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NO SHOCK WAVES THROUGH WALL STREET?

MARKET RESPONSES TO THE RISK OF NUCLEAR WAR

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Parentibus carissimis

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"I want to say, and this is very important: At the end, we *lucked out.* It was *luck* that prevented nuclear war. We came *that close* to nuclear war at the end."

–Robert S. McNamara on the Cuban Missile Crisis (Morris (2003, 14:48-15:01))

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I could not have made it through this degree without my family's support, patience and faith in me, so a big thank you goes out to Mom, Dad and Marissa.

ABSTRACT

Do investors correctly price extreme events that they have never seen occur? To shed light on this question, I examine market responses to the risk of nuclear war during the Cuban Missile Crisis. I find evidence that investors indeed priced firms' exposures to nuclear destruction: Firms headquartered in areas that American national-security experts and the general public perceived more at risk of nuclear destruction experienced lower returns. Such discrimination is plausible given contemporary survey evidence that investors generally believed that the US could recover from a nuclear war. Employing a calibrated model to reconcile survey expectations with aggregate market responses, I find that i.) Investors underreacted to the risk of nuclear war; ii.) Investors exhibited a lower level of risk aversion than is standard in the literature; or iii.) Investor heterogeneity or noise makes survey data inaccurate indicators of investors' perceived exposures to extreme risks.

CHAPTER 1

INTRODUCTION

A growing literature demonstrates that market prices reflect exposures to climate risk, but are investors correctly pricing the most extreme scenarios? Estimates of the potential impact of climate change have exceeded 20 per cent of global output, *e.g.*, Burke et al. (2015), and the ambiguity, parameter uncertainty and potential misspecification that blight climate-change analyses lead to significant tail risk, *e.g.*, Weitzman (2011), Pindyck (2013) and Barnett et al. (2020). To obtain insights into the market impact of historically unrealised risks, I consider the most extreme disaster risk of the twentieth century: nuclear war. I exploit the natural experiment of the Cuban Missile Crisis and test whether investors priced the risk of nuclear destruction on American soil. I proceed to undertake a model-based assessment of whether observed aggregate market movements can at least be reconciled with survey expectations pertinent to nuclear war.

Nuclear conflict is an attractive setting for the study of the pricing of an extreme but unrealised disaster risk. Unlike the threats posed by climate change, investors do not need sophisticated analytic machinery to understand the first-order impacts of nuclear war. Americans also broadly perceived that a nuclear exchange would be catastrophic. The damage that even a single low-yield nuclear weapon would inflict had been clear since the atomic bombings of Hiroshima and Nagasaki, and a Gallup poll indicates that by the 1960s most Americans put their odds of surviving a nuclear war at no better than 50-50 (Gallup Organisation (1963)). Critically, though, nuclear war was not generally perceived as apocalyptic even into the early 1960s. In a 1963 survey, the majority of respondents, including those in demographics more likely to hold shares, believed that the US could recover from a nuclear war (National Opinion Research Centre (1963)). A perception that property rights might remain valuable and eventually be claimed is therefore plausible. Finally, surveys provide direct insights into subjective probabilities of nuclear conflict. With particular relevance for

the *ex-ante* probability assigned to extreme tail risk, Americans did not perceive nuclear war to be a remote possibility: During tense periods of the Cold War, Gallup polls indicate that almost half thought that another world war was likely within 5 years, and most expected nuclear weapons to be used if one broke out.

The Cuban Missile Crisis provides a natural experiment to identify market responses to the risk of nuclear war. Facilitating identification, during the Crisis the risk of nuclear conflict increased sharply and then abated within a short period. On the evening of 22 October 1962, President John F. Kennedy made a surprise address in which he reported the discovery of Soviet medium- and intermediate-range missile sites in Cuba. He announced a naval quarantine of Cuba to prevent the further accumulation of offensive weapons and that he would not shy away from the risk of nuclear war to bring about the removal of Soviet strategic weapons from Cuba.[1][2][3] Within a week, Soviet Premier Nikita S. Khrushchev announced that he would withdraw the missiles, and within a month the Crisis ended with

1. "We will not prematurely or unnecessarily risk the costs of worldwide nuclear war in which even the fruits of victory would be ashes in our mouth–but neither will we shrink from that risk at any time it must be faced." (May and Zelikow (2002, p. 186))

2. Nuclear war can occur with positive probability even between two rational parties who would choose concession to the adversary over certain nuclear conflict; if the adversaries are not in total control of their situation or lack complete information, they may miscalculate or lose control over escalation (*e.g.*, Schelling (2008, ch. 3), Kroenig (2018, ch. 1)). During the Crisis, President Kennedy noted the risk of losing control, responding to a U-2's accidental entry into Soviet airspace that "There's always some son of a bitch who doesn't get the message," and Secretary of Defence Robert S. McNamara expressed concerns about the risk of an unauthorised launch of missiles from Cuba (John F. Kennedy Presidential Library and Museum (nd), May and Zelikow (2002, p. 84)). Situational awareness was also imperfect. During invasion planning, for instance, the US government was aware of the presence of a FROG short-range missile launcher on Cuba but did not appreciate that FROG missiles had been deployed there with nuclear warheads (Guided Missile and Astronautics Intelligence Committee, Joint Atomic Energy Intelligence Committee, and National Photographic Interpretation Centre (1962a, p. 11), Morris (2003, 16:24-16:44)). Believing his submarine to be under attack by US forces, Captain Valentin G. Savitskiy ordered a nuclear torpedo to be prepared for firing, and Captain Vasiliy A. Arkhipov noticed the signalling of an American apology only by chance (Plokhy (2021, p. 270-271)).

3. In an act of brinkmanship, a nuclear-armed power may rationally seek to deter or to compel another by increasing the risk of a descent into nuclear war by what it perceives to be a tolerable amount (*e.g.*, Schelling (2008, ch. 3), Kroenig (2018, ch. 1)). *Life* quotes President Dwight D. Eisenhower's Secretary of State John Foster Dulles as stating that "You have to take chances for peace, just as you must take chances in war.... Of course we were brought to the verge of war. The ability to get to the verge without getting into the war is the necessary art" (Shepley (1956)).

the lifting of the quarantine.[4]

The key identifying assumption is that firms with headquarters in areas facing a greater risk of nuclear destruction will experience a greater loss of value during a nuclear war. Whilst operations, critical human capital and corporate records may not all be located at headquarters, and consumers, key elements of supply chains and funding sources may be spread all around the world, broader geographic exposures would push a headquarters-location effect towards zero and away from significance. Declassified National Security Council (NSC) predictions of where the Soviet Union might strike and survey responses from the general public indicate a general perception that larger population centres were more at risk, and I consequently divide listed companies into those with headquarters in the 10 most populous municipal areas and those with headquarters elsewhere in the United States.[5]

I find that firms mapped to the riskier group of populous municipal areas indeed experienced significantly lower equity returns on the first trading day after Kennedy's address. However, whilst the baseline effect of -0.73 per cent (t-stat 3.87) is highly statistically significant and non-trivial relative to the aggregate equity market decline of 2.63 per cent, it is not large in absolute terms. The gap in cumulative returns between the two geographic groups then shrank during the dénouement of the Crisis. The relatively weak performance of firms headquartered in the most populous municipal areas is robust to the removal of the industry fixed effects and Fama-French 3 factor loadings used in the baseline specification.

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4. The Cuban Missile Crisis is popularly understood to be the thirteen days from President Kennedy's first briefing on the missile sites on 16 October through Premier Khrushchev's 28 October missile-withdrawal announcement, with "Thirteen Days" the title of Crisis-era Attorney General Robert F. Kennedy's account. Since my interest is in market responses to news pertinent to the risk of nuclear war, I begin with President Kennedy's 22 October address. In line with the Kennedy administration's belief that the developments of 20 November "dropped the curtain" on the Crisis and the International Crisis Behaviour Project's assessment, I select 20 November as the end of the Crisis (Goldberg (2006, p. 217), Brecher et al. (2020), Brecher and Wilkenfeld (2000)).

5. Whether Soviet missiles based in Cuba could reach each of those municipal areas is not of first-order importance since the Soviet Union could also launch nuclear strikes with submarines, ICBMs and bombers; see, *e.g.*, Net Evaluation Subcommittee (1962). For a discussion of the direct threat to the continental US posed by Soviet missiles based in Cuba, see Appendix D.

The result is not driven by a single major municipal area, and it is robust to the individual removal of each industry. A coarser mapping to state agglomerations yields a similar picture. Abnormally low returns for Floridian and Texan firms – respectively those closest to Cuba and those in an economically significant state relatively close to Cuba – further support a link to exposure to destruction.

The threat of nuclear war was not new in 1962, and investors who frequently priced exposure to nuclear destruction would surely have gathered information on the locations of firms' operations. Such information is publicly available in listed firms' annual reports, for instance, and headquarters do not move frequently. I only find a highly significant geographic effect immediately after Kennedy's address, however, among the largest fifty per cent of the sample, firms whose headquarters' locations would presumably be more likely to have been learned passively. Among these larger firms, the baseline effect is -0.99 per cent (t-stat 4.49). Moreover, the reversal of the gap as the Crisis unwound becomes starker when I limit my sample to larger firms. At the same time, I find at least weakly significant negative impacts among smaller firms at longer horizons and no reversal, but with the caveat that there is some evidence of a pre-trend. Together these results suggest that nuclear risk had been priced for larger firms and that market participants may have learned about smaller firms' exposures in response to the Crisis.

An alternative econometric approach and placebo tests provide additional evidence that investors discriminated among firms on the basis of exposure to nuclear destruction. Accounting for a richer correlation structure among returns with the Athey et al. (2021) matrix-completion approach, I obtain similar estimates of the geographic effect. In a first placebo test, randomisation of whether firms were mapped to top-10 CBSAs rarely yields estimates of comparable magnitude or significance. In a second placebo test, I find that firms in top-10 CBSAs experienced one of their largest and most significant abnormal returns in a multi-year span the day after President Kennedy's address.

Having found reduced-form evidence that investors responded to a change in the risk of nuclear disaster, I seek to answer whether market data can be rationalised given survey data on beliefs about nuclear conflict. I am not evaluating whether the expectations themselves reflected a high degree of situational awareness or even an efficient processing of readily available information; rather, I aim to shed light on whether investors at least acted consistently with their beliefs.[6] Beginning with a simplified version of the consumption and dividend dynamics of the representative-agent disaster-risk model in Gabaix (2012) and maintaining Epstein-Zin preferences, I add Markov switching between a good, a tense and a crisis state, with the simplifying assumption that a nuclear-war jump is only possible during a crisis. I infer transition intensities and the expected arrival rate of nuclear war from survey expectations and data on the crises during which Betts (1987) identifies at least a subtle threat of nuclear use. This calibration yields a probability that a crisis will end in nuclear war of 9 per cent.

Crises featuring nuclear threats were a semi-regular occurrence in the 1950s and early 1960s. Contemporary reporting suggests a perception among investors that the Cuban Missile Crisis was more serious than past crises over, for example, Berlin, but a general absence of panic (Nuccio (1962), Economist (1962b)). I consequently presume that the generic arrival rate of nuclear war is a reasonable approximation to that perceived in 1962. Given each of a set of possible losses of *per-capita* consumption, I calibrate the model to match the value-weighted CRSP return and the change in the four-week Treasury yield following President Kennedy's address, a typical price-dividend ratio during a multi-year span around the Crisis and the Hamilton et al. (2015) estimate of the mean *ex-ante* real return on very short-term debt.

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6. For accounts of risk perceptions among well-informed members of the American national-security apparatus, both as perceived in real time and after the obtainment of more complete information, see, *e.g.*, Morris (2003), Perry and Collina (2020) and May and Zelikow (2002). Additional information on the extreme proximity to nuclear war during the Cuban Missile Crisis specifically is reported from the Soviet perspective in, *e.g.*, Plokhy (2021).

Matching market data conditional on reported beliefs about nuclear war requires lower levels of risk aversion than are standard in the asset-pricing literature. With a 1958 NSC war game predicting that labour productivity might reach 50 per cent of its pre-nuclear-war level within a year, I select a decline of *per-capita* consumption of 50 per cent as the best possible outcome (Net Evaluation Subcommittee (1958, p. 15)). If nuclear war were expected to reduce survivors' *per-capita* consumption by 50 per cent, 75 per cent or 90 per cent, the calibrated coefficient of relative risk aversion would respectively be 2.00, 1.62 and 1.41. Given that investors' subjective probabilities of war during the Cuban Missile Crisis may have been greater than during the other crises, and given my omission of risks other than those pertinent to disasters, even lower risk aversion is likely to be required. The CRRA for the best-case scenario is just outside of the range of 2 to 5 that Barro (2006) presents as the finance literature's consensus, and all are far below the levels of 3 and 4 that he entertains in his attempt to solve the equity premium and risk-free rate puzzles.[7] They are also far below the levels of 3 to 6 with which Gabaix (2012) and Wachter (2013) explain numerous asset-pricing puzzles.

Closely related work is the Białkowski and Ronn (2017) study of Polish, French, British and Swedish market responses to the risk of state collapse posed by Nazi Germany. They examine bond and aggregate equity movements together with contemporary journals and argue that there was an initial underreaction in Poland and France but that European investors appeared eventually to learn. Whereas conventional wars occurred with regularity in Europe, and the First World War was recent history to 1930s investors, nuclear war and catastrophic climate change have not yet occurred. Given the evidence that personal experiences impact financial-market behaviour–*e.g.*, Malmendier and Nagel (2011)–this paper's assessment of investors' responses to an unrealised disaster is a significant departure. My use of a structural model also permits a more formal assessment of market behaviour.

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7. The CRRA with a consumption loss of 50 per cent is knife-edge below 2 and is associated with almost no additional discounting for the possibility of not surviving a nuclear war.

A large body of work has explored the importance of disaster risk in asset markets. Evidence for the pertinence of disaster risk comes directly from investors: 45 per cent of the Choi and Robertson (2020) sample of Americans report that disaster risk is at least a very important factor in their demand for equities. Berkman et al. (2011) examine market responses to political crises and find a rôle for disaster risk in moving markets. After Mehra and Prescott (1985) presented their difficulty in simultaneously rationalising high average US equity returns and low average US Treasury yields, Rietz (1988) demonstrated with a tuned model that the solution could be the rare occurrence of sharp declines in consumption. Barro (2006) provides empirical support for Rietz's disaster hypothesis, inferring a stationary distribution of disaster outcomes from historical contractions and returns across a large panel of countries. Building on Barro (2006) and the consumption-disaster data of Barro and Ursúa (2008), Gabaix (2012) and Wachter (2013) demonstrate that time-varying disaster risk can explain numerous other asset-pricing puzzles.[8] Whilst these works rationalise asset moments with the empirical distribution of economic disasters, they impose on investors the belief that potential disasters are unlikely to be more severe than those considered by the authors. Evidence that climate risk is priced–*e.g.*, Engle et al. (2020), Bernstein et al. (2019) and Bansal et al. (2019)–together with the prospect of economically catastrophic climate change, *e.g.*, Burke et al. (2015), motivate an assessment of investor behaviour when an extreme but unobserved disaster may not be highly unlikely.

Although the utility of the Cuban Missile Crisis for the study of disaster risk had been suggested in Mehra and Prescott (1988) and Barro (2006), and the Crisis features among the major news in Cutler et al. (1988), its asset-pricing implications have received little

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8. Analysis of options data has resulted in some pushback against the suggested importance of disaster risk. Backus et al. (2011) argue that Barro (2006) overestimates the likelihood of an extreme consumption disaster in the US, and Welch (2016) assesses a limited contribution of disaster risk to the equity premium. Welch (2016) notes, however, the key assumption that option contracts would be honoured in the event of a disaster. The potential losses of New York City and Chicago, *inter multa alia*, during a nuclear war introduce a certain level of counterparty risk. It is consequently questionable whether options could provide reliable insights into investors' perceptions about the risk of general nuclear war between the US and the USSR.

attention in the finance literature. Amid a broader assessment of investors' responses to time-varying geopolitical risk, Ferguson (2008) takes a narrative approach to the Cuban Missile Crisis and suggests that the relatively small market movements were the result of investors' inability to assess the economic impact of nuclear war or the pointlessness of acting on the risk. In contemporaneous work, Burdekin and Siklos (2020) examine equity returns during the Cuban Missile Crisis and discuss variation across industries, but their focus is on the relations between uncertainty and returns across American, Canadian and Mexican equities. The closest empirical setting in the economics literature is Raschky and Wang (2017), in which proximity to Cuba or a military base during the Cuban Missile Crisis is found to be correlated with higher fertility months later. My cross-section by exposure to nuclear destruction also bears a similarity to the Bolton and Kacperczyk (2020) cross-section by CO_2 emissions that provides evidence of a premium for emission risk.

A large body of literature produced during the Cold War makes predictions about the economic impact of nuclear war and the subsequent recovery, *e.g.*, Goen (1971), Feinberg (1979), Sastry et al. (1987) and Hill (1987); and game theorists have long examined nuclear conflict, *e.g.*, Schelling (2008) and Dixit et al. (2019); but little has been written on the financial impact of nuclear risk. Russett and Slemrod (1993) find evidence of a negative relation between the American savings rate and the probability of nuclear conflict. Kollias et al. (2014) and Huh and Pyun (2018) find a small decline in South Korean equities following North Korean nuclear tests but do not specifically identify the rôle of extreme tail risk. The finance literature has included nuclear crises in broader sets of events, *e.g.*, Berkman et al. (2011), but the impact of their extreme tail risk has been left largely unexplored. Pindyck and Wang (2013) also critique the absence of events such as nuclear wars from the empirical disaster distributions frequently used in the literature. Whilst they proceed to obtain beliefs about generic disasters from the calibration of a general-equilibrium model, my interest is specifically in whether the risk of an historically unrealised disaster is priced.

My two main contributions are i.) evidence that investors priced the risk of an extreme disaster outside of historical experience; and ii.) the inability to reconcile market responses to that risk with both survey data on Americans' beliefs and standard levels of risk aversion. The robust evidence that firms more exposed to destruction experienced lower equity returns during the Cuban Missile Crisis provides a counterargument to the Ferguson (2008) claim that investors could hardly process the devastation of nuclear war or were rationally unmotivated to assess the economic implications. The pricing of an extreme but unrealised risk raises the prospect that the common approach of using the distribution of past economic disasters as the distribution of potential ones may lead to incorrect inference. Moreover, survey evidence that Americans assigned far-from-trivial probabilities to war with the Soviet Union and to its escalation to nuclear conflict suggests caution in the use of power laws to infer the probabilities of extreme events, $e.g.$, Pindyck and Wang (2013).

At the same time, the data do not permit one to claim with confidence that extreme tail risk was efficiently priced even in a simpler context than climate change. Whilst this paper focuses on the Cuban Missile Crisis to facilitate identification, the Cold War provides decades of variation in the risk of nuclear war, and work in the spirit of Pástor and Stambaugh (2003) with Cold War tension in lieu of liquidity may prove fruitful. An investigation that explicitly accounts for investor heterogeneity may also resolve the puzzles raised in this paper and further clarify how market participants price the most extreme, unrealised risks.

This paper is structured as follows. Chapter 2 is an examination of whether equities responded to the time-varying risk of nuclear war during the Cuban Missile Crisis. In Chapter 3, I develop a structural model in an attempt to rationalise market movements as the risk of nuclear destruction varied. Chapter 4 concludes.

CHAPTER 2

EMPIRICAL ANALYSIS

2.1   Data

Bulk mappings from CRSP firms to the locations of headquarters are not readily available
for the mid-twentieth century. I produce them from data in annual reports made available
by Mergent Archives and ProQuest Historical Annual Reports.[1] I first collect the metadata
produced by searches for all annual reports for 1962, which include a city and a state. These
reports were generally published in early 1963, and most headquarters can be assumed not
to have relocated since the autumn of 1962. As part of ongoing work, I have also collected
annual-report data for 1945, 1949 and 1956, and where a location is missing for 1962, I
employ the latest available observation among the earlier years.

I clean the metadata, match firm names in the metadata to those in the CRSP and
CRSP/Compustat Merged databases made available by WRDS and produce mappings from
CRSP permanent numbers to locations. Cleaning includes the remapping of a firm's SIC
code in a given year to a value in another year that appears better to correspond to the
firm's 1962 operations. A complication is that annual reports can list multiple locations as
headquarters. Where there is a conflict between the locations obtained from Mergent and
ProQuest or an apparent inconsistency across years, I directly consult the company's annual
reports and select the headquarters location that appears more central to the productive
operations of the firm. Given the wide areas over which strategic nuclear weapons can cause
significant disruption, the lowest resolution used in this paper is the CBSA (core-based
statistical area) level.[2] I proceed to map cities to ZIP codes using the Personal dataset from

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1. The text processing and dataset merging are discussed in more detail in Appendix B.

2. The Census Bureau introduced CBSAs long after the Cuban Missile Crisis (US Census Bureau (2020)).
I consequently use the 1963 SMSA (standard metropolitan statistical area) populations in Census Bureau
(1965) as approximations of the CBSA populations. The population of the CBSA of New York City is
obtained as the sum of the New York City and Newark SMSA populations.

UnitedStatesZipCodes.org and then to CBSAs using the 2019Q3 mapping made available by the US Department of Housing and Urban Development.

Factor and industry data are obtained from Kenneth R. French's website. I obtain both daily Fama and French (1992) 3-factor returns and daily Fama-French 49 industry returns.[3] The mappings from SIC codes to Fama-French 49 industries are used to obtain firms' baseline industries from the raw CRSP SIC codes.

2.2 Investor attention

As a first step in my assessment of whether extreme tail risk was priced during the Cuban Missile Crisis, I establish that investors were paying attention to the situation's economic implications. As context for the empirical investigation, investors would have had trouble avoiding Crisis news: President Kennedy preëmpted prime-time television on 22 October 1962 with an address in which he explained the Cuban situation and made the risk of nuclear war explicit; and for weeks Crisis developments were displayed prominently on newspapers' front pages. The first financial reporting in *The New York Times* after the address was filled with references to the Crisis, *e.g.*, Rutter (1962b) and Nuccio (1962), and, days later on 26 October, *The New York Times* notes that observers "believe that at least in the near-term future the course of the market would be decisively influenced by international developments..." (Rutter (1962a)). Writing shortly before the lifting of the quarantine, Abele (1962a) credits the Crisis with market gyrations over the previous weeks.[4]

Market reactions support the reporting of investor attention, with the cross-section of industry abnormal returns following the contours of the Crisis. Nuclear destruction was

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3. The 49-industry classification is a minor variation of the Fama and French (1997) 48-industry classification.

4. "Fearful of a belligerent Soviet reaction to the American challenge, frenzied investors created a near-panic as they rushed to sell their securities.... The morale of the nation rallied strongly at the success of the American challenge. Spirits along Wall Street rose along with those of the rest of the country. So did stock prices." (Abele (1962a))

not the only potential outcome of the Crisis with economic repercussions. In line with President Kennedy's statement that Americans could expect a long period of sacrifice and with post-address reporting about the prospect of a war economy, the industries with the highest abnormal returns the day after the address are associated with war production, and those with the lowest are associated with consumer discretionary spending (May and Zelikow (2002, p. 188)), Economist (1962a); Table 4.1).[5] The pattern is very similar when raw returns are used. The cumulative abnormal return of a portfolio long the weakest 5 industries and short the strongest 5 industries closely traces developments during the first week of the Crisis (Table 4.2, Figure 4.1). On 24 October, when news reached markets of a letter from Premier Khrushchev to Bertrand Russell in which Khrushchev noted that he would not act rashly, the gap fell sharply (Farnsworth (1962)). Khrushchev capitulated on 28 October, and the next business day the gap between the industry abnormal returns fell essentially to 0. Though there may be a moderate pre-trend, the magnitudes of the spreads early in the Crisis are abnormally large for the period of the Crisis. Figure 4.1 presents the span from the 0.5 per-cent through the 99.5 per-cent quantile for each offset when I recentre the cumulative returns on each date in a 1000 trading-day window around President Kennedy's address, and the early spreads are well outside of it.

2.3   Risk of nuclear war

2.3.1   Cross-sectional regression analysis

Mid-century Americans broadly perceived a significant risk of a third world war. During tense periods, almost half of Gallup respondents reported an expectation of one within 5 years (Figure 4.2). Moreover, survey evidence indicates that most Americans expected that nuclear weapons would be used in a major war (Figure 4.3) and that the overwhelming

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5. All Fama-French 3 factor loadings used in this paper are obtained with the Welch (2019) age-decayed slope-winsorised beta estimator given evidence of its relatively strong predictive performance.

majority believed that they had no better than even odds of surviving a nuclear war (Figure 4.4). Though nuclear conflict was clearly viewed as catastrophic, survey data showing a belief that the United States could recover suggest a general expectation that the economy and the security of property rights would not completely and irrecoverably collapse (Figure 4.5). The higher-income individuals and college graduates who were more likely to be marginal in the stock market were generally less pessimistic than the rest of the population about the prospect of war, but during tense periods roughly a third expected one within half a decade. Expectations of nuclear use and personal survival exhibit little variation with income and education.

Though the cross-section of industry returns indicates that investors considered economic implications of the Crisis, a response to a change in tail risk is not immediately apparent. The aggregate market decline of 2.63 following President Kennedy's announcement was by a significant margin not even the largest of 1962–the CRSP value-weighted return was -6.95 per cent, for instance, on 28 May–and Treasury yields barely moved amid light trading (Figure 4.6; Kraus (1962)). Ferguson (2008) interprets the small market movements as an indication that investors struggled to process the enormity of the destruction of nuclear war or saw no point in doing so. Anecdotal evidence provides some backing for such views, *e.g.*, Nuccio (1962), but the survey data presented in this paper indicate significant heterogeneity in beliefs. An increased likelihood of nuclear conflict may have largely been baked into asset prices. *The New York Times* had referred to a "Cuban crisis" involving a Soviet military presence in Cuba prior to the discovery of the missile sites, for instance Szulc (1962). To shed light on the pricing of tail risk, I proceed to examine the cross-section of returns with respect to exposure to nuclear destruction.

Firms were not equally exposed to nuclear destruction. To the extent that there was geographic variation in the risks posed by nuclear war, variation in firms' geographic exposures implies variation in their exposures to nuclear war. The National Security Council's Net

Evaluation Subcommittee (NES) was tasked with estimating the impacts of nuclear conflict on the United States, and its experts predicted that major American population, economic and political centres would be targeted in addition to sites of military significance such as Strategic Air Command bases (Figures 4.7, 4.8).[6] Survey data also suggest a public perception of differential exposure: Americans believed that the most populous and the most economically and politically important cities would be struck first, and New York City in particular (Gallup Organisation (1951)).

I employ the location of a firm's headquarters as my indicator of its exposure to nuclear tail risk. The key identifying assumption is that *ceteris paribus*, firms with headquarters in areas more likely to be struck by nuclear weapons will experience a greater loss of value as a result of nuclear war than firms with headquarters elsewhere. Listed firms will, of course, generally have operations, critical human capital, records, customers, supply chains and sources of funding spread over a much wider area. Such dispersion of geographic exposures would push the variation of returns with respect to headquarters' location towards zero and thus work against any inference of significant tail-risk exposure.

My baseline empirical specification is meant to answer whether, *ceteris paribus*, firms more exposed to nuclear attack experienced lower returns during the Cuban Missile Crisis:

$$r_{it} = \sum_g \iota_i^g \gamma_t^g + \sum_j \iota_i^j \theta_t^j + \hat{\beta}_{it}^{rmrf} \phi_t^{rmrf} + \hat{\beta}_{it}^{smb} \phi_t^{smb} + \hat{\beta}_{it}^{hml} \phi_t^{hml} + \epsilon_{it} \qquad (2.1)$$

where ι_i^g is an indicator for firm i's presence in geography g; ι_i^j is an indicator for firm i's presence in industry j; $\hat{\beta}_{it}^k$ is the estimated rolling loading for firm i on Fama-French 3 factor k obtained from the implementation of the Welch (2019) age-decayed slope-winsorised beta

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6. I use war-game data to obtain broad patterns of exposure. I consequently abstract away from the distinction between targeting and war-game outcomes. The war game yielding these maps was predicated on a forward-looking 1965 scenario, but the broad targeting also featured in earlier reports which lacked such vivid depictions, *e.g.*, Net Evaluation Subcommittee (1957).

estimation procedure, and ϵ_{it} is noise.[78]

My first geographic classification is whether a firm is in one of the 10 most populous CBSAs. Table 4.3 presents CBSA populations and firm counts, with each CBSA labelled by its major city. Of the 601 firms in the sample, about a third had headquarters in the vicinity of New York City around the Cuban Missile Crisis. Each of the other top CBSAs contained the headquarters of at least 7 firms except for that of Washington, DC, which contained 2. 214 firms were located outside of the top-10 municipal areas.

As a first pass, I estimate the effect of being located in one of the top-10 CBSAs without controls. Figure 4.9 presents estimates of the geographic effect on cumulative returns around President Kennedy's address. The effects before President Kennedy's 22 October 1962 address are estimated over a window from the date on the x-axis through the date of the address, with a negative value indicating that firms in the top-10 CBSAs experienced a higher return over the interval. The effects after the address are estimated over a window starting the day after the address and extending through the date on the x-axis, with a negative value indicating that firms in the top-10 CBSAs experienced lower returns over the interval.[9]

One observes a large and highly significantly negative geographic effect on the first trading day after the address, and significance at a lower level of confidence is observed again over the span from the address through the final trading day before Khrushchev's withdrawal announcement (Figure 4.9). Whilst firms in the top-10 CBSAs exhibited declines in the days prior to Kennedy's address, the cumulative changes lack significance, and the sharp

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7. I only estimate Eq. 2.1 cross-sectionally. I employ a panel data structure in Subsection 2.3.2.

8. Potential correlation among residuals presents a significant econometric challenge in this setting. Standard errors in a cross-sectional regression can be refined with covariances inferred from time-series data, *e.g.*, Kolari and Pynnönen (2010), but the stability of the residuals' covariance structure around and during the Cuban Missile Crisis is far from clear given the abnormal and potentially large shocks associated with the risks of a shift to war production and of nuclear war. I currently cluster at the Fama-French 49 industry level for robustness to such time variation with minimal assumptions about it, but this comes at the expense of the assumption of zero correlation among residuals across industries.

9. The same firms are present in each window.

post-address decline is inconsistent with a potential shallow pre-trend. As with the industry spread, there is a large reversal on 24 October coincidental with a reported market response to Khrushchev's letter (Farnsworth (1962)). The geographic effect, however, becomes increasingly negative through 8 November. The gap sharply narrows on 9 November, the first trading day after the Department of Defence's publication of photographic evidence of Soviet missile removal, and has reversed by the end of the lifting of the quarantine. Supporting a causal link to the Cuban situation, the 13 November 1962 edition of the *The New York Times* reports that the missiles' removal had been cited as a factor behind the rising stock market (Abele (1962b)).

I repeat the estimation but with controls for Fama-French 49 industry and Fama-French 3 factor loadings to mitigate the impact of potentially confounding effects.[10] Given the factor structure of returns and the strong heterogeneity among abnormal returns at the industry level, I take this specification as my baseline. I find stronger evidence that firms in major CBSAs underperformed those with headquarters elsewhere (Figure 4.10). There is weaker evidence of a confounding pre-trend, and the gap is significant at at least the 10 per-cent confidence level for horizons through 8 November. The underperformance broadly reverses through the end of the Crisis, but, in contrast to the results without controls, a gap reëmerges afterward.

The large and significant negative shock on the first trading day after the address is robust to a large variety of modifications to the regression specification. An absence of controls (Column 1), controls only for factor loadings (Column 2) and controls for factor loadings and industry (Column 3, the baseline specification) yield similar, highly significant effects (Table 4.4). When the top-10 CBSAs are divided into the top 5 and the bottom 5 of the group by population, the point estimates are very close to that for the aggregate group,

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10. Fama-French 3 factor loadings are similar across firms headquartered in top-10 CBSAs and elsewhere (Table A.1), but industry composition varies non-trivially (Figure A.1). The median firm size is also similar, but the presence of very large firms causes the mean for top-10 CBSAs to be roughly double that for firms headquartered elsewhere.

but only that for the top 5 is statistically significant (Column 4). Switching from the top 10 to the top 5 yields a significant geographic effect (Column 5). Use of SIC-2 industries reduces the significance to below the 1 per-cent confidence level (Column 6), but Figure A.2 demonstrates that this is a consequence of an extreme outlier among the industries.[11] No single industry appears to be particularly influential when Fama-French 49 industries are used (Figure A.3). The robustness to industry removal also indicates that no individual firm is driving the finding of significance.[12] Finally, there is only a trivial geographic effect on the date of the address, suggesting an absence of leakage and that the address can be treated in this paper as the sharp onset of the Crisis (Column 7).[13]

The geographic effect is not driven by an outlier among the top-10 CBSAs. Disaggregating the top 10, I find numerous significantly negative impacts, particularly among the more populous CBSAs (Table 4.5).[14] Whilst the difference in significance between the larger and smaller CBSAs in this set may also reflect variation in the number of firms in each, the key result is a consistently worse return than firms headquartered in broadly less attractive targets. The big picture is also robust to a change in the geographic classification. When I employ a resolution no finer than a state, I again find that firms in major population centres experienced lower returns, but the effect is less significant (Table 4.6). Similar to the finding about post-Crisis fertility in Raschky and Wang (2017), Florida and Texas experienced significantly negative returns consistent with concern about their proximities to Cuba, though

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11. The outlier is SIC-2 category 36, Electronic and other equipment.

12. There are also no extreme values among the sample of returns on the first trading day after President Kennedy's address. The most negative return is -16.16 per cent, and the most positive is 6.19 per cent.

13. Rumours about Cuba and a crisis had spread on 22 October, and the aggregate market had fallen (Figure 4.6; Rutter (1962b)). It appears that the address carried information pertinent to the geographic cross-section of returns such as a significant increase in the risk of nuclear destruction whilst the rumours did not.

14. With only two firms mapped to DC–Washington Gas Light Co. and Dover Corp.–idiosyncratic noise is likely to be highly problematic for the estimation of a DC effect. Given evidence presented below that smaller firms initially exhibit a limited geographic effect, Dover Corp.'s relatively small market capitalisation may further complicate inference. I consequently do not include DC firms in the sample used to estimate geographic effects at the CBSA level.

with the caveat that the Floridian sample is small (Table 4.7). At the same time, firms headquartered in a group of less-populous states with sites of military significance that the Net Evaluation Subcommittee predicted would be heavily targeted did not seem to experience negative returns.[15] Hardened missile sites were predicted by the NES to be struck with ground bursts, which would have resulted in particularly large volumes of radioactive fallout (Net Evaluation Subcommittee (1962)). Given the small sample size of 10 firms, it is unclear whether this reflects noise or a lack of appreciation of nuclear risk. The District of Columbia and adjacent states also exhibit limited responses, but only two firms are mapped to DC itself.

As a test of the extent to which investors actively pursued geographic information, I separately assess the geographic effect among the top 50 per cent of firms by market capitalisation on the trading day prior to President Kennedy's address and among those in the bottom 50 per cent. Investors had been living in a world with Soviet nuclear weapons since 1949, and information pertinent to firms' exposures to destruction was readily available at the very least in annual reports. If investors paid close attention to nuclear risk, one would expect to see a geographic effect among both larger and smaller firms; however, if investors only passively learned about the geography of firms' operations, the effect should be stronger among the generally more prominent larger firms. Empirically, the geographic effect on 23 October is large and significant among the larger firms and both smaller in magnitude and insignificant among the smaller ones (Table 4.8). Examining the impact of headquarters' location on cumulative returns, I find a stronger tendency towards reversal of the shock as the Crisis unwound among larger firms and, if anything, a pre-trend in the opposite direction

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15. These states are Arkansas, Arizona, Colorado, Kansas, Nebraska, New Mexico, Oklahoma and Washington. I obtain this specific set by visual examination of the locations of actual ground zeroes in the maps from Net Evaluation Subcommittee (1962) and consultation of Schwartz (1998). Public reporting prior to the Crisis associates military installations with nuclear command and control and warhead deployment, *e.g.*, Hyman (1961) and Witkin (1961). The literature has also provided evidence that investors have at least inferred classified information and restricted data, *e.g.*, coup authorisations (Dube et al. (2011)) and the use of lithium in thermonuclear warheads (Newhard (2014)).

18

(Figure 4.11). Among smaller firms, I find a moderate but insignificant negative effect on the cumulative return over the first days of the Crisis. The gap grows to a magnitude of over 1 per cent and can reach a moderate level of statistical significance up to a horizon of 8 November. Unlike that for larger firms, the gap persists through the end of the Crisis (Figure 4.12). Though the associated geographic effects are statistically insignificant, there is, however, some evidence of a pre-trend. Together, these results suggest that nuclear risk had been priced for large firms before the Crisis but that there may have been learning about smaller firms' exposures.

2.3.2 Accounting for additional factors

To account for the influence of potentially confounding latent factors, I employ the Athey et al. (2021) matrix-completion approach. I assume that the return r_{it} for stock i on date t satisfies

$$r_{it} = L_{it} + \alpha_t + \hat{\beta}_{it}^{rmrf}\phi_t^{rmrf} + \hat{\beta}_{it}^{smb}\phi_t^{smb} + \hat{\beta}_{it}^{hml}\phi_t^{hml} + \epsilon_{it} \qquad (2.2)$$

where L_{it} captures the contributions of common factors in excess of those associated with the FF3 factor loadings and a period fixed effect, and each ϵ_{it} is independent of $\{L_{it}\}$ and $\{\hat{\beta}_{it}^k\}$. Let $\mathcal{O}$ be the set of all (i,t) with available observations over the span $\{t_{-T}, ..., t_0\}$ except those for firms in geography g on date t_0. In this analysis, g is the set of top-10 CBSAs. I estimate $\Pi \equiv \{L_{it}, \alpha_t, \phi_t^{rmrf}, \phi_t^{smb}, \phi_t^{hml}\}$ using only (i,t) in $\mathcal{O}$. I define the geographic effect of a firm's being headquartered in g at t_0, denoted γ_0^g, as the average of ϵ_{it} at t_0 for firms headquartered in g.

The parameter estimates are obtained as

$$\hat{\Pi} = \underset{\Pi}{\arg\min} \frac{1}{|\mathcal{O}|} \sum_{(i,t) \in \mathcal{O}} \left(r_{it} - L_{it} - \alpha_t - \hat{\beta}_{it}^{rmrf} \phi_t^{rmrf} - \hat{\beta}_{it}^{smb} \phi_t^{smb} - \hat{\beta}_{it}^{hml} \phi_t^{hml} \right)^2 + \lambda \|L\|_*$$

(2.3)

where $|\mathcal{O}|$ is the cardinality of $\mathcal{O}$; λ is a penalty term, and $\|L\|_*$ is the nuclear norm of the matrix L with element $[i,t]$ equal to L_{it}. I also perform the estimation without the factor loadings as controls. The regularisation involving the nuclear norm permits the data-driven reduction in the number of common linear factors that underlie the L_{it}. I obtain the λ by cross-validation, seeking that which prior to t_0 had on average yielded the best predictions of returns for firms headquartered in top-10 municipal areas given the returns on the same day of firms headquartered elsewhere.[16][17] Let $\mathcal{O}_0^g$ be the set of (i, t_0) of firms headquartered in g at t_0. The estimate of the geographic effect is

$$\hat{\gamma}_0^g = \frac{1}{|\mathcal{O}_0^g|} \sum_{(i,t) \in \mathcal{O}_0^g} \left(r_{it} - \hat{L}_{it} - \hat{\alpha}_t - \hat{\beta}_{it}^{rmrf} \hat{\phi}_t^{rmrf} - \hat{\beta}_{it}^{smb} \hat{\phi}_t^{smb} - \hat{\beta}_{it}^{hml} \hat{\phi}_t^{hml} \right)$$

(2.4)

The cumulative geographic effects in Figure 4.13 obtained from matrix completion paint a very similar picture to those obtained from the purely cross-sectional regressions.[18][19] The

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16. Athey et al. (2021) discuss the relation of matrix completion to the synthetic-controls approach.

17. For each λ in a large set, I estimate the model with the window $\{t_{-T}, ..., t_0\}$ shifted back each of 1 through 500 trading days. The optimal λ is that which yields the lowest mean over the windows of the mean squared $\hat{\epsilon}_{it}$ for firms headquartered in g on the last trading day of the window. The matrix-completion approach implicitly entails the estimation of constant factor loadings, but Welch (2019) presents evidence of instability in the loading on the aggregate market. Given his assessment of a half-life of 3 to 5 months and his advocacy of the use of at least 12 to 18 months of observations in the estimation of a market β, I balance stability concerns and data requirements by setting T to 18 months, approximated as 378 trading days.

18. Unlike the estimates from the purely cross-sectional regressions, I cumulate estimated daily geographic effects obtained via matrix completion.

19. Due to the computational cost of the incorporation of industry fixed effects, I only present results for no economic controls and for Fama-French 3 factor loadings as controls.

full set of firms, the set of large firms and the set of small firms each experience negative returns on 23 October 1962 of a similar size to those found above, and again there is a substantial reversal after the release of evidence of missile removal on the evening of 8 November. Once more, large firms show a much more negative initial shock, and smaller firms do not exhibit the same reversal.

2.3.3 Placebo tests

I seek to answer two questions: *i*.) Did the firms in the 10 largest municipal areas experience greater abnormal returns after Kennedy's address than an arbitrary selection of firms could be expected to?; and *ii*.) Did firms in the 10 largest municipal areas experience greater abnormal returns after Kennedy's address than would be expected on an arbitrarily selected date? To answer the first question, I employ the placebo approach of Alquist and Chabot (2011) and reëstimate the top-10 effect with each of 1000 random permutations of the mapping to a top-10 municipal area or elsewhere. To answer the second, I estimate the top-10 effect on each date in a 1000 trading-day window around Kennedy's address.[20][21]

The permutations of geographic mappings demonstrate the specificity of abnormal returns to top-10 CBSAs following President Kennedy's address. Random assignments of firms to a top-10 CBSA or elsewhere very rarely yield coefficient magnitudes or *t*-statistic magnitudes equal to or greater than the actual values, and the largest magnitudes obtained are not massively different from the actual values (Tables A.2 and A.3). This holds for both the cross-sectional and the matrix-completion results for both the full set of firms and just large firms. The rarity of larger and more-significant effects when geographic mappings are permuted provides additional confidence that the magnitudes and levels of significance of

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20. Though presumably a second-order matter given that headquarters do not move frequently, locations in years other than 1962 were not subjected to the same degree of verification.

21. Due to the computational cost of the selection of the penalty parameter λ by cross-validation, the value employed for the original 23 October 1962 estimation is employed for all dates.

the actual estimates are not driven by a small set of firms.

Few dates within a 1000 trading-day window around President Kennedy's address yield coefficient or t-statistic magnitudes at least as large (Tables A.4, A.5). Again this is consistent across all of the metrics, and where a placebo magnitude is greater, the gap is not exceedingly large. There is, however, evidence of a positive correlation between the value-weighted CRSP return and the geographic effect (Figures A.4, A.5, A.6, A.7). Still, 23 October 1962 is a clear outlier in those scatter plots, particularly with respect to the t-statistic.

CHAPTER 3

STRUCTURAL MODEL

3.1 Framework

Having obtained reduced-form evidence that nuclear tail risk was priced during the Cuban Missile Crisis, I develop a structural model to assess whether market returns were consistent with survey beliefs about the risk of nuclear war. I begin with the continuous-time consumption and dividend dynamics of the Gabaix (2012) partial-equilibrium model of disaster risk, which includes a representative agent and an equity security. Informed by narrative evidence and variation in survey expectations of war, I add three states of nuclear tension between the United States and the Soviet Union: good (G), tense (T) and crisis (C). In addition to the Gabaix (2012) disaster jump, I include a nuclear-war jump that can only occur when the economy is in the crisis state.[1] As my interest is in market movements during the transition from a tense state to a crisis and averages over multiple years, I remove the higher-frequency dynamics of Gabaix (2012), leaving as the only state variables the set of indicators for the level of tension $\{\iota_t^k | k \epsilon \{G(ood), T(ense), C(risis)\}\}$.

Consumption C_t follows the process

$$\frac{dC_t}{C_t} = g_C dt + (\bar{B}^E - 1)dJ^E + (\bar{B}^N - 1)dJ^N \tag{3.1}$$

where g_C is a constant growth rate; $\bar{B}^E$ is the fraction of *per-capita* consumption that remains in the event of a representative consumption disaster from Barro and Ursúa (2008), and $\bar{B}^N$ is the fraction of *per-capita* consumption that remains for survivors of a nuclear war. Following Gabaix (2012), I model the stream of dividends as equalling consumption, *i.e.*,

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1. This is certainly an oversimplification in light of the possibility of a surprise attack, a response to a false alarm or an accident (Perry and Collina (2020)). The meaningful assumption is that there is a much lower intensity of nuclear war outside of a crisis.

$D_t = C_t$ for all t. An inconvenient fact in this representative-agent model is that investors may die in a nuclear war. For the sake of clarity, I defer the incorporation of death until I have presented more of the model's structure.

Let $\zeta_t \equiv P_t / D_t$. As the indicators of the tension levels are the only state variables, $\zeta_t \epsilon \{\zeta^k | k \epsilon \{G, T, C\}\}$. With the t subscript henceforth suppressed, let k be the current tension state and k' be the state after a jump. The price dynamics are

$$\frac{dP_t}{P_t} = \frac{d(\zeta_t C_t)}{\zeta_t C_t} = \begin{cases} g_C dt & \text{No disaster, no change in state} \\ \frac{\zeta^{k'}}{\zeta^k} - 1 & \text{Change in state from } k \text{ to } k', \text{ no disaster} \\ \bar{B}^E - 1 & \text{Barro and Ursúa (2008) disaster} \\ \frac{\zeta^G \bar{B}^N}{\zeta^C} - 1 & \text{Nuclear war} \end{cases} \tag{3.2}$$

The instantaneous return on equity may thus be expressed as

$$
\begin{aligned}
dR_t &= \frac{dP_t}{P_t} + \frac{C_t}{P_t} dt \\
&= \left(g_C + \frac{1}{\zeta^k} \right) dt + \sum_{k' \neq k} \left(\frac{\zeta^{k'}}{\zeta^k} - 1 \right) dJ^{k \to k'} + \left(\bar{B}^E - 1 \right) dJ^E + \left(\frac{\zeta^G \bar{B}^N}{\zeta^C} - 1 \right) dJ^N
\end{aligned}
$$
$$\tag{3.3}$$

where $dJ^{k \to k'}$ represents a change in tension state from k to k'. Given the depletion of nuclear arsenals and the capacity to deliver warheads that can be expected following a nuclear exchange, I assume that a nuclear war leads to a transition from the crisis state to the state in which a nuclear war is most distant, the state Good. The agent has Epstein-Zin

preferences, leading to the SDF dynamics

$$\frac{dM_t}{M_t} = e^{-\frac{\rho}{\chi}dt}\left(1 + \frac{dC_t}{C_t}\right)^{-\frac{1}{\chi\psi}}\left(1 + dR_t\right)^{\frac{1}{\chi}-1} - 1$$

$$= \left[-\frac{\rho}{\chi} - \gamma g_C + \left(\frac{1-\chi}{\chi}\right)\frac{1}{\zeta^k}\right]dt + \sum_{k'\neq k}\left[\left(\frac{\zeta^{k'}}{\zeta^k}\right)^{\frac{1-\chi}{\chi}} - 1\right]dJ^{k\to k'} \qquad (3.4)$$

$$+ \left[\left(\bar{B}^E\right)^{-\gamma} - 1\right]dJ^E + \left[\left(\bar{B}^N\right)^{-\gamma}\left(\frac{\zeta^G}{\zeta^C}\right)^{\frac{1-\chi}{\chi}} - 1\right]dJ^N$$

where ψ is the intertemporal elasticity of substitution; γ is the coefficient of relative risk aversion, and $\chi \equiv \frac{1-1/\psi}{1-\gamma}$.

As a reduced-form way of incorporating death without perversely increasing the representative agent's propensity to save, I model the agent as pricing an asset's stream of payments conditional on non-survival as if she would receive a survivor's consumption stream but only a fraction θ between 0 and 1 of the asset's payments. One interpretation is that this captures the value to an investor of payoffs to her surviving heirs in the spirit of, *e.g.*, Barro (1974). The agent thus prices the equity security as if the dividend evolved as

$$\frac{dD_t}{D_t} = g_C dt + (\bar{B}^E - 1)dJ^E + (\bar{B}^N - 1)dJ^{N,L} + (\theta\bar{B}^N - 1)dJ^{N,D} \qquad (3.5)$$

where I decompose the nuclear-war jump into a jump $dJ^{N,L}$ in which the agent lives and a jump $dJ^{N,D}$ in which the agent dies.

To solve for the price-dividend ratio in each state, I first map the dynamics to the

linearity-generating process framework of Gabaix (2007).

$$
\begin{aligned}
\frac{E_t[d(M_t D_t)]}{M_t D_t dt} =\ & -\frac{\rho}{\chi} - \left(\gamma - 1\right)g_C + \left(\frac{1-\chi}{\chi}\right)\frac{1}{\zeta^k} \\
& + \sum_{k' \neq k}\left[\left(\frac{\zeta^{k'}}{\zeta^k}\right)^{\frac{1-\chi}{\chi}} - 1\right]\lambda^{k\to k'} + \left[\left(\bar{B}^E\right)^{1-\gamma} - 1\right]\lambda^E \\
& + \left[\left(1 - \pi\left(1 - \theta\right)\right)\left(\bar{B}^N\right)^{1-\gamma}\left(\frac{\zeta^G}{\zeta^C}\right)^{\frac{1-\chi}{\chi}} - 1\right]\lambda^{N,k} \\
=\ & -a - \sum_k \beta^k \iota_t^k
\end{aligned}
\tag{3.6}
$$

where $\lambda^{k\to k'}$ is the transition intensity from k to k'; λ^E is the intensity of Barro and Ursúa (2008) disasters; $\lambda^{N,k}$ is the nuclear war intensity for state k; π is the probability of death in the event of nuclear war; and a and β^k are defined as

$$
\begin{aligned}
a \equiv\ & -E\left[\frac{E_t[d(M_t D_t)]}{M_t D_t dt}\right] \\
=\ & \frac{\rho}{\chi} + \left(\gamma - 1\right)g_C - \left[\left(\bar{B}^E\right)^{1-\gamma} - 1\right]\lambda^E + \sum_k \hat{\beta}^k \tilde{\lambda}^k \\
\hat{\beta}^k \equiv\ & -\left(\frac{1-\chi}{\chi}\right)\frac{1}{\zeta^k} - \sum_{k'\neq k}\left[\left(\frac{\zeta^{k'}}{\zeta^k}\right)^{\frac{1-\chi}{\chi}} - 1\right]\lambda^{k\to k'} \\
& - \left[\left(1 - \pi\left(1 - \theta\right)\right)\left(\bar{B}^N\right)^{1-\gamma}\left(\frac{\zeta^G}{\zeta^C}\right)^{\frac{1-\chi}{\chi}} - 1\right]\lambda^{N,k} \\
\beta^k \equiv\ & \hat{\beta}^k - \sum_{k'} \hat{\beta}^{k'}\tilde{\lambda}^{k'}
\end{aligned}
\tag{3.7}
$$

where $\tilde{\lambda}^k$ is the weight on state k in the stationary distribution.[2] Unenlightening math yields

---

2. $\begin{pmatrix}1 & 0 & 0 & 0\end{pmatrix}'$ is clearly an eigenvector with eigenvalue a of ω defined below, and I make the adjustments by $\sum_k \hat{\beta}^k\tilde{\lambda}^k$ to avoid the eigenvalue negativity that would invalidate the use of Theorem 4 of Gabaix (2007) to solve for the price-dividend ratios.

the Gabaix (2007) linearity-generating process Y_t satisfying

$$E_t[dY_t] = -\omega Y_t dt \tag{3.8}$$

where

$$Y_t \equiv \begin{pmatrix} M_t D_t & M_t D_t \iota_t^G & M_t D_t \iota_t^T & M_t D_t \iota_t^C \end{pmatrix}'$$

$$\omega \equiv \begin{pmatrix} a & \beta^G & \beta^T & \beta^C \\ 0 & \Phi[0,0] & \Phi[0,1] & \Phi[0,2] \\ 0 & \Phi[1,0] & \Phi[1,1] & \Phi[1,2] \\ 0 & \Phi[2,0] & \Phi[2,1] & \Phi[2,2] \end{pmatrix}$$

$$\Phi[0,0] \equiv \frac{\rho}{\chi} + \left(\gamma - 1\right)g_C - \left[\left(\bar{B}^E\right)^{1-\gamma} - 1\right]\lambda^E + \lambda^{G\to T} - \left(\frac{1-\chi}{\chi}\right)\frac{1}{\zeta^G}$$

$$\Phi[0,1] \equiv -\left(\frac{\zeta^G}{\zeta^T}\right)^{\frac{1-\chi}{\chi}}\lambda^{T\to G}$$

$$\Phi[0,2] \equiv -\left(1 - \pi\left(1 - \theta\right)\right)\left(\bar{B}^N\right)^{1-\gamma}\left(\frac{\zeta^G}{\zeta^C}\right)^{\frac{1-\chi}{\chi}}\lambda^{N,C} \tag{3.9}$$

$$\Phi[1,0] \equiv -\left(\frac{\zeta^T}{\zeta^G}\right)^{\frac{1-\chi}{\chi}}\lambda^{G\to T}$$

$$\Phi[1,1] \equiv \frac{\rho}{\chi} + \left(\gamma - 1\right)g_C - \left[\left(\bar{B}^E\right)^{1-\gamma} - 1\right]\lambda^E + \lambda^{T\to G} + \lambda^{T\to C} - \left(\frac{1-\chi}{\chi}\right)\frac{1}{\zeta^T}$$

$$\Phi[1,2] \equiv -\left(\frac{\zeta^T}{\zeta^C}\right)^{\frac{1-\chi}{\chi}}\lambda^{C\to T}$$

$$\Phi[2,0] \equiv 0$$

$$\Phi[2,1] \equiv -\left(\frac{\zeta^C}{\zeta^T}\right)^{\frac{1-\chi}{\chi}}\lambda^{T\to C}$$

$$\Phi[2,2] \equiv \frac{\rho}{\chi} + \left(\gamma - 1\right)g_C - \left[\left(\bar{B}^E\right)^{1-\gamma} - 1\right]\lambda^E + \lambda^{C\to T} + \lambda^{N,C} - \left(\frac{1-\chi}{\chi}\right)\frac{1}{\zeta^C}$$

By Theorem 4 of Gabaix (2007) and with $\beta \equiv \begin{pmatrix} \beta^G & \beta^T & \beta^C \end{pmatrix}'$, the price-dividend ratios

are given implicitly by

$$\zeta^G = \frac{1}{a}\left[1 - \beta'\Phi^{-1}\begin{pmatrix} 1 & 0 & 0 \end{pmatrix}'\right]$$

$$\zeta^T = \frac{1}{a}\left[1 - \beta'\Phi^{-1}\begin{pmatrix} 0 & 1 & 0 \end{pmatrix}'\right] \tag{3.10}$$

$$\zeta^C = \frac{1}{a}\left[1 - \beta'\Phi^{-1}\begin{pmatrix} 0 & 0 & 1 \end{pmatrix}'\right]$$

This system of equations may be solved numerically given the other parameters. I model very short-term Treasury debt as being in zero net supply and riskless except in the event of nuclear war, in which case I presume an effective recovery rate of $\bar{B}^{N,bill}$. A sense of duty may motivate investors facing the prospect of war to treat government debt as if it were safer than it is, and this parameter will reflect both the assumed recovery rate and non-pecuniary returns. Given the SDF and the reduced-form handling of death, the yield in nuclear-tension state k is

$$r_t^{bill,k} = \frac{\rho}{\chi} + \gamma g_C - \left(\frac{1-\chi}{\chi}\right)\frac{1}{\zeta^k} + \sum_{k'\neq k}\left[1 - \left(\frac{\zeta^{k'}}{\zeta^k}\right)^{\frac{1-\chi}{\chi}}\right]\lambda^{k\to k'} + \left[1 - \left(\bar{B}^E\right)^{-\gamma}\right]\lambda^E$$

$$+ \left[1 - \left(1 - \pi\left(1 - \theta\right)\right)\bar{B}^{N,bill}\left(\bar{B}^N\right)^{-\gamma}\left(\frac{\zeta^G}{\zeta^C}\right)^{\frac{1-\chi}{\chi}}\right]\lambda^{N,C}\iota_t^C \tag{3.11}$$

3.2 Nuclear-tension state dynamics

As I seek to understand market responses to the Cuban Missile Crisis, I focus on the properties of nuclear tension and crises in years around it. There is no obvious starting point, so I begin my sample on 28 July 1953, the day after the Korean War armistice was signed and the beginning of a period without open war between the United States and major communist powers. Both the Americans and the Soviets had successfully tested fusion devices by 12 August 1953, so this starting point also largely coincides with a structural break in the

risks associated with war that presumably would impact the propensity to escalate tensions. A period for which I could obtain individual-level survey data on expectations of nuclear conflict without long gaps ended in mid-1965, so with a certain degree of arbitrariness, I end my sample on 27 July 1965 after precisely 12 years.[3]

Given the heterogeneity in beliefs about the likelihood of nuclear war (Figure 4.2) and evidence of imperfect risk sharing, *e.g.*, Brav et al. (2002), I focus on the expectations of respondents who are more likely to be marginal in the stock market. Individuals with higher income and college education had greater involvement in the stock market (Kreinin (1959), Lease et al. (1974), Bartscher et al. (2020)).[4] Where both income and education data are available, expectations pertinent to nuclear conflict are similar among higher-income individuals, college graduates and higher-income individuals with college degrees, and both groups with college degrees are generally less likely to expect a world war over a 5-year horizon (Figures 4.2, 4.3, 4.4; 4.5). Due to their greater availability, I use the expectations of college graduates as indicative of those of the marginal investor, and all references to investors' expectations for the rest of this section should be understood to derive from those of college graduates.

The crises during my sample period are those that Betts (1987) identifies as featuring at least subtle threats of nuclear use. These are the Taiwan Straits crisis of 1954-1955, the Suez Crisis of 1956, The Lebanon crisis of 1958, the Taiwan Straits crisis of 1958, the Berlin deadline crisis of 1958-1959, the Berlin *aide-mémoire* crisis of 1961 and the Cuban Missile Crisis of 1962.[5] I obtain start dates and end dates from version 13 of the International Crisis

---

3. The late 1960s until the late 1970s were years of détente between the United States and the Soviet Union, and using later data may yield average expectations that are excessively optimistic for the early 1960s (Office of the Historian, US Department of State (nd)). The Office of the Historian of the US Department of State points to the 1968 signing of the Nuclear Nonproliferation Treaty as early strong evidence of détente (Office of the Historian, US Department of State (nd)).

4. Around the time of the Crisis, most researchers and advisors at brokerages with research departments were also college graduates (H.R. Doc. No. 95, Pt. 1, 88th Cong., 1st Session (1963)).

5. Betts (1987) discusses the Indochina crisis of 1954 due to the American consideration of the use of nuclear weapons in Indochina, but I omit it due to his assessment of an absence of public signalling. Betts

Behaviour (ICB) Project's dataset. The frequency of crises over this span is 0.58 crises per year, and the mean duration is 0.30 years.[6] Under the presumption that a crisis can only transition to the tense state absent a nuclear war, the implied transition rate from a crisis to a tense state is 3.35 per year. As a measure of clustering, the standard deviation of the interval between crises is 1.00 years.

Data limitations necessitate a series of strong assumptions. Gallup polls available during this span provide the fraction of respondents who believe that a world war is likely to occur within 5 years. To map this to a fraction who believe a nuclear war to be likely within 5 years, I multiply it by the fraction of college graduates who believe that such a war would escalate into nuclear war. This fraction shows little variation over the Cold War, and I use the mean value of 0.65 (Figure 4.3). Without clear external data on whether each survey was taken during a relatively relaxed or tense period, I examine the surveys taken outside of crisis periods and group by their levels the inferred fractions of college-educated respondents who believe nuclear war to be likely within 5 years. I observe a cluster of 8 around 0.10 which averaged 0.09, which I take to be a typical fraction during a good period, and a cluster of 3 around 0.2 which averaged 0.19, which I take to be a typical fraction during a tense period.[7] Passing a sanity check, the highest fraction of respondents who believed that a war was likely to occur within 5 years came from the one readily exploitable survey during a crisis period, the Taiwan Straits crisis of 1954-1955.

I make a distributional assumption to map the share of respondents who believe that a nuclear war is likely to occur within 5 years to a representative median belief about the

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(1987) distinguishes between lower-risk and higher-risk crises, but I consolidate them in the interest of parsimony.

6. The duration of a crisis can differ among participant countries. I select the minimum among the US, USSR and China.

7. The partition into values informative about the good state and values informative about the tense state is {0.03, 0.06, 0.07, 0.08, 0.10, 0.11, 0.11, 0.12} and {0.19, 0.19, 0.21} There is a non-trivial gap, and the sole remaining value occurred during a Betts (1987) crisis. The surveys underlying these calculations are presented in Tables C.2, C.3 and C.4.

probability of nuclear war within 5 years. I observe in the survey data evidence that a significant share of the population assigns a very low probability to the likelihood of nuclear war. In the single granular survey that I have for the first half of the Cold War, 33 per cent of college graduates selected 0 or 1 on a scale of 0 to 10 for the probability of nuclear war within 5 years (National Opinion Research Centre (1963)). Later surveys before the end of the Cold War for both 5- and 10-year horizons yield similar fractions of responses that nuclear war was very unlikely. I consequently add a mass point at 0 equal to the average of these fractions, also 33 per cent. Allowing for a peak, skew and a fat tail, I presume that the full distribution is a mixture of this mass point and a specific form of the beta distribution called a PERT distribution.[8] The PERT distribution requires three parameters–the minimum of its domain, the maximum of its domain and a most-likely value–and only the most-likely value is free here.

To fit the distribution, I presume that a belief that nuclear war is likely implies a belief that the probability of nuclear war is at least 0.5. I proceed to select as the value of the free parameter that for which the density at and above a probability of 0.5 equals the inferred fraction of investors who expect nuclear war. I choose as the probability that the representative agent assigns to nuclear war the median of the fit distribution. The fraction of 0.09 deeming nuclear war likely within 5 years maps to a probability of 0.15 in the good state, and the fraction of 0.19 maps to a probability of 0.25 in the tense state.

I calibrate the remaining transition probabilities between the tension states and the intensity of nuclear war in the crisis state by the method of simulated moments (McFadden (1989)). I presume that the good state can only transition to the tense state; that the tense state can transition either to the good state or to the crisis state; and that the crisis state can only transition to the tense state unless there is a nuclear war. With four parameters, I choose four moments. I match: i.) the inferred probability of nuclear war over 5 years when

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8. This distribution is used in managerial applications and, coincidentally, was developed for the Polaris missile programme (Malcolm et al. (1959), MacCrimmon and Ryavec (1964)).

in the good state to the fraction of simulations starting in the good state in which nuclear war occurs over a 5-year span; *ii.*) the analogues for the tense state; *iii.*) the frequency of crises over the 12-year sample to the average frequency over 12-year simulations beginning in the tense state in which nuclear war does not occur;[9] and *iv.*) the standard deviation of the interval between crises to the average over 12-year simulations beginning in the tense state in which nuclear war does not occur. The moments obtained directly from the properties of crises and the method-of-simulated-moments calibration yield the following matrix of transition intensities in units of inverse years, with the source state along the columns and the destination state along the rows:

$$
\begin{array}{c} \\ Good \\ Tense \\ Crisis \end{array}
\begin{array}{ccc} Good & Tense & Crisis \end{array}
\begin{pmatrix}
\cdot & 0.40 & 0 \\
0.41 & \cdot & 3.35 \\
0 & 1.45 & \cdot
\end{pmatrix}
$$

The close correspondence of the model-implied values to the data to be matched is presented in Table 4.9. The calibrated intensity of nuclear war in a crisis state is 0.30 per year. Together with a mean crisis duration of 0.30 years, the probability at the onset of a typical crisis that it will end in nuclear war is estimated to be 0.09.

3.3   Calibration of the asset-pricing model

I follow Gabaix (2012) in employing a value of 2 for the IES ψ and a value of 0.025 for the consumption growth rate.[10] Given survey respondents' beliefs about their own survival

9. The sample begins immediately after the signing of the Korean War armistice, so it is reasonable to presume an initially high level of tension.

10. A consumption growth rate of 0.025 is broadly in line with the experience of the 1960s. From the peak of the first business cycle of the 1960s–1957Q3–through the peak of the final business cycle of the 1960s–1969Q4–real per-capita consumption grew at an annual rate of 0.027 (National Bureau of Economic Research (2020), FRBSL FRED series A794RX0Q048SBEA). With an end in 1965Q3 like the estimation of the state dynamics, the rate is 0.024. Whilst there was a particularly long span without a recession during

of nuclear war, I presume that the probability of survival π is 0.5 (Figure 4.4). I obtain the transition probabilities between the tension states and the intensity of nuclear war in the crisis state in the previous subsection. Without evidence on investor expectations of the consumption impact of nuclear war, I perform separate calibrations of the other parameters–the coefficient of relative risk aversion γ, the rate of time preference ρ, the expected recovery rate for very short-term debt conditional on nuclear war $\bar{B}^{N,bill}$ and the payoff multiplier associated with death θ–conditional on each of a set of possibilities. With four parameters, I choose four moments to match. The first two are the equity return and the change in the four-week T-bill yield the first trading day of the Crisis, 23 October 1962, respectively -2.63 per cent and -0.0052 per cent. The model outputs to which they correspond are the equity return and change in short-term debt yield upon a jump from a tense to a crisis state. With the price-dividend ratio of the aggregate market averaging around 30 in years around the Cuban Missile Crisis, and Hamilton et al. (2015) finding a typical *ex-ante* short-term real yield of 1.95 per cent, I match the unconditional expectations of the price-dividend ratio and the yield on very short-term debt to those values.[11][12][13]

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the 1960s–the trough of 1961Q1 to the peak of 1969Q4–and there was discussion of whether the US could indefinitely avoid recession, there remained serious concerns about the possibility of a downturn (National Bureau of Economic Research (2020) and, *e.g.*, Abele (1962a), Dale (1964), Dale (1965) and Mullaney (1967).

11. For an approximate price-dividend ratio in a given year, I invert the sum of the difference between the CRSP value-weighted returns with and without dividends over each month in that year. From the peak of the first NBER business of the 1960s in 1957 through the peak of the final NBER business cycle of the 1960s in 1969, the mean price-dividend ratio is 30.7 National Bureau of Economic Research (2020). With an end in 1965 like the estimation of the state dynamics, the mean is 29.9. The magnitude of the difference from the value of 23 to which Gabaix (2012) compares the price-dividend ratio yielded by his model for a much broader span justifies the use of an alternative.

12. Visual inspection of Hamilton et al. (2015) Exhibit 2.9 suggests that the mean over the 1958Q2-2014Q3 sample is broadly in line with values from the end of the 1950s until roughly 1968.

13. Specifically, I implement dual annealing in a global search for the parameters yielding the minimum distance between the implied and targeted values. Accepted points are refined by local minimisation with the TNC algorithm. Given the approximate nature of the longer-run averages, I assign less weight to deviations from them. The distance is the squared deviation in the equity return plus the squared deviation in the yield change plus one-hundredth the squared deviation in the typical real yield on short-term debt and one-ten-thousandth the squared fractional deviation in the price-dividend ratio. I restrict the CRRA (γ) to be between 1.05 and 5, the post-nuclear-war debt recovery rate ($\bar{B}^{N,bill}$) to be between 0.001 and 1, the payoff multiplier if the agent dies (θ) to be between 0 and 1 and the rate of time preference to be between 0.001

The set of potential recovery rates for *per-capita* consumption and, consequently, dividends conditional on survival, are 0.5, 0.25 and 0.1. A best-case scenario of 0.5 is motivated by a 1958 NES prediction that labour productivity might reach half of its pre-war level within a year of a nuclear exchange (Net Evaluation Subcommittee (1958, p. 15)). The calibrations are presented in Table 4.10. The key result is that the calibrated values of the coefficient of relative risk aversion are below the levels typically found in the finance literature. The best-case scenario yields a γ of 2.00, whilst the worst outcome considered yields a γ of 1.41. In light of perceptions that the Cuban Missile Crisis presented a greater danger than a typical crisis, and given the broad set of risks that I have neglected in the interest of parsimony, these estimates of the CRRA are likely to be too high by a non-trivial margin. The CRRA estimates are all outside of the range of 2 to 5 that Barro (2006) presents as the consensus of the finance literature, and they are all far below the values of 3 to 6 with which other prominent works in the disaster-risk literature fit market data, *e.g.*, Gabaix (2012) and Wachter (2013).[14] The discrepancy in the CRRA consequently suggests that either market participants underreacted to the Crisis, or market participants' risk aversion should be reconsidered. The Barro and Ursúa (2008) disasters are commonly used in this strand of the literature, so a clear extension is to assess whether key findings are robust to the inclusion of unrealised catastrophes and, if so, with which levels of risk aversion.

An alternative explanation is that survey data may provide an inaccurate picture of investors' perceptions of risk. The choice to become an active investor may be associated with unobserved heterogeneity in beliefs. The marginal investor's beliefs may more closely resemble those of the group that assign a low probability to a disastrous war than the median of the inferred probability distribution. Additionally, heterogeneity in the nature of trading

and 0.1. The use in Gabaix (2012) of a CRRA of 4 and the use in Barro (2006) of a maximum CRRA of 4 when neither paper includes the risk of nuclear war motivates an upper bound of 5 in my search.

14. The estimate for the best-case scenario of 1.996 is just barely outside of the Barro (2006) range, but in that calibration, the agent applies almost no additional discounting for the possibility of her death.

may be important. In the event of nuclear war, a portfolio manager might expect at most a small benefit from her partial hedging of others' wealth against nuclear risk–and, of course, only if she survives. If, however, nuclear war should not occur, she might expect to pay a professional price for the associated lower returns. Abele (1962a) reports that the activity of retail investors had declined significantly in 1962, so the incentives of professional portfolio managers may have been particularly important in driving market movements.

With a caveat about the precise estimates, the calibrated model also suggests that caution should be exercised in the interpretation of event studies of the impact of tail risk. In addition to the impact of tail risk on the long-run averages of price-dividend ratios and debt yields, much of their responses to the evolution of tail risk can occur well before an acute crisis arises. The three calibrations yield shocks to the price-dividend ratio upon the transition from the good state to the tense state ranging from -4.57 per cent to -4.58 per cent, which are over 70 per cent larger in magnitude than the shock at the onset of the Crisis (Table 4.10). The impact on short-term yields is also much larger, with a drop of -8.73 to -13.28 bp rather than a fraction of a basis point. To the extent that a trend in tension may be shallow or that tension may grow over highly variable windows, such market responses prior to a crisis may be challenging to identify.

CHAPTER 4

CONCLUSION

In this paper, I present novel evidence that investors priced the risk of nuclear destruction. Firms with headquarters in regions more likely to be targeted generally experienced lower returns at the onset of the Cuban Missile Crisis. Larger firms' exposures appear to have been largely priced, with a reversal of their initial underperformance as the crisis unwound, but I find evidence consistent with investors' gradual learning about smaller firms' exposures. To reconcile the moderate market reactions to the increased risk of nuclear conflict with survey data on expectations about nuclear war, a representative agent requires a lower level of risk aversion than is typically used to explain market behaviour. With implications for the pricing of climate risk, these results suggest that whilst investors price the risk of historically unobserved disasters, they either behave inconsistently with standard models, or their perceived exposures to extreme risks are incongruous with survey data.

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Figure 4.1: Fama-French 3 residual of the cumulative return on the industry spread formed on responses to President Kennedy's 22 October 1962 Cuba address. The portfolio is long the 5 industries with the lowest abnormal returns and short the 5 with the highest. A negative value before the address indicates a positive return through the final trading day before the address. A negative value after the address indicates a negative return from the first trading day after the address. The shaded region spans the 0.5 per-cent through the 99.5 per-cent quantiles of values obtained from the recentering of the cumulative returns on each date in a 1000 trading-day window around 22 October 1962. Industries not available directly from Kenneth R. French's website for the period of interest are omitted, including Guns and Gold. Weakest Fama-French 49 industries: Toys, PerSv, Cnstr, RlEst, Smoke. Strongest Fama-French 49 industries: Aero, Steel, Ships, Coal, ElcEq.
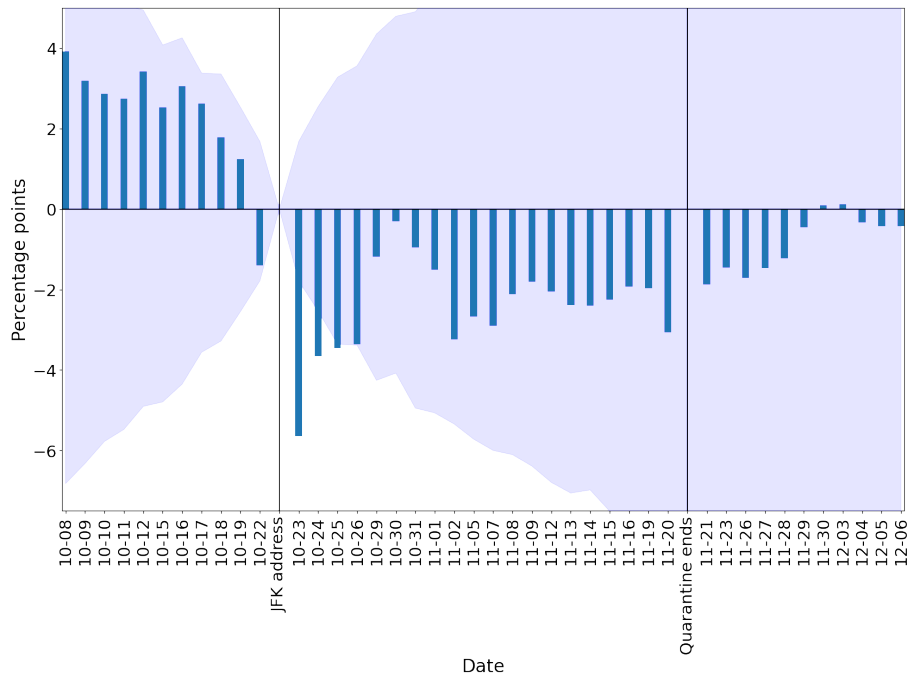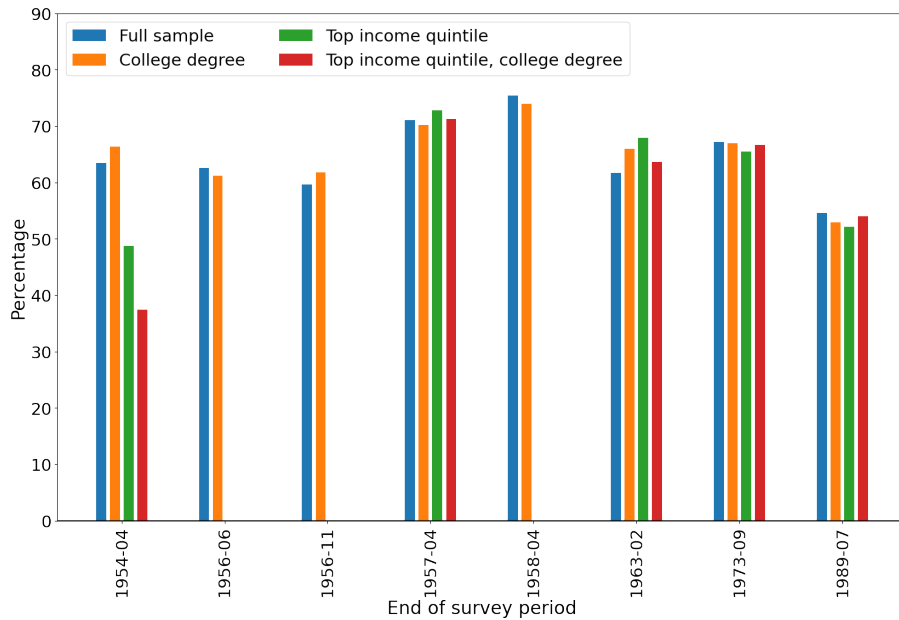

SOURCE: Kenneth R. French; author's calculations

Figure 4.2: Fraction of the American population who believe that a world war is likely within 5 years. The underlying surveys are presented in Table C.1. Approximate top income quintiles are derived from US Bureau of the Census Series P-60 reports. Income is reported as a range in the surveys.
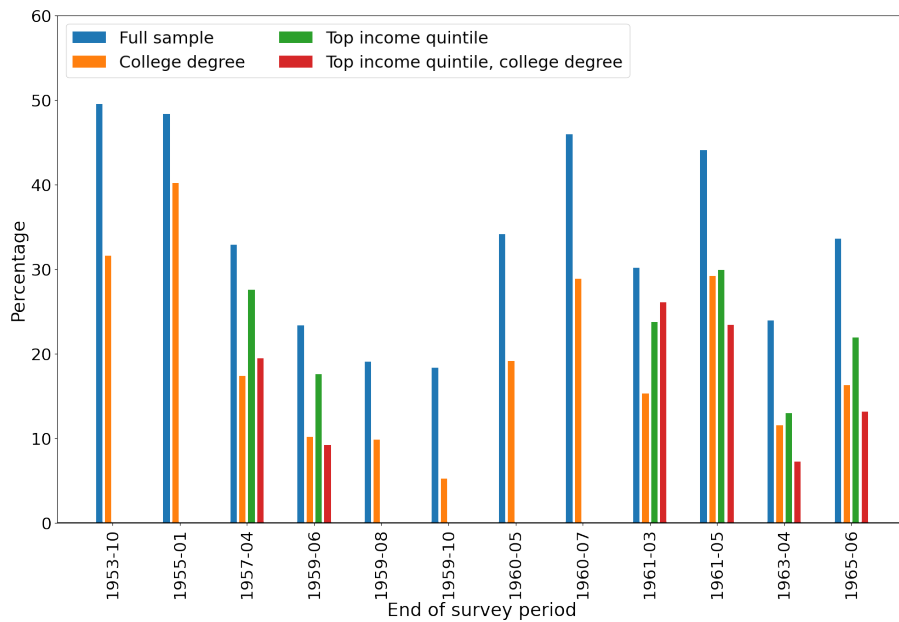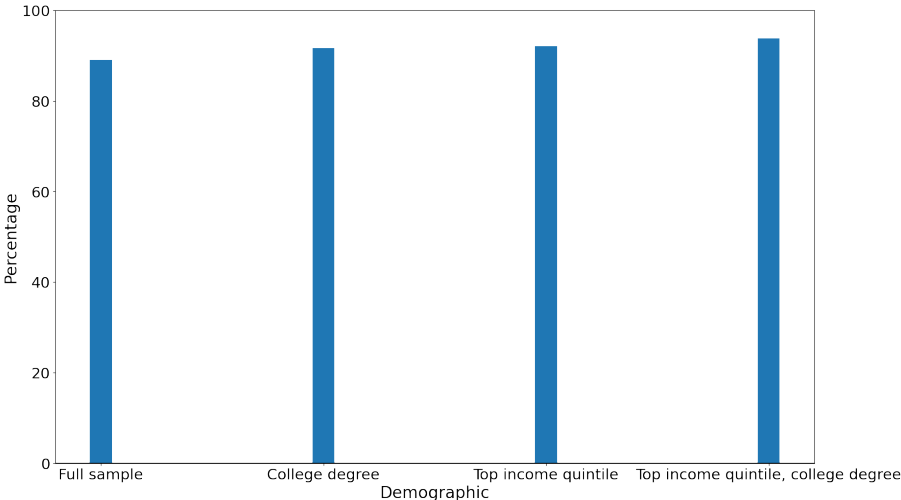

SOURCE: Gallup via Roper Centre; US Census Bureau; author's calculations

Figure 4.3: Fraction of the American population who expect the use of nuclear weapons in a major war. The underlying surveys are presented in Table C.2. Approximate top income quintiles through 1963 are derived from US Bureau of the Census Series P-60 reports. Top income quintiles in later years are obtained from US Census Bureau Table H-1. Income is reported as a range in the surveys.

Figure 4.4: Fraction of the American population who believe that they would survive a nuclear war with P ≤ 0.5. An approximate top income quintile is derived from US Bureau of the Census report P-60, no. 43. Income is reported as a range in the surveys.


SOURCE: Gallup Poll #1963-0668 via Roper Centre; US Census Bureau; author's calculations

Figure 4.5: American beliefs in December 1963 about the outcome of a nuclear war. Respondents were to select the statement that best reflected their beliefs. Americans will cope: "If nuclear war does come, people in the US will make the best of the situation." US can survive: "Although nuclear war would be a terrible thing, it would be possible to survive as a nation." Possible to rebuild: "Enough people would survive a nuclear war to pick up the pieces and carry on with a good chance of rebuilding a system which lives under American values, as we know them." End of civilisation: "A nuclear war would mean the end of civilisation as we know it." End of all life: "A nuclear war would mean the end of the world and all life in it." An approximate top income quintile is derived from US Bureau of the Census report P-60, no. 43. Income is reported as a range in the surveys.
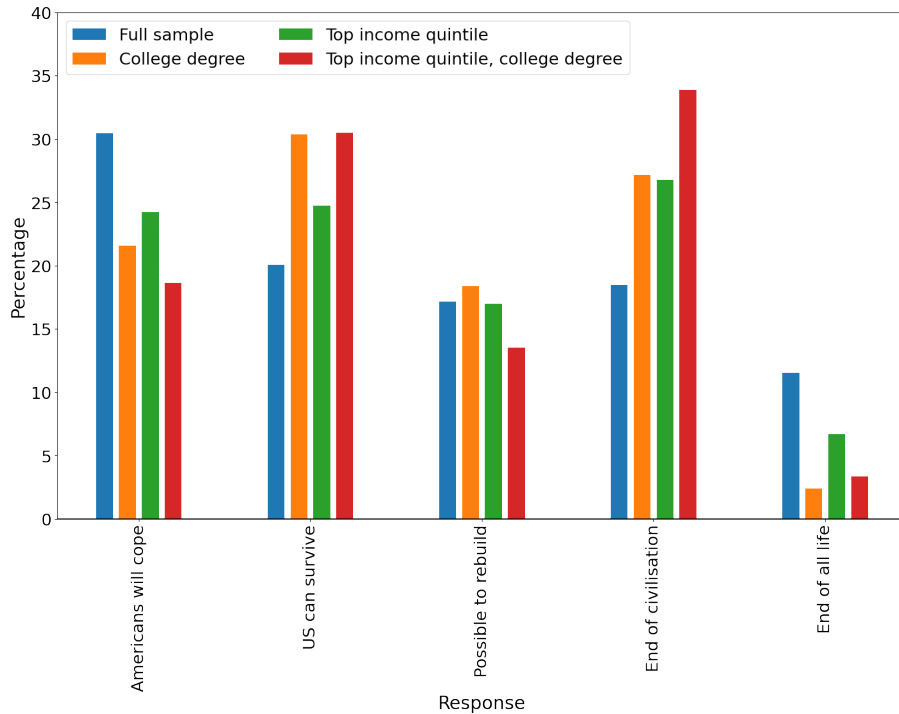
SOURCE: NORC Amalgam Study #330 via Roper Centre; US Census Bureau; author's calculations

Figure 4.6: Observed Treasury and aggregate-equity movements around President Kennedy's 22 October 1962 19:00 EDT Cuba address. For the cumulative value-weighted CRSP return, a positive value on a date up to and including that of the address indicates a negative return through the date of the address, and a negative value after the address indicates a negative return from the first trading day after the address.
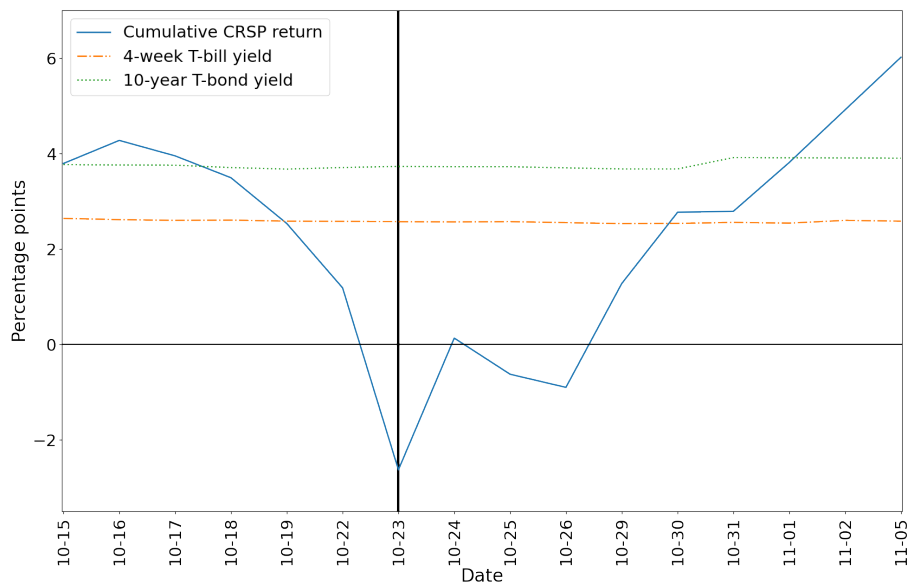
SOURCE: CRSP via WRDS; author's calculations

Figure 4.7: Ground zeroes in a Soviet-initiated war in a 1962 Net Evaluation Subcommittee of the National Security Council war game

ACTUAL GROUND ZEROS SOVIET TOTAL ATTACK

" LOW " FORCE

TOP SECRET
RESTRICTED DATA
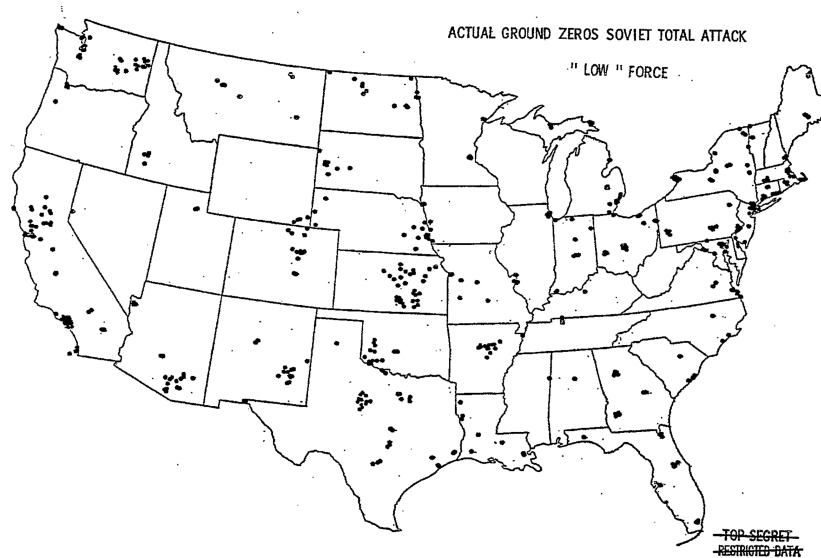
SOURCE: "1962 Report of the Net Evaluation Subcommittee National Security Council", p. 28a, map 3, made available by the National Security Archive

Figure 4.8: Ground zeroes in a Soviet retaliatory strike in a 1962 Net Evaluation Subcommittee of the National Security Council war game

ACTUAL GROUND ZEROS
SOVIET TOTAL ATTACK "LOW" FORCE

TOP SECRET
RESTRICTED DATA

SOURCE: "1962 Report of the Net Evaluation Subcommittee National Security Council", p. 91a, map 8, made available by the National Security Archive

Figure 4.9: Impact of a headquarters' presence in a top-10 CBSA by population on cumulative returns around President Kennedy's 22 October 1962 Cuba address without economic controls. A negative value before the address indicates a positive return through the final trading day before the address. A negative value after the address indicates a negative return from the first trading day after the address. Clustering is by Fama-French 49 industry, and significance is asymptotic.
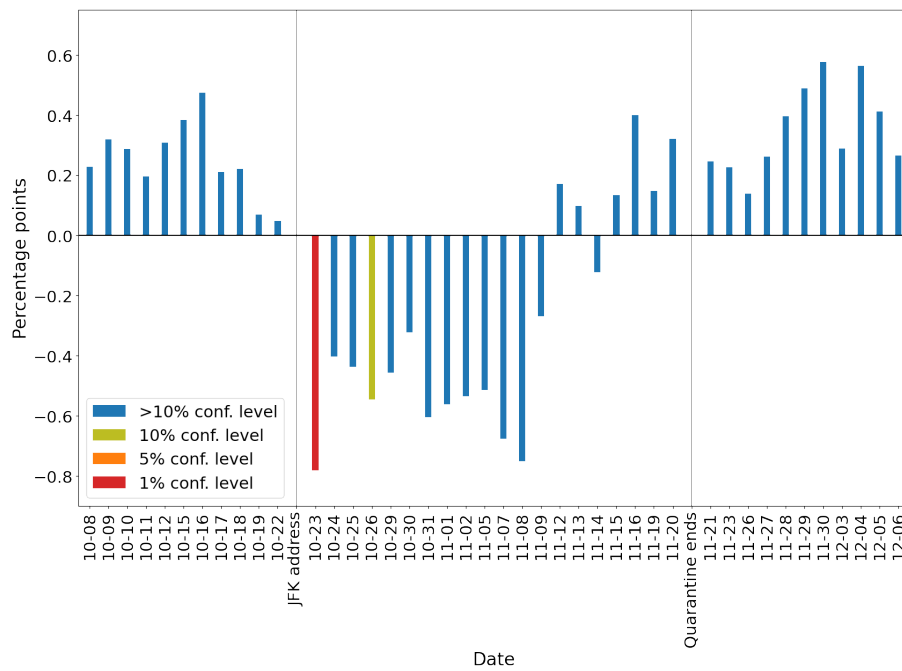
Figure 4.10: Baseline impact of a headquarters' presence in a top-10 CBSA by population on cumulative returns around President Kennedy's 22 October 1962 Cuba address. Fama-French 49 fixed effects and Fama-French 3 factor loadings are employed. Clustering is by Fama-French 49 industry, and significance is asymptotic. A negative value before the address indicates a positive return through the final trading day before the address. A negative value after the address indicates a negative return from the first trading day after the address.
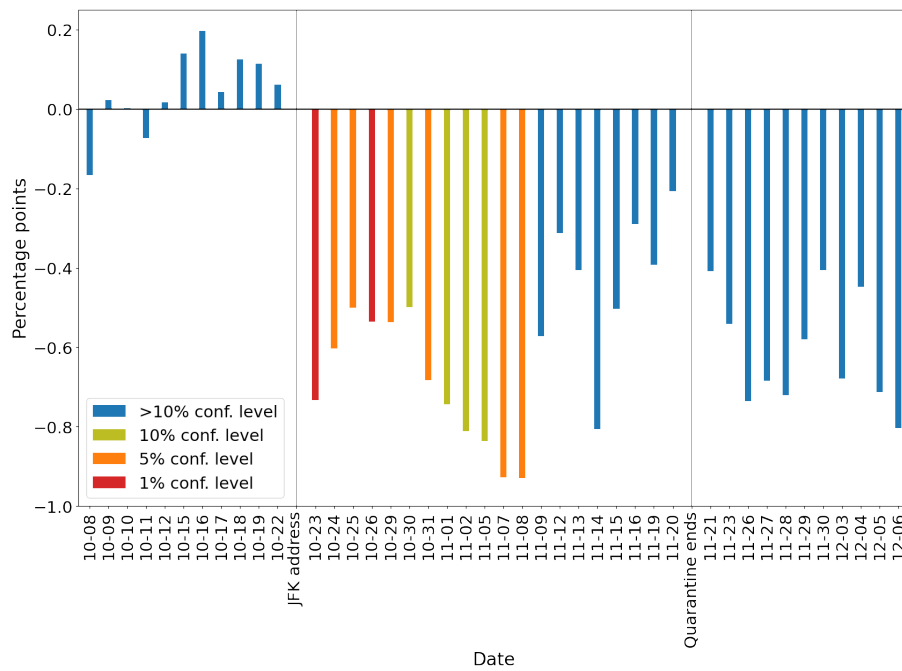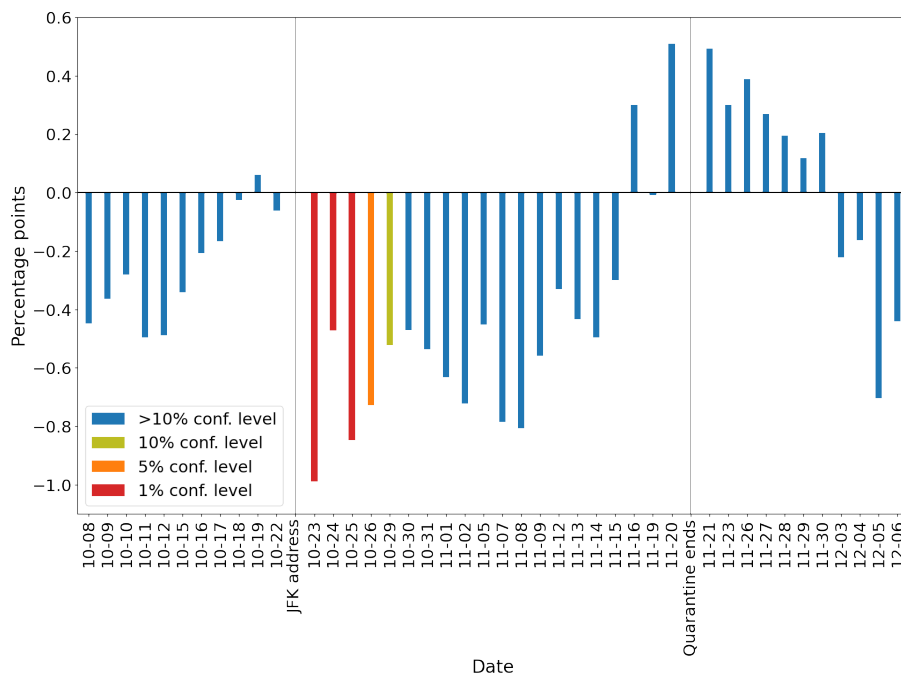

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Figure 4.11: Impact among the top 50 per cent of sample firms by market capitalisation of a top-10-CBSA presence on cumulative returns around President Kennedy's 22 October Cuba address. Each bar is the coefficient on an indicator of a headquarters' presence in a top-10 CBSA by population with controls for Fama-French 49 industry and Fama-French 3 factor loadings. Clustering is by Fama-French 49 industry. A negative value before the address indicates a positive return through the final trading day before the address. A negative value after the address indicates a negative return from the first trading day after the address.

Figure 4.12: Impact among the bottom 50 per cent of sample firms by market capitalisation of a top-10-CBSA presence on cumulative returns around President Kennedy's 22 October Cuba address. Each bar is the coefficient on an indicator of a headquarters' presence in a top-10 CBSA by population with controls for Fama-French 49 industry and Fama-French 3 factor loadings. A negative value before the address indicates a positive return through the final trading day before the address. A negative value after the address indicates a negativ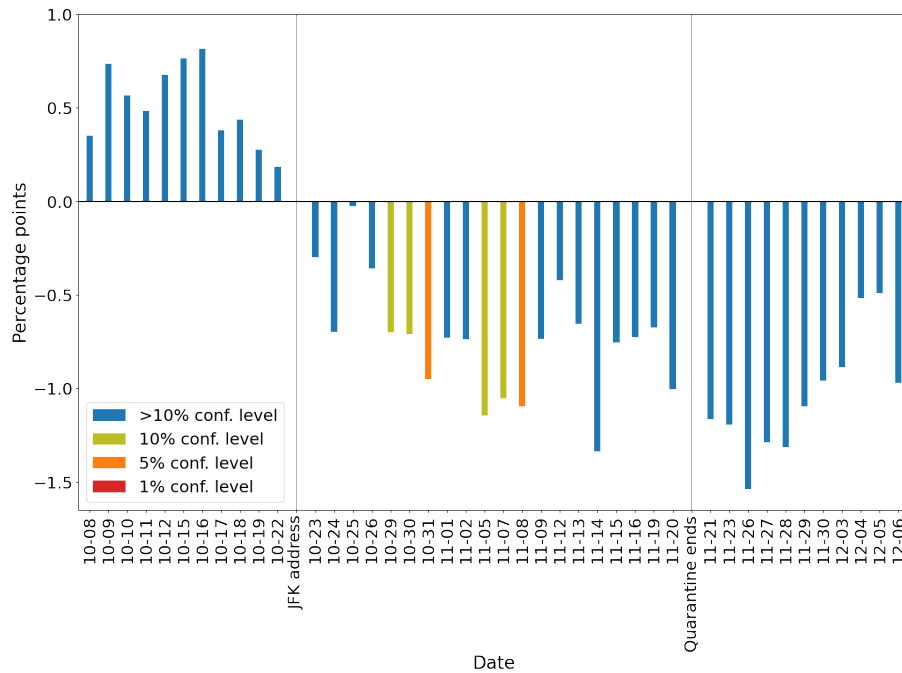e return from the first trading day after the address. Clustering is by Fama-French 49 industry, and significance is asymptotic.

Figure 4.13: Estimates of the cumulative top-10-CBSA effect obtained via matrix completion. Vertical bars indicate the first trading day after President Kennedy's 22 October 1962 address and the first trading day after President Kennedy's 20 November announcement of the lifting of the quarantine. A negative value before the 22 October address indicates a positive return through the final trading day before the address, and a negative value after the address indicates a negative return from the first trading day after the address. Large firms are those in the top 50 per cent of sample firms by market capitalisation on 22 October 1962, and small firms are those in the bottom 50 per cent. Cumulative returns are obtained from the cumulation of estimates of the geographic effect on single trading days. All estimations include date-specific effects.
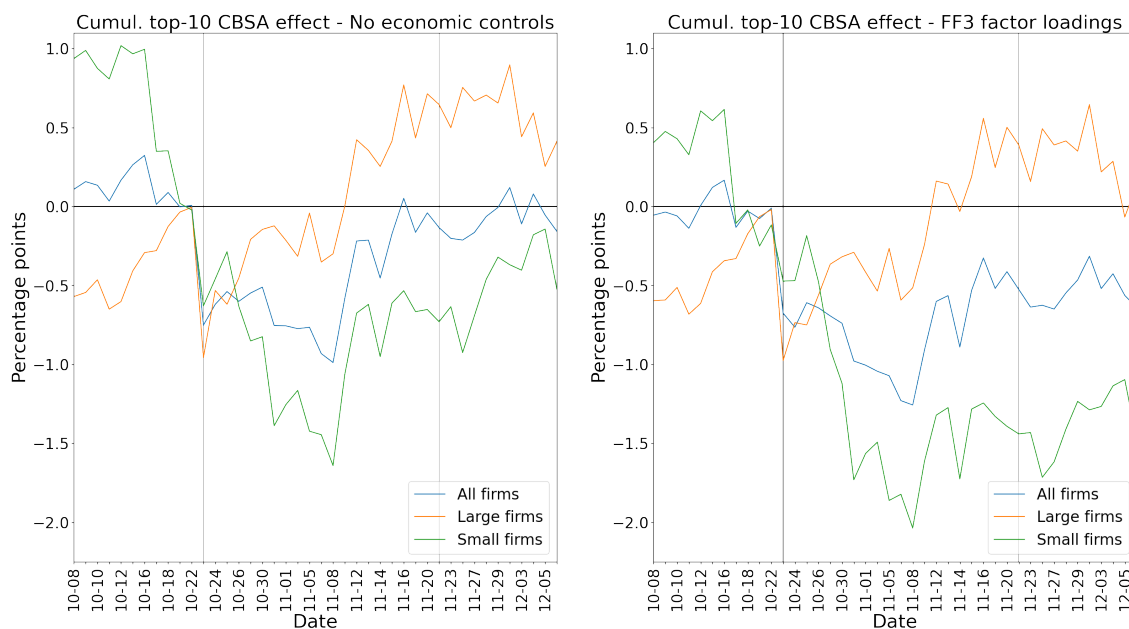
Table 4.1: Fama-French 49 industry returns on the first trading day after President Kennedy's 22 October 1962 Cuba address. Returns are sorted from the most positive to the most negative. Industries not available directly from Kenneth R. French's website for the period of interest are omitted, including Guns and Gold.

Fama-French 3 residuals		*Raw returns*	
Industry	*Change (%)*	*Industry*	*Change (%)*
Aero	4.45	Steel	1.41
Steel	3.81	Aero	0.60
Ships	2.19	Coal	0.44
Coal	2.16	Ships	-0.43
ElcEq	1.88	Trans	-0.81
...		...	
Smoke	-2.13	Books	-5.16
RlEst	-2.40	Fun	-5.18
Cnstr	-2.74	PerSv	-5.30
PerSv	-2.81	Cnstr	-6.08
Toys	-3.96	Toys	-8.84

SOURCE: Kenneth R. French; author's calculations

Table 4.2: Timeline of the 1962 Cuban Missile Crisis. Critical developments are in italics.

Date	Events
14-15 Oct.	United States Government discovers missile sites
22 Oct.	*Kennedy delivers his address at 19:00 EDT*
24 Oct.	*Khrushchev writes that the USSR will not act rashly*
28 Oct.	*USSR announces intention to remove missiles*
	Secretary of State Rusk: "[I]t is not yet the time to say this is over."
28 Oct.- 20 Nov.	Negotiations over verification, IL-28 bombers, Cuba...
8 Nov.	DoD presents photographic evidence of missile removal
20 Nov.	*At 18:00 EST Kennedy announces the end of the quarantine*

SOURCE: *The New York Times*, Chang and Kornbluh (1998)

Table 4.3: Top-10 CBSAs by population and the number of sample firms with headquarters identified in each. The population figure is that for the corresponding SMSA except in the case of the CBSA of New York City, in which case it is the sum of the New York City and Newark SMSA populations. The 1963 population counts employ the 1964 SMSA definitions (Census Bureau (1965, p. 14)).

Major city in CBSA	Population (1963)	Firms in CBSA
New York City	13075000	207
Los Angeles	6559000	16
Chicago	6480000	56
Philadelphia	4554000	33
Detroit	3889000	26
Boston	3174000	7
San Francisco	2838000	7
Pittsburgh	2356000	19
Washington, DC	2250000	2
St. Louis	2180000	14
Other		214
Total		601

SOURCE: US Census Bureau, Mergent Archives, ProQuest Historical Annual Reports, HUD, UnitedStatesZipCodes.org; author's calculations

Table 4.4: Geographic variation in firm returns by CBSA group. *t*-statistics are presented in parentheses, and significance is asymptotic. Column 3 is the baseline specification. Where industry fixed effects are employed, industries with fewer than two firms in the sample are dropped, and the within estimator is used.

(pp)	*First trading day after JFK address (23 October)*						*Address (22 October)*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Top 10	-0.78***	-0.62***	-0.73***			-0.58**	-0.06
	(3.62)	(3.03)	(3.87)			(2.47)	(0.29)
Top 5				-0.74***	-0.61***		
				(3.59)	(2.64)		
Top 6-10				-0.70			
				(1.37)			
$\hat{\beta}_{rmrf}$		-2.28***	-2.42***	-2.40***	-2.46***	-2.36***	-0.99**
		(4.36)	(5.29)	(5.25)	(5.45)	(3.96)	(2.44)
$\hat{\beta}_{smb}$		-0.40	-0.23	-0.25	-0.23	-0.28	-0.40***
		(1.48)	(1.26)	(1.34)	(1.23)	(1.52)	(2.78)
$\hat{\beta}_{hml}$		1.16*	0.75	0.66	0.65	0.80*	0.34
		(1.67)	(1.51)	(1.36)	(1.35)	(1.68)	(0.99)
Ind. FE			FF49	FF49	FF49	SIC2	FF49
Clustering	FF49	FF49	FF49	FF49	FF49	SIC2	FF49
$\bar{R}^2$	0.01	0.10	0.10	0.10	0.10	0.10	0.03
N	601	601	568	577	575	558	568

***/**/*: Significant at the 1%/5%/10% confidence level

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Table 4.5: Geographic variation in firm returns at the individual-CBSA level. *t*-statistics are presented in parentheses, and significance is asymptotic. Where industry fixed effects are employed, industries with fewer than two firms in the sample are dropped, and the within estimator is used. Washington, DC, is not included in the disaggregated sample due to data limitations.

(pp)	First trading day after JFK address (23 October)		
	(1)	(2)	(3)
New York City	-0.99***	-0.72***	-0.78***
	(3.97)	(3.12)	(3.52)
Los Angeles	-1.04	-0.42	-0.94
	(0.90)	(0.36)	(1.47)
Chicago	-0.75*	-0.68*	-0.69**
	(1.78)	(1.76)	(2.00)
Philadelphia	-0.45	-0.36	-0.24
	(1.08)	(0.87)	(0.58)
Detroit	-0.87	-0.90**	-1.01***
	(1.51)	(2.04)	(3.05)
San Francisco	-2.54**	-3.07***	-3.15***
	(2.15)	(2.69)	(2.60)
Boston	-1.32	-1.38	-2.09**
	(1.35)	(1.64)	(2.05)
Pittsburgh	1.14	1.03	0.05
	(1.12)	(0.97)	(0.09)
St. Louis	0.17	-0.02	-0.05
	(0.20)	(0.02)	(0.05)
$\hat{\beta}_{rmrf}$		-2.32***	-2.46***
		(4.62)	(5.67)
$\hat{\beta}_{smb}$		-0.39	-0.27
		(1.44)	(1.43)
$\hat{\beta}_{hml}$		1.10*	0.62
		(1.78)	(1.31)
Ind. FE			FF49
Clustering	FF49	FF49	FF49
$\bar{R}^2$	0.02	0.11	0.11
N	599	599	581

***/**/*: Significant at the 1%/5%/10% confidence level

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Table 4.6: Geographic variation in returns at the level of state aggregates on the first trading day after President Kennedy's 22 October 1962 Cuba address. Clustering is by FF49 industry; t-statistics are presented in parentheses, and significance is asymptotic. Where industry fixed effects are employed, industries with fewer than two firms in the sample are dropped, and the within estimator is used. Tri-state area: CT, NJ and NY. Industrial: IN, MI and OH. Capital region: DC, DE, MD and VA. Southern New England: MA and RI. Heavily targeted bases: AR, AZ, CO, KS, NE, NM, OK and WA.

(pp)	First trading day after JFK address (23 October)		
	(1)	(2)	(3)
Tri-state area	-1.34***	-0.87**	-0.93**
	(3.36)	(2.06)	(2.23)
California	-1.47*	-0.94	-1.37**
	(1.70)	(1.02)	(2.19)
Illinois	-1.09*	-0.82	-0.88
	(1.92)	(1.50)	(1.63)
Pennsylvania	0.00	0.19	-0.21
	(0.00)	(0.24)	(0.38)
Industrial	-0.63	-0.28	-0.15
	(1.12)	(0.56)	(0.43)
Capital region	-0.19	-0.05	0.03
	(0.37)	(0.09)	(0.04)
Florida	-3.35***	-3.11***	-3.22***
	(3.70)	(3.43)	(2.90)
Texas	-2.10***	-1.88***	-1.88***
	(3.90)	(2.73)	(2.89)
Southern New England	-0.79	-0.58	-1.24
	(1.25)	(0.91)	(1.42)
Heavily targeted bases	0.67	0.82	-0.01
	(1.45)	(1.42)	(0.01)
$\hat{\beta}_{rmrf}$		-2.26***	-2.40***
		(4.35)	(5.29)
$\hat{\beta}_{smb}$		-0.41	-0.25
		(1.60)	(1.41)
$\hat{\beta}_{hml}$		1.01	0.52
		(1.54)	(1.06)
Ind. FE			FF49
$\bar{R}^2$	0.03	0.11	0.11
N	601	601	582

***/**/*: Significant at the 1%/5%/10% confidence level

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Net Evaluation Subcommittee (1962), Schwartz (1998), US Census Bureau; author's calculations

Table 4.7: State aggregates and the number of sample firms with headquarters identified in each. Tri-state area: Connecticut, New Jersey and New York. Industrial: Indiana, Michigan and Ohio. Capital region: District of Columbia, Delaware, Maryland and Virginia. Southern New England: Massachusetts and Rhode Island. Heavily targeted bases: Arkansas, Arizona, Colorado, Kansas, Nebraska, New Mexico, Oklahoma and Washington.

Area	Firms in region
Tri-state area	234
California	30
Illinois	63
Pennsylvania	48
Industrial	94
Capital region	24
Florida	6
Texas	15
Southern New England	12
Heavily targeted bases	10
Other	65
Total	601

SOURCE: Mergent Archives, ProQuest Historical Annual Reports, Net Evaluation Subcommittee (1962), Schwartz (1998), US Census Bureau; author's calculations

Table 4.8: Variation of the top-10 CBSA effect with respect to market capitalisation. The effect is estimated for the first trading day after President Kennedy's 22 October 1962 Cuba address. Columns 3 and 6 are respectively the baseline specifications for large firms and small firms. Market capitalisation is as of 22 October 1962, prior to President Kennedy's address. *t*-statistics are presented in parentheses, and significance is asymptotic. Where industry fixed effects are employed, industries with fewer than two firms in the sample are dropped, and the within estimator is used.

(pp)	Top 50 per cent by market cap.			Bottom 50 per cent by market cap.		
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Top 10	-0.91***	-0.86***	-0.99***	-0.67	-0.35	-0.30
	(4.14)	(3.31)	(4.49)	(1.46)	(0.77)	(0.68)
$\hat{\beta}_{rmrf}$		-1.28**	-2.05***		-2.98***	-2.52***
		(2.33)	(4.66)		(4.14)	(3.20)
$\hat{\beta}_{smb}$		0.05	0.10		-0.89***	-0.65***
		(0.12)	(0.37)		(4.35)	(2.87)
$\hat{\beta}_{hml}$		1.01	0.66		1.52*	1.66**
		(1.49)	(1.20)		(1.80)	(2.25)
Ind. FE			FF49			FF49
Clustering	FF49	FF49	FF49	FF49	FF49	FF49
$\bar{R}^2$	0.02	0.07	0.12	0.01	0.14	0.11
N	299	299	276	299	299	264

***/**/*: Significant at the 1%/5%/10% confidence level

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Table 4.9: Calibration of the dynamics of nuclear-tension states. Intensities and frequencies are rates per year, and intervals are in years. The crisis frequency and standard deviation of the intervals between crises are conditional on a 12-year simulation beginning in a tense state and the non-realisation of nuclear war.

Parameter		Matching		
Via method of simulated moments		*Value*	*Data*	*Fit*
Nuclear war intensity in crisis ($\lambda^{N,C}$)	0.30	P(nuclear war within 5Y|*good*)	0.15	0.15
Intensity *good* $\rightarrow$ *tense* ($\lambda^{G \rightarrow T}$)	0.41	P(nuclear war within 5Y|*tense*)	0.25	0.25
Intensity *tense* $\rightarrow$ *good* ($\lambda^{T \rightarrow G}$)	0.40	Crisis frequency	0.58	0.58
Intensity *tense* $\rightarrow$ *crisis* ($\lambda^{T \rightarrow C}$)	1.45	St. dev. of crisis interval	1.00	1.04
Direct		*Value*	*Data*	*Fit*
Intensity *crisis* $\rightarrow$ *tense* ($\lambda^{C \rightarrow T}$)	3.35	1/mean crisis duration	3.35	3.35

SOURCE: CBS News and The New York Times, Gallup, Media General/Associated Press, Newsweek Magazine/Gallup, NORC, Potomac Associates/Gallup and The Roper Organisation via the Roper Centre; ICB Project; author's calculations

Table 4.10: Joint calibration of the remaining model parameters conditional on the selection of the recovery rate of consumption after a nuclear exchange. In line with Gabaix (2012), an IES (ψ) of 2 and a non-stochastic component of the growth rate of consumption and dividends (g_c) of 2.50 per cent are imposed on each calibration. The recovery rate of dividends is the same as that of consumption after both an economic disaster and a nuclear war. The Barro and Ursúa (2008) distribution of disasters is used to calculate the CRRA-dependent effective recovery rate in an economic disaster $\bar{B}^E$, and, accordingly, economic disasters occur at the Barro and Ursúa (2008) rate of 0.0363 per year. In the calibrations, deviations from observed changes upon the transition from a tense state to a crisis state are penalised more heavily than deviations from estimates of the unconditional means. The surveys underlying the conditional probabilities are presented in Tables C.4 and C.3.

Panel A: Calibrated parameters

	Consumption recovery rate ($\bar{B}^N$)		
	0.50	0.25	0.10
CRRA (γ)	2.00	1.62	1.41
Post-nuclear-war debt recovery ($\bar{B}^{N,bill}$)	0.65	0.34	0.14
Payoff multiplier if die (θ)	1.00	0.35	0.08
Time preference (ρ) (%)	1.80	1.90	1.93

Panel B: Model fit

		Consumption recovery rate ($\bar{B}^N$)		
	Data	0.50	0.25	0.10
Uncond. mean price-dividend ratio	30.0	29.9	30.0	30.2
Uncond. mean short-term yield (%)	1.95	1.62	2.01	2.18
Growth in equity price *tense → crisis* (%)	-2.63	-2.60	-2.63	-2.64
Change in short-term yield *tense → crisis* (*bp*)	-0.53	1.77	-0.52	-1.07

*Panel C: Implied impacts of transition from a good to a tense state*

	Consumption recovery rate ($\bar{B}^N$)		
	0.50	0.25	0.10
Growth in equity price *good → tense* (%)	-4.57	-4.57	-4.58
Change in short-term yield *good → tense* (*bp*)	-13.28	-10.42	-8.73

SOURCE: Barro and Ursúa (2008), Gabaix (2012), Hamilton et al. (2015); CRSP via WRDS; FRBSL FRED, NBER; sources for Table 4.9; author's calculations

APPENDIX A

SUPPLEMENTARY DATA AND ROBUSTNESS CHECKS

Figure A.1: Fama-French 49 industry shares for sample firms headquartered in top-10 CBSAs versus those for sample firms headquartered elsewhere in the US. Multiple industries may be represented by the same point.
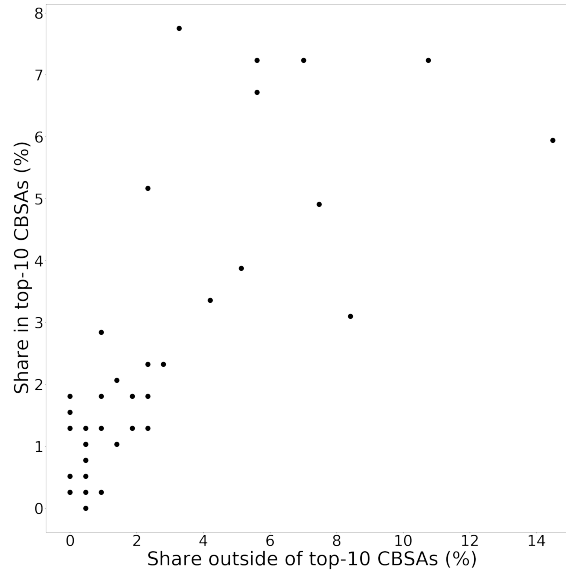
SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Figure A.2: Sensitivity of the top-10-CBSA effect with respect to SIC-2 industry removal. SIC-2 fixed effects and FF3 factor loadings are included as controls. Clustering is by SIC-2 industry. Regressions only include industries with at least 2 firms.
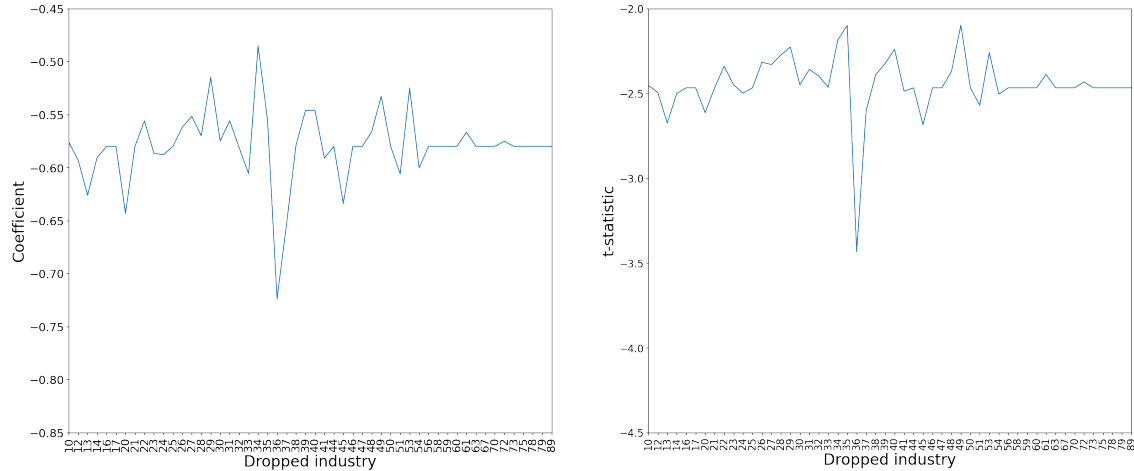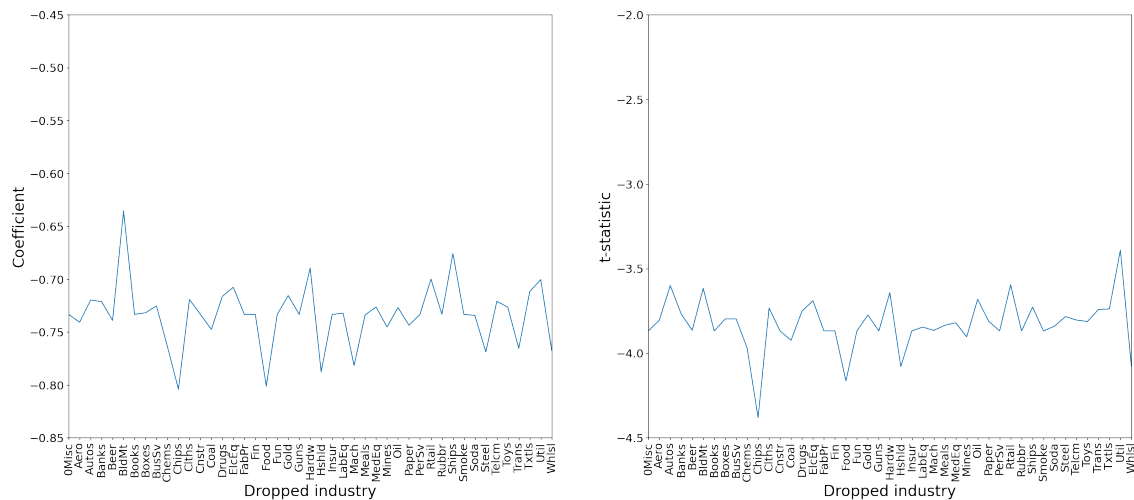

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Figure A.3: Sensitivity of the top-10-CBSA effect with respect to FF49 industry removal. FF49 fixed effects and FF3 factor loadings are included as controls. Clustering is by FF49 industry. Regressions only include industries with at least 2 firms.
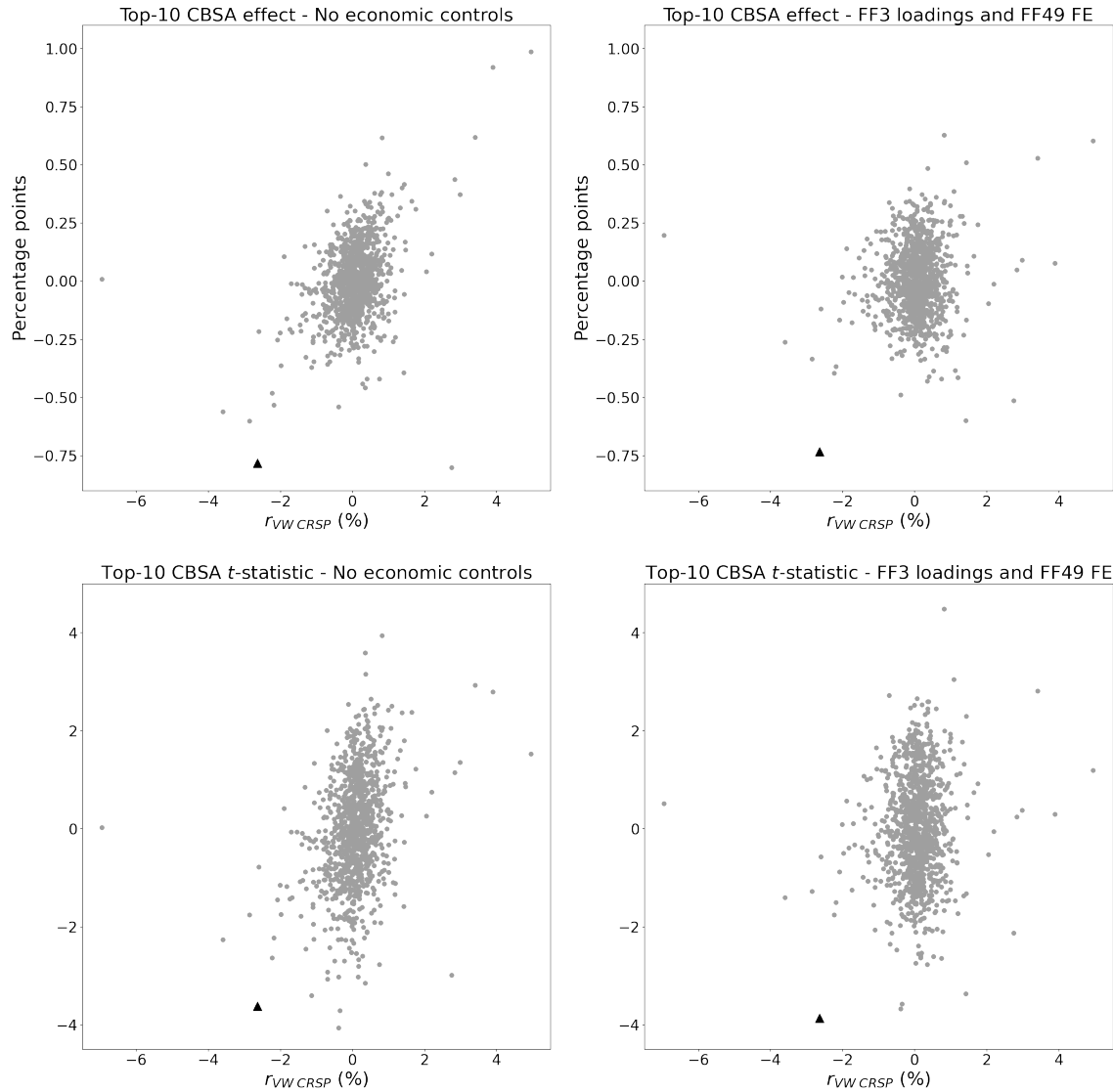

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Figure A.4: Scatter of the cross-sectional estimate of the geographic effect for all firms against the value-weighted CRSP return on each trading day within a window of 1000 trading days around President Kennedy's 22 October 1962 address (26 October 1960 through 16 October 1964). Clustering is by FF49 industry. The observation for the first trading day after President Kennedy's address is indicated with a triangle.

Figure A.5: Scatter of the cross-sectional estimate of the geographic effect for large firms against the value-weighted CRSP return on each trading day within a window of 1000 trading days around President Kennedy's 22 October 1962 address (26 October 1960 through 16 October 1964). Large firms are those in the top 50 per cent of market capitalisation at the close of trading on 22 October 1962. Clustering is by FF49 industry. The observation for the first trading day after President Kennedy's address is indicated with a triangle.
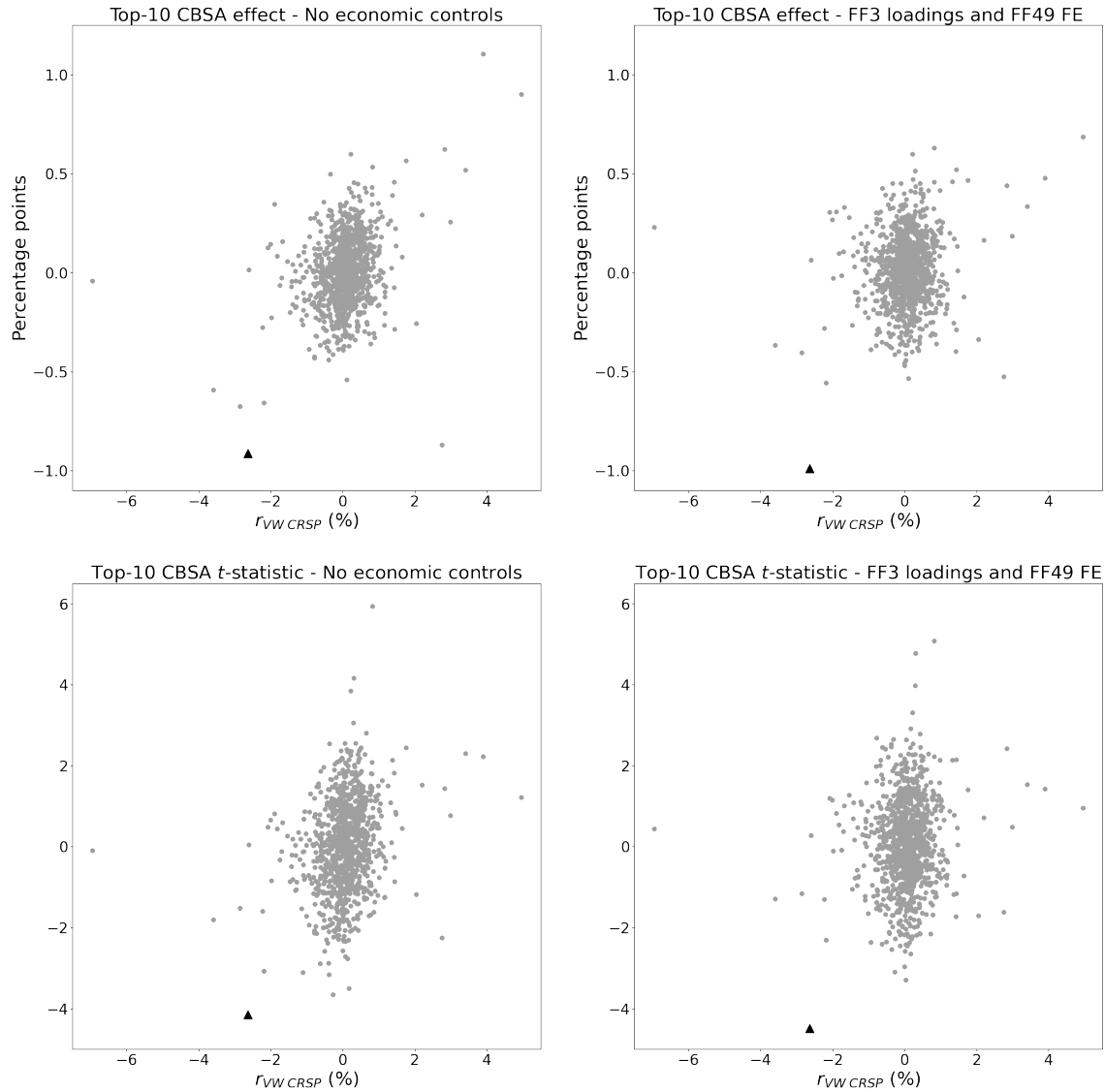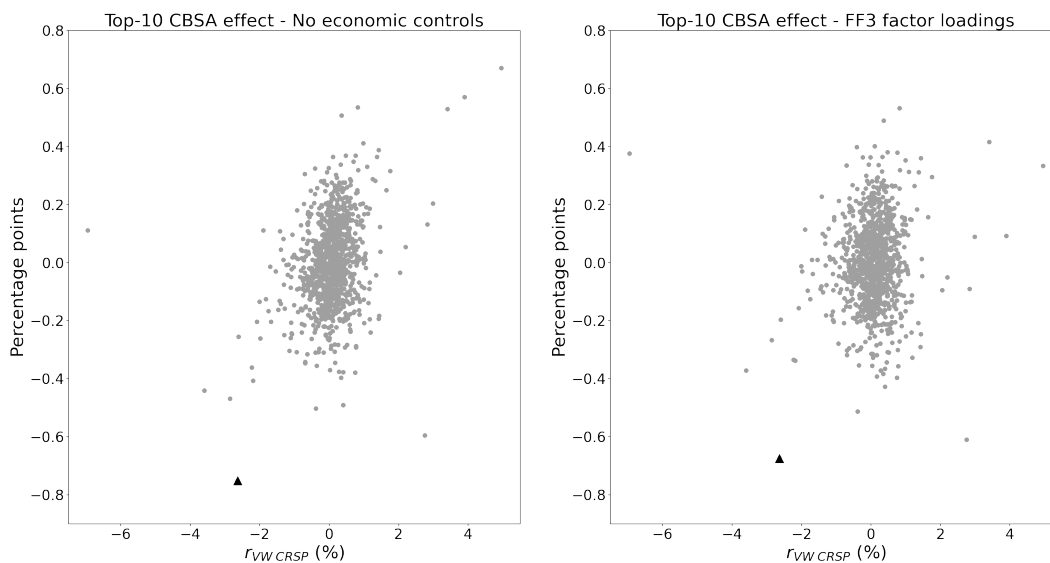
Figure A.6: Scatter of the matrix-completion estimate of the geographic effect for all firms against the value-weighted CRSP return on each trading day within a window of 1000 trading days around President Kennedy's 22 October 1962 address (26 October 1960 through 16 October 1964). The penalty parameter λ employed for the original 23 October 1962 estimation is employed for all dates. All estimations include date-specific effects. The observation for the first trading day after President Kennedy's address is indicated with a triangle.

Figure A.7: Scatter of the matrix-completion estimate of the geographic effect for large firms against the value-weighted CRSP return on each trading day within a window of 1000 trading days around President Kennedy's 22 October 1962 address (26 October 1960 through 16 October 1964). The penalty parameter λ employed for the original 23 October 1962 estimation is employed for all dates. All estimations include date-specific effects. Large firms are those in the top 50 per cent of market capitalisation at the close of trading on 22 October 1962. The observation for the first trading day after President Kennedy's address is indicated with a triangle.

Table A.1: Summary statistics for firms headquartered in top-10 CBSAs and elsewhere in the US. Fama-French 3 betas are for 23 October 1962 and are calculated with the Welch (2019) age-decayed slope-winsorised beta estimator using only prior data. Market capitalisation is from the end of trading on 22 October 1962.

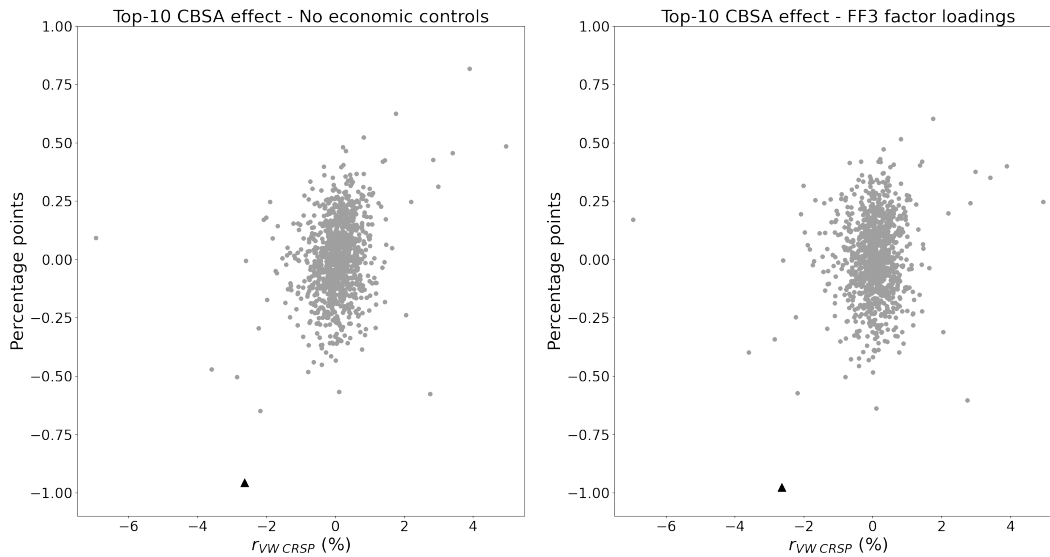|		*Top-10 CBSAs*	*Elsewhere*
$\hat{\beta}^{rmrf}$	*Mean*	0.99	0.92
	Std. dev.	0.36	0.37
$\hat{\beta}^{smb}$	*Mean*	0.43	0.52
	Std. dev.	0.81	0.81
$\hat{\beta}^{hml}$	*Mean*	0.21	0.24
	Std. dev.	0.38	0.41
Market cap. ($M)	*Mean*	443.28	237.85
	Median	90.38	99.58
	Std.dev.	1726.69	414.00
N		387	214

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Table A.2: Largest-magnitude geographic effects and *t*-statistics from cross-sectional regressions for 23 October 1962 obtained from the random geographic assignment of firms. 1000 simulations were performed with the random permutation of the indicator variable for being in a top-10 CBSA. Large firms are those in the top 50 per cent of market capitalisation at the close of trading on 22 October 1962. Where industry fixed effects are employed, industries with fewer than two firms in the sample are dropped, and the within estimator is used. All standard errors are clustered at the FF49 level.

Panel A: Largest geographic effects

(pp)	All firms		Large firms	
	(1)	(2)	(3)	(4)
Actual	-0.78	-0.73	-0.91	-0.99
Quantile of actual magnitude in simulated (%)	0.40	0.00	3.30	0.70
Largest simulated magnitude	0.84	0.70	1.44	1.22
FF3 factor loadings, FF49 FE		Yes		Yes

Panel B: Largest t-statistics for geographic effects

	All firms		Large firms	
	(1)	(2)	(3)	(4)
Actual magnitude	3.62	3.87	4.14	4.49
Quantile of actual magnitude in simulated (%)	0.20	0.00	0.00	0.00
Largest simulated magnitude	4.16	3.52	4.01	3.88
FF3 factor loadings, FF49 FE		Yes		Yes

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Table A.3: Largest-magnitude geographic effects from matrix completions for 23 October 1962 obtained from the random geographic assignment of firms. 1000 simulations were performed with the random permutation of the indicator variable for being in a top-10 CBSA. Large firms are those in the top 50 per cent of market capitalisation at the close of trading on 22 October 1962. All estimations include date-specific effects.

(pp)	All firms		Large firms	
	(1)	(2)	(3)	(4)
Actual	-0.75	-0.68	-0.96	-0.98
Quantile of actual magnitude in simulated (%)	0.40	0.70	0.00	0.10
Largest simulated magnitude	0.78	0.85	0.60	1.00
FF3 factor loadings		Yes		Yes

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Table A.4: Largest-magnitude top-10-CBSA effects and *t*-statistics from cross-sectional regressions performed on each of 1000 trading days around 22 October 1962 (26 October 1960 through 16 October 1964). Large firms are those in the top 50 per cent of market capitalisation at the close of trading on 22 October 1962. Where industry fixed effects are employed, industries with fewer than two firms in the sample are dropped, and the within estimator is used. All standard errors are clustered at the FF49 level.

Panel A: Largest top-10-CBSA effects

(pp)	All firms		Large firms	
	(1)	(2)	(3)	(4)
Number 1	0.99	-0.73†	1.10	-0.99†
Number 2	0.92	0.63	-0.91†	0.69
Number 3	-0.80	0.60	0.90	0.63
Number 4	-0.78†	-0.60	-0.87	0.60
Number 5	0.62	0.53	-0.67	-0.56
Number 6	0.62	-0.51	-0.66	-0.53
Number 7	-0.60	0.51	0.62	-0.53
Number 8	-0.56	-0.49	0.60	0.52
Number 9	-0.54	0.48	-0.59	0.51
Number 10	-0.53	-0.43	0.57	0.48
FF3 loadings, FF49 FE		Yes		Yes

Panel B: Largest t-statistics for top-10-CBSA effects

	All firms		Large firms	
	(1)	(2)	(3)	(4)
Number 1	4.07	4.48	5.94	5.09
Number 2	3.94	3.87†	4.16	4.78
Number 3	3.72	3.68	4.14†	4.49†
Number 4	3.62†	3.58	3.84	3.97
Number 5	3.59	3.37	3.66	3.31
Number 6	3.41	3.04	3.50	3.29
Number 7	3.16	2.81	3.16	3.10
Number 8	3.15	2.77	3.11	2.96
Number 9	3.08	2.74	3.07	2.91
Number 10	3.03	2.72	3.06	2.79
FF3 loadings, FF49 FE		Yes		Yes

†: Value for 23 October 1962

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

Table A.5: Largest-magnitude top-10-CBSA effects from matrix completions for each of 1000 trading days around 22 October 1962 (26 October 1960 through 16 October 1964). The penalty parameter λ employed for the original 23 October 1962 estimation is employed for all dates. Large firms are those in the top 50 per cent of market capitalisation at the close of trading on 22 October 1962. All estimations include date-specific effects.

(pp)	All firms		Large firms	
	(1)	(2)	(3)	(4)
Number 1	-0.75†	-0.68†	-0.96†	-0.98†
Number 2	0.67	-0.61	0.82	-0.64
Number 3	-0.60	0.53	-0.65	-0.60
Number 4	0.57	-0.51	0.63	0.60
Number 5	0.54	0.49	-0.58	-0.57
Number 6	0.53	-0.43	-0.57	0.52
Number 7	0.51	0.42	0.52	-0.50
Number 8	-0.50	0.40	-0.50	-0.48
Number 9	-0.49	0.40	0.49	0.47
Number 10	-0.47	-0.40	-0.48	-0.46
FF3 loadings		Yes		Yes

†: Value for 23 October 1962

SOURCE: CRSP via WRDS; Mergent Archives, ProQuest Historical Annual Reports, Kenneth R. French, US Census Bureau, HUD, UnitedStatesZipCodes.org; author's calculations

APPENDIX B

PRODUCTION OF FIRM DATASET

A sketch of the dataset production is presented below. Full details are available upon request.

A critical step is the merging of firm geographic data with returns data. Mergent Archives and ProQuest Historical Annual Reports provide mappings from firm names to locations, and CRSP and the CRSP/Compustat Merged Database provide mappings from firm names to PERMNOs that can be linked to CRSP returns. At a high level, I perform the merge on the basis of exact matches between each of a set of Mergent and ProQuest cleaned firm names and each of a set of processed CRSP and CRSP/Compustat firm names. I employ Python and make heavy use of regular expressions to automate most of the steps.

As part of a broader research agenda, I searched Mergent Archives and ProQuest Historical Annual Reports for annual reports for 1945, 1949, 1956, 1962, 1968, 1973, 1979 and 1985 and consolidated the pages of search results from each source. For Mergent, the firm name was in column "Company", the report year in "Doc Date", the city in "City" and the state in "State".[1] For ProQuest, the firm name is an element of the field in column "Title". I select as the raw name the text in that field until "Annual Report". I extract the city and state from the field in column "subjectTerms". They may be on either side of "United States–US" and are separated from it and any other adjacent element by a comma and are ordered as city plus space plus state. The full name of a state is sought in this extracted text and, if found, that state is mapped to a two-letter abbreviation. The city is the residual after the removal of the state. Where there is no city, but the state is "dc", the city is set to "washington". The report year is in column "year".

I obtain CRSP data from 1945 through 1991. The firm name is in "COMNAM". The year is obtained as the floor of "date"/10000. I only keep observations where "SHRCD" is 10 or 11 as in Fama and French (2015); "EXCHCD" is 1, 2 or 3; and "SHRCLS" is not

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1. I shall refer to the District of Columbia as a state for simplicity.

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in "B" through "Z" or "0" through "9"; and I drop duplicates. I seek only one equity per firm, which allows PERMNO to serve as a unique firm identifier. PERMNO is obtained from column "PERMNO". I obtain CRSP/Compustat data from 1950 through 1991.[2] The PERMNO is obtained from column "LPERMNO", the year from "fyear" and the firm name from "conml", and I drop any duplicates.

Firm names require significant processing. I remove superfluous elements including punctuation, items in brackets and extra spaces. I convert all alphabetical characters to lowercase and standardise elements such as "and" and spacing in names in "mc". I remove elements like "company", "inc", initial "the" and geographic information like "of new york". I address cases where a firm name includes a personal name with the surname first.

CRSP names require additional processing. I remove the designations "new" and "old". Many abbreviations are used in CRSP names, and I render a large set of them as full words, *e.g.*, "airl" as "airlines" and "wks" as "works". I also drop processed firm names for which there is ambiguity in the mapping to PERMNO. A firm's name may change over the course of a year, but a span of multiple years where the same PERMNO is mapped to multiple names is problematic given that each firm should only be associated with one stock. I only keep observations with names for which the longest span of PERMNO overlap at yearly frequency is one year. If years are missing, the span of available years instead of adjacent years is employed instead. Similarly, I only keep processed CRSP/Compustat names mapped to a single PERMNO.

Geographic data also require some processing. I impose consistency on "new york city", "washington, dc" and cities with names beginning with "saint". With problems and their handling varying across datasets, I address matters like the mapping of New York City to "ny", "washington" to "dc" and "scranton" to "pa" and the correction of "pittsburg" to "pittsburgh".

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2. The later start date is a matter of data availability.

I only keep annual report data with a non-empty name, city, state and year. I only keep processed CRSP-Compustat firms with PERMNOs also in the dataset with processed CRSP names that has been filtered on the basis of SHRCD, SHRCLS and EXCHCD.

I merge the CRSP and CRSP/Compustat name-year-PERMNO datasets and drop duplicate rows. I merge the Mergent and ProQuest name-year-city-state datasets and drop duplicate rows. I proceed to merge the name-year-PERMNO and name-year-city-state datasets on name and year. Thereafter, I obtain the list of firms mapped to multiple cities in the same year. Where there are such multiple mappings, I draw on annual reports to select the city that seems to be most operationally important. If I cannot make such a judgement, I drop the firm in that year. Over 1945, 1949, 1956, 1962, 1968, 1973, 1979 and 1985, I impose judgement on 313 firm-year observations and drop 15 observations.

Having obtained cities where they have headquarters, I proceed to map firms to CBSAs. With 2019Q3 mappings from ZIP Codes to CBSAs made available by the US Department of Housing and Urban Development, I require mappings from cities to ZIP Codes.[3] I obtain for each city a ZIP Code from the Personal dataset from UnitedStatesZipCodes.org. No firm may actually have headquarters in that ZIP Code, but I do not work at such a high resolution.

When merging this geographic dataset with daily CRSP returns, I map a firm on a given date to the latest available geographic mapping for the firm through the year of that date. For example, for 23 October 1962, a firm mapped to a city on the basis of a 1962 annual report will be mapped to the city obtained from that report. If, however, the most recent annual report for that firm in my dataset is from 1956, the city obtained from the 1956 report will be used. Additionally, I restrict the set of firms to NYSE firms and remove highly extreme outliers with fractional returns outside of the range $[-0.99, 10]$.

The mapping from SIC to FF49 industry is on the basis of the CRSP SIC code rather

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3. The 2019Q3 data were obtained from https://www.huduser.gov/portal/datasets/usps_crosswalk.html.

than the CRSP-Compustat SIC code since I found it generally to match apparent primary activities better for 1962. If the SIC-FF49 correspondences from Kenneth R. French's website do not yield a mapping, I map the firm to "0Misc". Where an industry appeared very highly inconsistent with primary activities in 1962, I remapped the firm to a likely better match observed in close years. There were a total of 19 remappings. One firm's CRSP data were sufficiently inconsistent with supplementary data that it was dropped entirely.

APPENDIX C

SURVEY DATA

Table C.1: Surveys underlying Figure 4.2. All surveys were obtained from the Roper Center.

Period	Survey
1953-10	Gallup Poll #1953-0521
1955-01	Gallup Poll #541
1957-04	Gallup Poll #1957-0582
1959-06	Gallup Poll #614
1959-08	Gallup Poll #1959-0617
1959-10	Gallup Poll #1959-0619
1960-05	Gallup Poll #1960-0628
1960-07	Gallup Poll #631
1961-03	Gallup Poll #1961-0642
1961-05	Gallup Poll #1961-0644
1963-04	Gallup Poll #1963-0670
1965-06	Gallup Poll #713

Table C.2: Surveys underlying Figure 4.3. All surveys were obtained from the Roper Center.

Period	Survey
1954-04	Gallup Poll #1954-0529
1956-06	Gallup Poll #1956-0566
1956-11	Gallup Poll #1956-0575
1957-04	Gallup Poll #1957-0582
1958-04	Gallup Poll #1958-0598
1963-02	Gallup Poll #1963-0668
1973-09	Gallup Poll #1973-0878
1989-07	Media General/Associated Press Poll: National Poll #27

Table C.3: Surveys underlying the estimation of the mass point at 0 probability of nuclear war. The fraction answering the lowest probability used except for the more granular NORC Amalgam Study #330, in which the fraction assigning a value of 0 or 1 used. All surveys were obtained from the Roper Center.

Period	Survey
1963-12	NORC Amalgam Study #330
1974-4	Potomac Associates/Gallup State of the Nation, 1974
1981-6	Gallup Poll #1175G
1981-12	Roper Report #1982-01
1982-5	Gallup Poll #1194G
1982-5	CBS News and The New York Times National Survey, May 1982
1983-5	Gallup Poll #1214G
1983-11	Gallup Poll #1227G
1985-1	CBS News and The New York Times Foreign Policy Survey, January 1985
1987-10	Newsweek Magazine/Gallup Organisation Poll #1987-87220

Table C.4: Mapping of surveys to good and tense periods. All surveys were obtained from the Roper Center.

State	Period	Survey
Good	1957-04	Gallup Poll #1957-0582
	1959-06	Gallup Poll #614
	1959-08	Gallup Poll #1959-0617
	1959-10	Gallup Poll #1959-0619
	1960-05	Gallup Poll #1960-0628
	1961-03	Gallup Poll #1961-0642
	1963-04	Gallup Poll #1963-0670
	1965-06	Gallup Poll #713
Tense	1953-10	Gallup Poll #1953-0521
	1960-07	Gallup Poll #631
	1961-05	Gallup Poll #1961-0644
Crisis	1955-01	Gallup Poll #541

Table C.5: Survey data omitted due to challenges in the extraction of fields

Survey	Discussion
Gallup Poll #1957-0592	Contains expectations of war within 5 years, but the mapping from raw data to values of interest is unclear.
Gallup Poll #1959-0619	Contains expectations of war within 5 years across income groups, but the encoding of some income data is unclear.
Gallup Poll #650	Contains expectations of war within 5 years, but documentation is missing.
Roper Report 83-10	Contains expectations of war relevant to the calculation of the mass point, but the presence of multiple versions of the survey significantly complicates processing.

APPENDIX D

DIRECT EXPOSURE TO CUBA-BASED MISSILES

Special National Intelligence Estimate (SNIE) 85-3-62 of 19 September 1962 suggests that Cuba-based missiles could increase the number of targets that Soviet missiles could reach and the destructive power they could unleash, but in 16 October 1962 discussions, Secretary of Defence Robert S. McNamara and Special Assistant to the President for National Security Affairs McGeorge Bundy declared their belief that the missiles did not significantly change the strategic balance between the US and the Soviet Union (Director of Central Intelligence (1962), May and Zelikow (2002, p. 61)). Noting the likely psychological effect, Chairman of the Joint Chiefs of Staff Maxwell D. Taylor added: "I think from a cold-blooded point of view, Mr. President, you're quite right in saying that these are just a few more missiles targeted on the United States. However, they can become a very, rather important, adjunct and reinforcement to the strike capability of the Soviet Union. We have no idea how far they will go. But more than that, these are, to our nation it means a great deal more, as we all are aware, if they have them in Cuba and not over in the Soviet Union" (May and Zelikow (2002, p. 61)).

In an 18 October discussion of military options to address the missile threat, Secretary of Defence McNamara raised the prospect that Soviet forces in Cuba might fire their missiles against the US without authorisation outside of a planned full attack (May and Zelikow (2002, p. 84)). It is inconceivable, though, that further nuclear escalation would not follow. President Kennedy explicitly stated in his 22 October address that an attack against the Western Hemisphere with a Cuba-based nuclear missile would precipitate full retaliation against the Soviet Union (May and Zelikow (2002, p. 186)).

Whilst not exposing American cities to a novel threat, the Cuba-based missiles directly threatened many of them. SNIE 85-3-62 suggested that if based in Cuba, Soviet medium-range ballistic missiles (MRBMs) in Cuba could reach Philadelphia, Cleveland and Oklahoma

City, and Soviet intermediate-range ballistic missiles (IRBMs) could reach almost everywhere in the continental US (Director of Central Intelligence (1962, p. 8)). American estimates during the Crisis of the SS-4 MBRMs' range spanned at least 1020 nautical miles to 1100 nautical miles, and my measurement of the distances from the Sagua La Grande MRBM sites to the southern tip of Manhattan using Google Maps are slightly under 1125 nautical miles (Guided Missile and Astronautics Intelligence Committee, Joint Atomic Energy Intelligence Committee, and National Photographic Interpretation Centre (1962a, p. 1, 6), May and Zelikow (2002, p. 165, 216)). Dobbs (2008, p. 108) reports that Soviet forces believed that New York City could be reached by the Cuba-based SS-4 MRBMs, and the maximum range of the SS-4 presented in Podvig (2004, p. 185) puts Manhattan within range of the Sagua La Grande sites.[1]

CIA Deputy Director for Intelligence Ray S. Cline informed the National Security Council on 20 October that the missiles in Cuba could each deliver a nuclear payload of 2 to 3 megatons (May and Zelikow (2002, p. 127)). By 22 October, the United States had identified 24 MRBM launchers, 12 IRBM launch pads, roughly 30 MRBMs and no IRBMs (May and Zelikow (2002, p. 165)). After reporting that US intelligence collection might not be able to shed light on the presence of nuclear warheads, DCI McCone indicated that the missiles were not particularly useful without them (May and Zelikow (2002, p. 166)). McCone also asserted that Soviet forces controlled the missiles (May and Zelikow (2002, p. 166)). By 26 October, Westinghouse president William E. Knox had informed the State Department that Khrushchev had personally told him that nuclear warheads were on Cuba (Hilsman (1962)). Through 28 October, the US had still not observed IRBMs and had detected no nuclear warheads, but evidence had accumulated that each missile site was meant to have a nuclear-warhead storage capacity (Guided Missile and Astronautics Intelligence Committee, Joint

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1. Suggesting a certain degree of reliability are the original 1998 *Стратегическое Ядерное Вооружение России*'s positive reception among Russian experts and the FSB's manifestly less enthusiastic response to the public distribution of its contents (Podvig, 2004, p. xiii).

Atomic Energy Intelligence Committee, and National Photographic Interpretation Centre (1962b, p. 1), Guided Missile and Astronautics Intelligence Committee, Joint Atomic Energy Intelligence Committee, and National Photographic Interpretation Centre (1962c, p. 1)).

Assistant Secretary of Defence for Civil Defence Steuart Pittman stated to President Kennedy that 92 million people and 58 cities with more than 100000 residents in the US were at least at risk of fallout if MRBMs were launched from Cuba (May and Zelikow (2002, p. 216)). Director of Central Intelligence John A. McCone reported that MRBM sites were operational as of 22 October and that IRBM sites would not be operational much before December of 1962 (May and Zelikow (2002, p. 165-166)).

In his national address, President Kennedy noted that MRBMs could travel more than 1000 nautical miles and reach Washington, DC, and the southeastern US, and he reported that the probable IRBM sites had not been completed (May and Zelikow (2002, p. 184)). The address did not provide estimates of missile counts (May and Zelikow (2002, p. 183-190)).