d^* p_{qu}^u - f^u}{\beta_u - p_{qu}^u}$$

The first derivatives with respect to p_u are

$$q_{dv}^* p_u = -\frac{1}{\beta_d - p_{qd}^d}$$

$$q_{uv}^* p_u = \frac{\beta_d - p_{qd}^d + p_{qu}^u}{(\beta_u - p_{qu}^u)(\beta_d - p_{qd}^d)}$$

There are eight different cases to consider, corresponding to case 1.a through case 4.a and case 1.b through case 4.b. For each of these eight cases, I will show that the first derivative of the vertical firm's profit function is less in magnitude than that of the specialized firms. Therefore, I conclude that the expected profit of the vertical firm is less affected by the uncertainty in upstream prices. The detailed discussion can be found in the appendix.

Case 1.a

In this case, I discuss the scenario where the firm allocates surplus capacity to the downstream, the firm's upstream produces at capacity, and the firm's downstream produces below capacity. The profit is given by

$$\pi = t_u^* [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u^* - \frac{1}{2}\beta_d q_d^*] + (q_d - t_u^*) [p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_d^*] - f^u t_u^* - f^d t_d^*$$

and the first derivative with respect to p_u is given by

$$\pi p_u = \frac{-\beta_u + p_{qd}^u}{\beta_u(\beta_d + p_{qd}^u - p_{qd}^d)} [p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_d^*] - q_d^* + t_u^*$$

When there's an increase in the upstream price, the downstream segment of the vertically integrated firm will lose profits. It will decrease its production, and the per unit profit from downstream production decreases. The firm cannot further increase its upstream production. As a result, its profit is only increased by t_u^* .

I want to show the following inequality holds:

$$t_{u_s}^* > t_{u_v}^* + \frac{-\beta_u + p_{qd}^u}{\beta_u(\beta_d + p_{qd}^u - p_{qd}^d)} [p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{d_v}^*] - q_{d_v}^* > -\frac{2p_d - 2p_u - 2\alpha_d - f^d - \frac{1}{2}\beta_d q_{d_s}^*}{\beta_d + p_{qd}^u - p_{qd}^d}$$

Note that $t_{u_s}^* < t_{u_v}^*$ because the upstream segment of the vertically integrated firm eliminates the negative influence of "double marginalization" by producing everything in house. Since I assume the firm produces more in the downstream than in the upstream, and the per unit profit in the downstream decreases by the same amount as the per unit profit increase in the upstream, the firm is losing profits as p_u increases. As a result, the second term in this inequality is negative and the first inequality holds.

Notice that I can rewrite the first derivative of the vertically integrated firm's profit as

$$t_{u_v}^* + \frac{p_{qd}^u(p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{d_v}^*)}{\beta_u(\beta_d + p_{qd}^u - p_{qd}^d)} - \frac{2p_d - 2p_u - 2\alpha_d - f^d + t_{u_v}^* p_{qd}^u - \frac{1}{2}\beta_d q_{d_v}^*}{\beta_d + p_{qd}^u - p_{qd}^d}$$

where the third term represents change generated by the firm's loss in downstream profits due to the increase in upstream price, and the second term represents the change generated by the decrease in downstream production due to the increase in upstream price.

Rearranging the second inequality,

$$t_{u_v}^* + \frac{p_{qd}^u(p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{d_v}^*)}{\beta_u(\beta_d + p_{qd}^u - p_{qd}^d)} > \frac{t_{u_v}^* p_{qd}^u + \frac{1}{2}\beta_d(q_{d_v}^* - q_{d_s}^*)}{\beta_d + p_{qd}^u - p_{qd}^d}$$

Note that

$$\frac{t_{u_v}^* p_{qd}^u}{\beta_d + p_{qd}^u - p_{qd}^d} < \frac{1}{2} t_{u_v}^*$$

Under the Cournot framework, the magnitudes of the partial derivatives p_{qu}^u , p_{qd}^d , and p_{qd}^u increase with the number of firms in the market. The intuition is straightforward: the

partial derivative pq reflects the change in the market equilibrium price when each firm marginally increases its output by one unit. When there are many firms in the market, the total increase in output resulting from each firm producing an additional unit is larger compared to a market with fewer firms. Consequently, the price responds more significantly to the larger change in total output. For example, when there are more downstream firms in the final goods market than in the intermediate goods market, $p_{q_d}^u < |p_{q_d}^d|$.

Also note that because $\beta_d > 0$, $p_{q_d}^u > 0$, and $p_{q_d}^d < 0$,

$$\frac{t_{u_v}^* p_{q_d}^u + \frac{1}{2} \beta_d (q_{d_v}^* - q_{d_s}^*)}{\beta_d + p_{q_d}^u - p_{q_d}^d} < \frac{1}{2} (q_{d_v}^* - q_{d_s}^*)$$

Because the difference between $q_{d_v}^*$ and $q_{d_s}^*$ caused by vertically integrated firm's elimination of "double marginalization" when the intermediate goods are produced in-house, this difference should be less than the upstream production, and in this case, the upstream capacity. Also note that $p_d - p_u - \alpha_d - \frac{1}{2} \beta_d q_d$ is a necessary condition for production. Therefore, the second inequality also holds.

Case 2.a

In this case, I discuss the scenario where the firm allocates surplus capacity to the downstream segment and both the firm's upstream and downstream produce below the capacity constraint. The profit is

$$\pi = q_u^* [p_d - \alpha_d - \alpha_u - \frac{1}{2} \beta_u q_u^* - \frac{1}{2} \beta_d q_d^*] + (q_d^* - q_u^*) [p_d - p_u - \alpha_d - \frac{1}{2} \beta_d q_d^*] - f^u t_u^* - f^d t_d^*$$

The first derivative with respect to p_u is

$$\pi p_u = -(q_d^* - q_u^*) + \frac{p_u - \alpha_u - \frac{1}{2} \beta_u q_u^*}{\beta_u} + \frac{-\beta_u + p_{q_d}^u}{\beta_u (\beta_d + p_{q_d}^u - p_{q_d}^d)} [p_d - p_u - \alpha_d - \frac{1}{2} \beta_d q_d^*]$$

I want to show that

$$\frac{2p_u - 2\alpha_u - f^u - \frac{1}{2} \beta_u q_{u_s}^*}{\beta_u - p_{q_u}^u} > \pi p_u > -\frac{2p_d - 2p_u - 2\alpha_d - f^d - \frac{1}{2} \beta_d q_{d_s}^*}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

In the first inequality, note that the vertically integrated firm faces an increase in its upstream segment's profits and a decrease in its downstream segment's profits. Since the final goods price is held fixed, the downstream price will go down by the same amount as the upstream

price goes up. Since I assume that the upstream production is less than the downstream production, this vertically integrated firm is actually losing some profits after an increase in upstream price. Thus, the first inequality holds.

Note that πp_u can be re-written as

$$q_{uv}^* + \frac{p_u - \alpha_u - \frac{1}{2}\beta_u q_{uv}^*}{\beta_u} + \frac{p_{q_{dv}}^u (p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{dv}^*)}{\beta_u (\beta_d + p_{q_d}^u - p_{q_d}^d)} - \frac{2p_d - 2p_u - 2\alpha_d - f^d - \frac{1}{2}\beta_d q_{dv}^*}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

without looking at the term $\frac{p_u - \alpha_u - \frac{1}{2}\beta_u q_{uv}^*}{\beta_u}$, this question reduces to the second inequality in case 1. Since $p_u - \alpha_u - \frac{1}{2}\beta_u q_{uv}^*$ is a necessary condition for the upstream segment to produce, the term $\frac{p_u - \alpha_u - \frac{1}{2}\beta_u q_{uv}^*}{\beta_u}$ is positive. In addition, its interpretation is the increase in the upstream production due to the increase in the intermediate goods price, so it naturally is positive. Therefore, the second inequality also holds.

Case 3.a

In this case, I discuss the scenario where the firm allocates surplus capacity to the downstream segment, and both of the firm's upstream and downstream segments produce at full capacity. The expected profit function is given by

$$\pi = t_u^* [p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u^* - \frac{1}{2}\beta_d t_d^*] + (t_d^* - t_u^*) [p_d - p_u - \alpha_d - \frac{1}{2}\beta_d t_d^*] - f^u t_u^* - f^d t_d^*$$

and the first derivative with respect to p_u is

$$\pi p_u = t_{uv}^* - t_{dv}^*$$

which is just the capacity difference between the upstream and downstream. When the upstream has higher capacity, then the firm will make more profits. Otherwise, the firm will still lose some profits.

I want to show that

$$t_{us}^* > t_{uv}^* - t_{dv}^* > -t_{ds}^*$$

Notice that $t_{dv}^* - t_{ds}^*$ is the capacity expansion generated by the elimination of double marginalization when things are produced in-house. This is caused by the simple fact that the firm is also producing in the upstream segment. Therefore, it has to be the case that the upstream segment's capacity is greater than the expansion in its downstream segment when

the downstream firm backward integrates.

Case 4.a

In this case, I discuss the scenario where the vertical firm allocates surplus capacity to the downstream, and on the firm's downstream segment produces at capacity constraint. The expected profit function is given by

$$\pi = q_u^*[p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u q_u^* - \frac{1}{2}\beta_d t_d^*] + (t_d^* - q_u^*)[p_d - p_u - \alpha_d - \frac{1}{2}\beta_d t_d^*] - f^u t_u^* - f^d t_d^*$$

and the first derivative with respect to p_u is

$$\pi_{p_u} = \frac{p_u - \alpha_u - \frac{1}{2}\beta_u q_u^*}{\beta_u} - (t_d^* - q_u^*) = \frac{2p_u - 2\alpha_u - f^u - \frac{1}{2}\beta_u q_u^*}{\beta_u} - t_d^*$$

Whether this first derivative is positive or negative is undetermined. When the upstream price increases, the upstream segment of the vertically integrated firm can make more profits through two channels: the higher upstream market price and the higher output quantity. The firm is also losing profits in the downstream segment because each unit of intermediate input is more expensive. Productivity shifters of the firm determine whether the firm's profit in the upstream segment can offset the loss in the downstream.

I want to show that

$$\frac{2p_u - 2\alpha_u - f^u - \frac{1}{2}\beta_u q_{u_s}^*}{\beta_u - p_{q_u}^u} > \frac{2p_u - 2\alpha_u - f^u - \frac{1}{2}\beta_u q_{u_v}^*}{\beta_u} - t_{d_v}^* > -t_{d_s}^*$$

The first term represents the derivative of the specialized upstream firm's profits with respect to intermediate goods price. The middle term captures the change in the vertically integrated firm's profits, which experiences an increase in its upstream segment's profits but a decrease in its downstream segment's profits. Since the final goods price is held constant, any increase in the upstream price results in an equivalent decrease in the downstream price. Given the assumption that upstream production is less than downstream production, the vertically integrated firm experiences an overall reduction in profits following an increase in the upstream price. Therefore, the first inequality holds.

As for the second inequality, $t_{d_v}^* > t_{d_s}^*$ because the vertically integrated firm gets rid of the negative influence of double marginalization. Thus, it has to be the case that the upstream segment's production is greater than the expansion in its downstream segment.

Note that $\frac{p_u - \alpha_u - \frac{1}{2}\beta_u t_u}{\beta_u} > 0$ is a necessary condition for the upstream to produce. Thus, $\frac{2p_u - 2\alpha_u - f^u - \frac{1}{2}\beta_u t_{uv}^*}{\beta_u}$ is greater than the expansion in the downstream segment of the vertically integrated firm. Since the downstream price will go down by the same amount as the upstream price goes up, the second inequality also holds.

Case 1.b

In this case, I discuss the scenario where the vertical firm allocates deficit capacity to the downstream, the firm's upstream produces at capacity, and the firm's downstream produces below capacity. The profit function is

$$\pi = q_d \left[p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d q_d \right] + (t_u - q_d) \left[p_u - \alpha_u - \frac{1}{2}\beta_u t_u \right] - f^u t_u - f^d t_d$$

and the derivative with respect to p_u is

$$\pi p_u = t_{uv} - q_{dv} - \frac{1}{\beta_d - p_{qd}^d} \left[p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{dv} \right]$$

and I want to show that

$$t_{us}^* > t_{uv} - q_{dv} - \frac{p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{dv}}{\beta_d - p_{qd}^d} > -\frac{2p_d - 2p_u - 2\alpha_d - f^d - \frac{1}{2}\beta_d q_{ds}^*}{\beta_d + p_{qd}^u - p_{qd}^d}$$

Note that the per unit profit in the downstream decreases by the same amount as the per unit profit increase in the upstream. Since I assume the firm produces more in the upstream than in the downstream, when p_u increases, the firm is making positive profits. Thus, the second inequality naturally holds. In fact, the same argument can also be applied to case 2.b to case 4.b.

As for the first inequality, since $p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{dv} > 0$ is a necessary condition for the downstream segment to produce, the third term of the right-hand side of the first inequality is negative. Even though $t_{us} < t_{uv}$, this difference in capacity is caused by the elimination of the double marginalization issue when the specialized upstream firm forward integrates. Thus, it has to be the case that the downstream segment's size should be far greater than the capacity difference before and after the specialized upstream firm forward integrates. Therefore, the first inequality holds.

Case 2.b

In this case, I discuss the scenario where the vertical firm allocates surplus capacity to the upstream segment and both the firm's upstream and downstream produce below the capacity constraint. The profit function is

$$\pi = q_d[p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u q_u - \frac{1}{2}\beta_d q_d] + (q_u - q_d)[p_u - \alpha_u - \frac{1}{2}\beta_u q_u] - f^u t_u - f^d t_d$$

and the derivative with respect to p_u is

$$\pi p_{u_v} = \frac{\beta_d - p_{q_d}^d + p_{q_u}^u}{(\beta_u - p_{q_u}^u)(\beta_d - p_{q_d}^d)}[p_u - \alpha_u - \frac{1}{2}\beta_u q_{u_v}] - \frac{1}{\beta_d - p_{q_d}^d}[p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{d_v}] + q_{u_v} - q_{d_v}$$

and I want to show that

$$\begin{aligned} \frac{2p_u - 2\alpha_u - f^u - \frac{1}{2}\beta_u q_{u_s}^*}{\beta_u - p_{q_u}^u} &> \frac{\beta_d - p_{q_d}^d + p_{q_u}^u}{(\beta_u - p_{q_u}^u)(\beta_d - p_{q_d}^d)}[p_u - \alpha_u - \frac{1}{2}\beta_u q_{u_v}] - \frac{1}{\beta_d - p_{q_d}^d}[p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{d_v}] \\ &+ q_{u_v} - q_{d_v} > -\frac{2p_d - 2p_u - 2\alpha_d - f^d - \frac{1}{2}\beta_d q_d^*}{\beta_d + p_{q_d}^u - p_{q_d}^d} \end{aligned}$$

As discussed in case 1.b, the second inequality always holds by the assumption that the firm produces more in the upstream segment than in the downstream segment. As for the first inequality, I can rewrite the first derivative of the vertical firm's profit function as

$$\frac{2p_u - 2\alpha_u - f^u - \frac{1}{2}\beta_u q_{u_v}^*}{\beta_u - p_{q_u}^u} + \frac{p_{q_u}^u[p_u - \alpha_u - \frac{1}{2}\beta_u q_{u_v}]}{(\beta_u - p_{q_u}^u)(\beta_d - p_{q_d}^d)} - \frac{p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{d_v}}{\beta_d - p_{q_d}^d} - q_{d_v}$$

Subtracting the left-hand side of the first inequality from both sides of the inequality, I am left with the difference between the left-hand side and the right-hand side of the following equation

$$-\frac{\frac{1}{2}\beta_u(q_{u_v}^* - q_{u_s}^*)}{\beta_u - p_{q_u}^u} + \frac{p_{q_u}^u[p_u - \alpha_u - \frac{1}{2}\beta_u q_{u_v}]}{(\beta_u - p_{q_u}^u)(\beta_d - p_{q_d}^d)} - \frac{p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{d_v}}{\beta_d - p_{q_d}^d} - q_{d_v}$$

and I want to show that this is negative. Since $q_{u_v}^* > q_{u_s}^*$, the first term is negative. Since $p_u - \alpha_u - \frac{1}{2}\beta_u q_u$ is a necessary condition for the upstream segment to produce and $p_{q_u}^u < 0$, the second term is negative. Similarly, $p_d - p_u - \alpha_d - \frac{1}{2}\beta_d q_{d_v} > 0$ is a necessary condition for the downstream segment to produce, which implies the third term is also negative. Therefore, the expression above is negative, as desired.

Case 3.b

In this case, I study the scenario where the firm maintains a deficit surplus in the downstream, and both the firm's upstream and downstream produce at capacity. The expected profit function is given by:

$$\pi = t_d[p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u t_u - \frac{1}{2}\beta_d t_d] + (t_u - t_d)[p_u - \alpha_u - \frac{1}{2}\beta_u t_u] - f^u t_u - f^d t_d$$

and the derivative with respect to p_u is

$$\pi p_u = t_{u_v}^* - t_{d_v}^*$$

I want to show that

$$t_{u_s}^* > t_{u_v}^* - t_{d_v}^* > -t_{d_s}^*$$

Notice that the difference between $t_{u_v}^*$ and $t_{u_s}^*$ is the capacity expansion generated by the elimination of double marginalization when things are produced in-house. Since the firm is also producing in the downstream segment, it has to be the case that the downstream segment's capacity is greater than the expansion in its upstream segment when the upstream firm forward integrates.

Case 4.b

In this case, I study the scenario where the vertical firm maintains deficit capacity in the downstream, and only the firm's downstream produces at capacity constraint. The expected profit function is given by

$$\pi = t_d[p_d - \alpha_d - \alpha_u - \frac{1}{2}\beta_u q_u - \frac{1}{2}\beta_d t_d] + (q_u - t_d)[p_u - \alpha_u - \frac{1}{2}\beta_u q_u] - f^u t_u - f^d t_d$$

and the derivative with respect to p_u is

$$\pi p_u = q_u - t_d + \frac{\beta_d - p_{q_d}^d + p_{q_u}^u}{(\beta_u - p_{q_u}^u)(\beta_d - p_{q_d}^d)}[p_u - \alpha_u - \frac{1}{2}\beta_u q_u]$$

and I want to show that

$$\frac{2p_u - 2\alpha_u - f^u - \frac{1}{2}\beta_u q_u^*}{\beta_u - p_{q_u}^u} > q_{u_v} - t_{d_v} + \frac{\beta_d - p_{q_d}^d + p_{q_u}^u}{(\beta_u - p_{q_u}^u)(\beta_d - p_{q_d}^d)}[p_u - \alpha_u - \frac{1}{2}\beta_u q_{u_v}] > -t_{d_s}^*$$

As discussed in case 1.b, the second inequality always holds by the assumption that the firm produces more in upstream than in downstream. As for the first inequality, I can rewrite the first derivative of the vertical firm's profit function as

$$\frac{2p_u - 2\alpha_u - f^u - \frac{1}{2}\beta_u q_{uv}^*}{\beta_u - p_{qu}^u} + \frac{p_{qu}^u [p_u - \alpha_u - \frac{1}{2}\beta_u q_{uv}]}{(\beta_u - p_{qu}^u)(\beta_d - p_{qd}^d)} - q_{dv}$$

Subtracting the left-hand side of the first inequality from both sides of the inequality, I am left with the difference between the left-hand side and the right-hand side of the following equation

$$-\frac{\frac{1}{2}\beta_u(q_{uv}^* - q_{us}^*)}{\beta_u - p_{qu}^u} + \frac{p_{qu}^u [p_u - \alpha_u - \frac{1}{2}\beta_u q_{uv}]}{(\beta_u - p_{qu}^u)(\beta_d - p_{qd}^d)} - q_{dv}$$

and I want to show that this is negative. Since $q_{uv}^* > q_{us}^*$, the first term is negative. Since $p_u - \alpha_u - \frac{1}{2}\beta_u q_u$ is a necessary condition for the upstream segment to produce and $p_{qu}^u < 0$, the second term is negative. Therefore, the expression above is negative, and the first inequality holds.

This completes the proof for comparing the partial derivative of profits of the vertical firm and the specialized firm with respect to intermediate goods price p_u .

The conglomerate firm

Note that

$$\frac{\partial \pi_c}{\partial p_u} = \frac{\partial \pi_s}{\partial p_u} + \frac{\partial \pi_r}{\partial p_u}$$

Suppose that the intermediate goods pricing p_u is independent with the demand for industry r outputs, then

$$\frac{\partial \pi_c}{\partial p_u} = \frac{\partial \pi_s}{\partial p_u}$$

and

$$\left| \frac{\partial \pi_c}{\partial p_u} \right| = \left| \frac{\partial \pi_s}{\partial p_u} \right| > \left| \frac{\partial \pi_v}{\partial p_u} \right|$$

In this case, conglomeration does not provide any risk mitigation benefits. Suppose

$$\frac{\partial \pi_{cr}}{\partial p_u} < 0$$

This implies

$$\left| \frac{\partial \pi_c}{\partial p_u} \right| > \left| \frac{\partial \pi_s}{\partial p_u} \right| > \left| \frac{\partial \pi_v}{\partial p_u} \right|$$

In this case, conglomeration amplifies uncertainties in returns compared to the specialized firm or the vertical firm. Finally, suppose

$$\frac{\partial \pi_{c_r}}{\partial p_u} > 0$$

Since $\partial \pi_s / \partial p_u < 0$,

$$\left| \frac{\partial \pi_s}{\partial p_u} \right| > \left| \frac{\partial \pi_c}{\partial p_u} \right|$$

In this case, conglomeration reduces variances in returns compared to the specialized firm. □

E.2 Proof for Theorem 3

Proof. I will show that the partial derivative of vertically integrated firm's profit with respect to the final goods price in industry, p_d , is larger in magnitude than that of the specialized firm. When the price in the related industry r is not affected or less affected by p_d than the price in the upstream industry u , then the partial derivative of vertically integrated firm's profit with respect to p_d is also larger in magnitude than that of the conglomerate firm. I will first derive the partial derivative of specialized firm's and conglomerate firm's profit function with respect to p_d and compare them with the partial derivatives of the vertical firm.

Specialized downstream firm

Suppose p_u is a function of p_d . Mathematically, $p_u = g(p_d)$. When the final goods price increases, so does the intermediate goods price level. Note that $0 < g'(\mathbb{E}[p_d]) < 1$. The increment of the upstream price should be less than the final goods price because the downstream firms also have the market power to price above marginal cost. I also require that $p_u < p_d$.

The expected profit of the specialized downstream firm given prices p_u and p_d is

$$\pi = \min\{q_d^*, t_d^*\} (p_d - p_u - \alpha_d - \frac{1}{2}b \min\{q_d^*, t_d^*\}) - f^d t_d^*$$

where q_d^* and t_d^* are given by the equations listed earlier in this section

$$q_{d_s}^* = \frac{p_d - p_u - \alpha_d - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d} \quad \text{and} \quad t_{d_s}^* = \frac{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_d - f^d}{\beta_d + \mathbb{E}[p_{q_d}^u] - \mathbb{E}[p_{q_d}^d]}$$

Therefore,

$$q_{s_d}^* p_d = \frac{1 - g'(p_d)}{\beta_d + p_{q_d}^u - p_{q_d}^d} \quad \text{and} \quad t_u^* p_d = 0$$

The ex-ante chosen capacity from time period 2 is not affected by the realized demand shocks, while the actual production is determined by the realized price, which takes into account the demand shocks.

When the specialized downstream firm is producing below capacity, the first derivative of its profit with respect to p_d is

$$\pi_{s_d} p_d = q_d p_d \cdot [p_d - p_u - \alpha_d - \beta_d q_d] + q_d (1 - g'(p_d))$$

When the specialized downstream firm is producing at capacity, the firm still produces at capacity. Consequently, the derivative of its profit with respect to price is

$$\pi_{s_d} p_d = t_d^*$$

The Conglomerate firm

The conglomerate firm consists of two independent segments, the downstream segment d and the related subsidiary in industry r . Ex-post, after shocks are realized in time period 3, its profit is given by

$$\begin{aligned} \pi_c = & \left[\min\{q_d^*, t_d^*\} (p_d - p_u - \alpha_d - \frac{1}{2} \beta_d \min\{q_d^*, t_d^*\}) - f_d t_d \right] \\ & + \left[\min\{q_r^*, t_r^*\} (p_r - \alpha_r - \frac{1}{2} \beta_r \min\{q_r^*, t_r^*\}) - f_r t_r \right] \end{aligned}$$

Notice that its downstream segment shows results similar to those of a comparable specialized downstream firm. As for its operation in industry r , production quantity q_r^* in time

period 3 and capacity t_r^* in time period 2 are given by

$$q_r^* = \frac{p_r - \alpha_r - f_r}{\beta_r - p_{q_r}^r} \quad \text{and} \quad t_r^* = \frac{\mathbb{E}[p_r] - \alpha_r - f_r}{\beta_r - \mathbb{E}[p_{q_r}^r]}$$

Since the ex-ante chosen capacity from time period 2 is not affected by the realized demand shocks,

$$t_r^* p_d = 0$$

As for q_r^* , suppose p_r is not affected by the demand shock in industry d . In this case, p_r independent of p_d , and I have

$$p_r^* p_d = 0$$

Suppose the demand shock to industry d is decreasing in the demand shocks in industry r . In this case, p_r is negatively correlated with p_r . Then

$$p_r^* p_d < 0$$

Suppose the demand shock to industry d is increasing in the demand shocks in industry r . In this case, p_r is positively correlated with p_r . Then

$$p_r^* p_d > 0$$

Therefore, the partial derivative of the conglomerate firm's profit with respect to p_d is given by

$$\pi_c p_d = p_d \pi_{c_d} + p_d \pi_{c_r}$$

When the conglomerate firm's segment in industry d produces below capacity,

$$p_d \pi_{c_d} = q_d p_d \cdot [p_d - p_u - \alpha_d - \beta_d q_d] + q_d (1 - g'(p_d))$$

When the conglomerate firm's segment in industry d produces at full capacity,

$$p_d \pi_{c_d} = t_d^*$$

As for the conglomerate firm's segment in industry r , when p_r is not affected by the demand shock in industry d , then

$$p_r^* p_d = 0 \implies p_d \pi_{c_r} = 0$$

When the demand shock to industry d is increasing in demand shocks in industry r , then

$$p_r^* p_d < 0 \implies p_d \pi_{c_r} < 0$$

When the demand shock to industry d is decreasing in demand shocks in industry r , let us first define the relationship between p_d and p_r . In a similar fashion, let's define $p_r = k(p_d)$. I restrict their relationship to be $p_r p_d < 1$. Namely, the demand shock to industry d hits industry d more heavily than the related industry r . In this case, when the segment r of the conglomerate firm is operating at full capacity, the change in profit under demand shock to industry d is

$$p_d \pi_{c_r} = p_r \pi_{c_r} p_r p_d = t_{c_r}^* k'(p_d)$$

When the segment r of the conglomerate firm is operating below full capacity, the change in profit under the industry-specific demand shock to industry d is

$$p_d \pi_{c_r} = \frac{k'(p_d)}{\beta_r - p_{q_r}^r} \left[(2p_r - 2\alpha_r - f^r) - \frac{\beta_r}{\beta_r - p_{q_r}^r} (p_r - \alpha_r - f^r) \right]$$

The vertical firm

Here, I compare profit volatility across the three firm types without explicitly incorporating the value of risk reduction, providing justification for my parameterization of non-negative risk mitigation in Section 2.2. Consequently, when referencing results from Section 2.2, I omit the firm's risk reduction value σ .

For vertical firms with surplus downstream capacity, Section 2.2.2 states that its optimal choice of upstream quantity when the upstream segment is producing below full capacity is

$$q_{v_u}^* = \frac{p_u - \alpha_u - f^u}{\beta_u}$$

and the optimal choice of downstream quantity when $p_d - p_u < \mathbb{E}[p_d] - \mathbb{E}[p_u]$ is

$$q_{v_d}^* = \frac{p_d - p_u - \alpha_0 + q_u^* p_{q_d}^u - f^d}{\beta_d + p_{q_d}^u - p_{q_d}^d}$$

The derivatives of $q_{v_u}^*$ and $q_{v_d}^*$ with respect to p_d are

$$q_{v_u}^* p_d = \frac{g'(p_d)}{\beta_u} > 0$$

$$q_{v_d}^* p_d = \frac{\beta_u - (\beta_u - p_{q_d}^u)g'(p_d)}{\beta_u(\beta_d + p_{q_d}^u - p_{q_d}^d)} > 0$$

For vertical firms with downstream capacity deficit, Section 2.2.3 states that the optimal choice of downstream quantity when the downstream is producing below full capacity is

$$q_{v_d}^* = \frac{p_d - p_u - \alpha_0 - f^d}{\beta_d - p_{q_d}^d}$$

and the optimal choice of upstream quantity when the upstream is producing below full capacity is

$$q_{v_u}^* = \frac{p_u - \alpha_u - q_d^* p_{q_u}^u - f^u}{\beta_u - p_{q_u}^u}$$

The derivatives with respect to p_d are

$$q_{v_d}^* p_d = \frac{1 - g'(p_d)}{\beta_d - p_{q_d}^d} > 0$$

$$q_{v_u}^* p_d = \frac{(\beta_d - p_{q_d}^d)g'(p_d) - p_{q_u}^u[1 - g'(p_d)]}{(\beta_u - p_{q_u}^u)(\beta_d - p_{q_d}^d)} > 0$$

By definition, the cutoff price tuple $(\hat{p}_u, \hat{p}_d)$ for the downstream segment of the vertical firm is the lowest price at which the firm's downstream segment produces at full capacity. This expected upstream-downstream price difference also defines the cutoff price tuples for the specialized downstream firm. Thus, the vertical firm and the specialized firm face the same cutoff price in the downstream industry d .¹¹

Therefore, I only need to consider two scenarios when comparing the risk in expected returns for the specialized firm and the vertical firm

1. $p_d - p_u \geq \mathbb{E}[p_d - p_u]$
2. $p_d - p_u < \mathbb{E}[p_d - p_u]$

In the first scenario where $p_d - p_u \geq \mathbb{E}[p_d - p_u]$, both the specialized downstream firm

11. I omit the firm's risk reduction value σ in the proof here.

and the vertical firm's downstream segment produce at full capacity. In this case,

$$\pi_{s_d} p_d = t_{s_d}^* \quad \text{and} \quad \pi_{v_d} p_d = t_{v_d}^*$$

Note that

$$t_{v_d}^* = \begin{cases} \frac{\mathbb{E}[p_u] - \alpha_u - f^u}{\beta_u}, & \text{if } t_{v_d}^* < t_{v_u}^* \\ \frac{\mathbb{E}[p_d] - \mathbb{E}[p_u] - \alpha_0 + t_u^* \mathbb{E}[p_{q_d}^u] - f^d}{\beta_d + \mathbb{E}[p_{q_d}^u] - \mathbb{E}[p_{q_d}^d]}, & \text{if } t_{v_d}^* > t_{v_u}^* \end{cases}$$

$$t_{s_d}^* = \frac{\mathbb{E}[p_u] - \alpha_u - f^u}{\beta_u - \mathbb{E}[p_{q_u}^u]}$$

Thus, I observe that the specialized downstream firm restricts its capacity at every possible expected price level compared to the vertical firm. This implies

$$t_{s_d}^* < t_{v_d}^* \implies \pi_{v_d} p_d > \pi_{s_d} p_d$$

In the second scenario, there are three cases to discuss. The firm can maintain capacity surplus in either the upstream segment or the downstream segment. If the firm allocates surplus capacity to the downstream segment, its upstream segment may operate at either full capacity or below full capacity. Conversely, if the firm allocates surplus capacity to the upstream segment, its upstream segment always operates below full capacity in this scenario.

I can expand the partial derivative of the vertical firm's optimal profit function as

$$\pi_v p_d = \underbrace{q_d p_d \cdot [p_d - p_u - \alpha_d - \beta_d q_d] + q_d (1 - g'(p_d))}_{\text{part 1}} + \underbrace{q_u p_d \cdot [p_u - \alpha_u - \beta_u q_u] + q_u g'(p_d)}_{\text{part 2}} \quad (2.1)$$

Part 1 specifies the change in profits generated by the downstream segment, while Part 2 specifies the change in profits caused by the upstream segment. For each of the three cases, I will show that *part 1* $>$ $\pi_{s_d} p_d$.

Case 1: $p_d - p_u < \mathbb{E}[p_d - p_u]$, surplus capacity at downstream, upstream below capacity

In this case, I will plug in the corresponding expression for $\pi_{v_d} p_d$, q_{v_d} , and q_{v_u} . Subtracting $\pi_{s_d} p_d$ from part 1 of Equation (2.1),

$$q_d p_d \cdot [p_d - p_u - \alpha_d] + (q_{v_d} - q_{s_d})(1 - g'(p_d)) - \beta_d \left(q_{v_d} q_{v_d} p_d - q_{s_d} q_{s_d} p_d \right)$$

Expanding this expression,

$$\begin{aligned} & \frac{p_{q_d}^u}{\beta_u(\beta_d + p_{q_d}^u - p_{q_d}^d)} \left[\underbrace{g'(p_d)(p_d - p_u - \alpha_d)}_A + \underbrace{(1 - g'(p_d))[p_u - \alpha_u - f^u]}_B \right] \\ & - \underbrace{\frac{p_{q_d}^u g'(p_d)[p_d - p_u - \alpha_d - f^d]}{\beta_u(\beta_d + p_{q_d}^u - p_{q_d}^d)^2}}_C - \underbrace{\frac{p_{q_d}^u(1 - g'(p_d))[p_u - \alpha_u - f^u]}{\beta_u(\beta_d + p_{q_d}^u - p_{q_d}^d)^2}}_D - \underbrace{\frac{(p_{q_d}^u)^2 g'(p_d)[p_u - \alpha_u - f^u]}{\beta_u^2(\beta_d + p_{q_d}^u - p_{q_d}^d)^2}}_E \end{aligned}$$

Assume $\beta_d + p_{q_d}^u - p_{q_d}^d > 2p_{q_d}^u$, then

$$\frac{1}{2} \frac{p_{q_d}^u}{\beta_u(\beta_d + p_{q_d}^u - p_{q_d}^d)} > \frac{p_{q_d}^u}{\beta_u(\beta_d + p_{q_d}^u - p_{q_d}^d)^2}$$

This condition is not hard to satisfy as long as the upstream and the downstream are not highly concentrated. Therefore, it is obvious that $\frac{1}{2}A > C$ and $\frac{1}{2}B > D$.

What is left for us to show is that $\frac{1}{2}A + \frac{1}{2}B > E$. Simplifying the question in a similar fashion, then

$$g'(p_d)(p_d - p_u - \alpha_d) + (1 - g'(p_d))[p_u - \alpha_u - f^u] > \frac{p_{q_d}^u}{\beta_u} g'(p_d)[p_u - \alpha_u - f^u]$$

Further assume $\beta_u > p_{q_d}^u$. This requires that the firm's buyer power in the upstream market is not too high. Then the question becomes

$$g'(p_d)(p_d - p_u - \alpha_d) + (1 - g'(p_d))[p_u - \alpha_u - f^u] > g'(p_d)[p_u - \alpha_u - f^u]$$

In fact, $g'(p_d)$ represents the relative market power of upstream firms in the vertical supply chain. The higher the value of $g'(p_d)$, the higher the profit margin is for upstream firms compared to that of downstream firms. The central idea is that when the downstream

market power is small, the final goods demand curve is close to the intermediate goods demand curve. This would lead to only a small difference in p_u and p_d , which is equivalent to a high value of $g'(p_d)$.

Now I want to show that

$$g'(p_d)(p_d - p_u - \alpha_d) + (1 - 2g'(p_d))[p_u - \alpha_u - f^u] > 0$$

Since $g'(p_d) < 1$, this inequality always holds when $p_d - p_u - \alpha_d > p_u - \alpha_u - f^u$. Note that $p_d - p_u - \alpha_d - f^d$ represents the per-unit profitability for the downstream firm when making ex-ante capacity decisions, and $p_u - \alpha_u - f^u$ represents the ex-ante profitability of the upstream firm in time period 2. Intuitively, this is just saying that the per-unit profit in the downstream plus its per-unit capacity fixed cost is higher than the per-unit profit in the upstream. Since there's surplus capacity in the downstream in this case,

$$\frac{p^d - p^u - \alpha^d - f^d}{p^u - \alpha^u - f^u} \geq \frac{\beta^d - p_{qd}^d}{\beta^u} \implies p^d - p^u - \alpha^d > (p^u - \alpha^u - f^u) \frac{\beta^d - p_{qd}^d}{\beta^u} + f^d$$

Thus, as long as the market power of the downstream firm in the downstream market is not too high (p_{qd}^d has a moderate value) the per-unit capacity fixed cost for the downstream f^d is non-trivial, then $p_d - p_u - \alpha_d > p_u - \alpha_u - f^u$ holds, as desired.

Next, I show that $part\ 2 > 0$. Rewriting part 2 of Equation (2.1) as

$$\begin{aligned} q_u p_d \cdot [p_u - \alpha_u - \beta_u q_u] + q_u g'(p_d) &= \frac{g'(p_d)}{\beta_u} [p_u - \alpha_u - \beta_u q_u] + q_u g'(p_d) \\ &= \frac{g'(p_d)}{\beta_u} (p_u - \alpha_u) \\ &> 0 \end{aligned}$$

Therefore, I conclude that

$$\pi_v p_d > \pi_s p_d$$

Finally, I discuss the case of the conglomerate firm. By the definition of the cutoff price tuples $(\hat{p}_u, \hat{p}_d)$ for the downstream industry, as discussed before, the conglomerate firm also faces the same cutoff prices in industry d as the specialized downstream firm and the vertical firm. The partial derivative of the conglomerate firm's profit with respect to p_d is given by

$$\pi_c p_d = p_d \pi_{c_d} + p_d \pi_{c_r}$$

Note that

$$p_d \pi_{c_d} = p_d \pi_{s_d} > p_d \pi_{v_d}$$

It only remains to compare the partial derivative of the upstream's profit for the vertical firm and the segment r 's profit for the conglomerate firm. When the demand shock to industry d is independent to demand for industry r , then

$$\pi_{c_r} p_d = 0 \implies \pi_c p_d = \pi_s p_d < \pi_v p_d$$

When the demand shock to industry d is decreasing in the demand for the related industry r , then

$$\pi_{c_r} p_d < 0 \implies \pi_c p_d < \pi_s p_d < \pi_v p_d$$

When the demand shock to industry d is increasing in the demand for industry r ,

$$\begin{aligned} p_d \pi_{c_r} &= \frac{k'(p_d)}{\beta_r - p_{q_r}^r} \left[(2p_r - 2\alpha_r - f^r) - \frac{\beta_r}{\beta_r - p_{q_r}^r} (p_r - \alpha_r - f^r) \right] \\ &= \frac{k'(p_d)}{\beta_r} \left[(2p_r - 2\alpha_r - f^r) \frac{\beta_r - p_{q_r}^r}{\beta_r} - (p_r - \alpha_r - f^r) \right] \\ &= \frac{k'(p_d)}{\beta_r} \left[p_r - \alpha_r \right] - (2p_r - 2\alpha_r - f^r) \frac{p_{q_r}^r}{\beta_r} \frac{k'(p_d)}{\beta_r} \end{aligned}$$

Therefore, whether conglomeration reduces uncertainties in profit is case-specific. When $\partial \pi_{c_r} / \partial p_d < 0$, then conglomeration reduces profit uncertainty.

Case 2: $p_d - p_u < \mathbb{E}[p_d - p_u]$, surplus capacity at downstream, and upstream producing at full capacity

In this case, *part 1* of Equation (2.1) is still greater than $\pi_{s_d} \pi p_d$, as discussed in the previous case. Nothing changed in the downstream segment of the vertical firm. As for part 2, since the upstream segment in this scenario is producing at full capacity, the change in profit when price p_d changes is simply $g'(p_d) t_{v_u}^*$, which is strictly positive. Thus, it is obvious that

$$\pi_v p_d > \pi_s p_d$$

It remains to compare the partial derivative of the upstream's profit for the vertical firm and the related segment r 's profit. As discussed before, due to the vertical firm's ability to resolve the double marginalization issue, the upstream segment of the vertical firm will

be greater than the conglomerate firm's segment in industry r even if these two segments share the same productivity parameters. In other words, $t_{v_u}^* > t_{c_r}^*$. When segment u of the vertical firm is producing at full capacity, a one unit change in the p_d would lead to a $g'(p_d)t_{v_u}^*$ change in the firm's profit from *part 2* of the vertical firm's profit function. When the price in segment r is less affected by the change in p_d than segment price in segment u , then $g'(p_d) > k'(p_d)$, which implies that $g'(p_d)t_{v_u}^* > k'(p_d)t_{c_r}^*$. Notice that $k'(p_d)t_{c_r}^* \geq \pi_{c_r}p_d$. This is because the change in profit when price changes comes from both the change in quantity and the change in per unit price. The change in per unit price is the same, and the total quantity after the change cannot exceed the total capacity. Therefore,

$$\pi_v p_d > \pi_c p_d \quad \text{when } g'(p_d) > k'(p_d)$$

Case 3: $p_d - p_u < \mathbb{E}[p_d - p_u]$, deficit capacity at downstream

The analysis for this case is very similar to that of the case where the vertical firm allocates surplus capacity to the downstream, and the upstream produces below capacity. For part 1 of Equation (2.1), in the long expression for

$$\pi_{v_d} p_d - \pi_{s_d} p_d$$

simply replace the β_u terms in the denominators with $(\beta_u - p_{q_u}^u)$ and $(\beta_d + p_{q_d}^u - p_{q_d}^d)$ with $(\beta_d - p_{q_d}^d)$, then the rest of the proof will follow through. This completes the proof. □