ESSAYS ABOUT CREDIT, EXECUTIVE COMPENSATION AND REAL ESTATE MARKETS

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Abstract

This dissertation comprises three chapters related to the risk-taking decisions of the firms and the households. The first two chapters study the risk-taking from the perspectives of the investment risk of the CEOs and its relation to their compensation structure. The third chapter looks at the housing market and we study the households' reactions to the risk of natural disasters.

Chapter 1 is a empirical work to study the link between executive ownership and firms' leverage in the presence of a government subsidized credit stimulus. We take advantage of the empirical results by using the 2008 year-end credit expansion in China and observe the reactions of all the listed firms. In the normal times, there is a negative relationship between leverage and variable compensation. This negative correlation is due to the risk-aversion of the top executives of the firms, who are in charge of the capital structure of the firm. This part has been well studied and confirmed by previous research. However, we find out that after a credit stimulus, larger variable compensation implies greater leverage change. This new finding is consistent with the facts that the executives with higher incentives are inclined to increase the debt level further than their lower incentives peers to boost the value of the firms under government stimulus. The policy implication is that the firms with more executive ownership tend to be more sensitive to the government stimulus.

Chapter 2 extends the empirical work above to the model studying the design of the CEO compensation contract into a theory of optimal leverage. In the cross-section of firms, a CEO's risk aversion causes a negative correlation between leverage and the CEO's ownership of the firm. However, the optimal compensation requires that both the fixed as well as the variable component of the compensation increase with leverage. We also show that the leverage and the ratio of variable-to-fixed compensation are positively correlated. Finally, we explain that for outward shifts in credit supply, greater CEO ownership implies higher leverage growth regardless of the CEO's risk aversion level.

Chapter 3 studies the housing market and natural disasters. This study analyzes a new database of natural disasters in the United States that we integrate with real estate and mortgage variables. This study uncovers several new facts: (1) Natural disasters permanently increase housing rents. The effects on housing prices are ambiguous. (2) Conforming mortgage applications for low-mid size homes decrease. However, jumbo applications slightly increase. Lending standards do not change; (3) Homeownership rates decline. The previous facts suggest a new tenure choice channel in which low and mid-income households hedge natural disasters by moving from the ownership to the rental market. Wealthy households expand their housing holdings. The tenure choice channel seems especially strong for flooding, which are the riskiest disasters as insurance companies do not cover them.

INDEX WORDS: Risk Taking, Credit Policies, Executive Ownership, Leverage, Credit Reactions, Inequality, Natural Disasters, Rentals, Housing, Tenure Choice.

Dedication

I would like to send my gratitudes toward my fiancée Lin for her continuous supports. This is also for you, Mom and Dad. Thanks for always being there for me.

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Table of Contents

List of Figures

List of Tables

Chapter 1

Empirical Evidences: Credit Stimulus, Executive Ownership, and Firm Leverage

1.1 Introduction

The Great Recession of 2008 triggered an extraordinarily large and rapid response by monetary authorities world-wide.[1] The key feature of these policies is to provide banks with additional funds at a reduced cost. The policymakers hope that increasing the credit available to corporations as well as the household will increase the real economic activity via larger corporate investment and consumer spending. Most of the previous literature examining the effectiveness of these policies has focused on the "supply" side frictions that create obstacles in smooth transmission of monetary policy. For example, Bebchuk and Goldstein (2011) develop a model in which the banks abstain from lending to firms even when the firms have good projects resulting in a credit freeze. Gambacorta and Shin (2016) provide a recent survey of the bank lending channel and argue that poorly capitalized banks have lower loan growth.

[1]For example, in his June, 2008 speech at the International Monetary Conference, Fed Chairman Ben Bernanke explained the highly aggressive monetary policy as "...we have eased monetary policy substantially and pro-actively to address the sharp deterioration in financial conditions and to forestall some of the potential adverse effects on the broader economy. Our decisive policy actions were premised on the view that a more gradual reduction in short-term rates could well have failed to contain the financial and economic problems confronting us (Bernanke 2008)." The Fed reduced its target rate from 4.25% in January of 2008 to 0.25% in December, 2018. Similar policies were adopted by the European, Japanese and Chinese policymakers.

Dell'Ariccia, Laeven and Suarez (2016) report an inverse relationship between interest rates and risk-taking by banks.

This paper takes a different approach from the ones cited above. There exists little work which examines how a credit stimulus interacts with the factors that affect the "corporate demand" for borrowing.[2] In this paper, we address this gap by focusing on how corporate borrowers react to a government-initiated credit expansion. We provide empirical evidence that the structure of executive compensation is an important element in transmission of monetary policy. Our central result is that the firms whose executives own a larger fraction of the firm-equity (i.e., stronger pay-for-performance incentives), increase leverage significantly more when a credit expansion policy is adopted. Our results suggest that policymakers can increase the impact of credit expansion policies by combining them with measures that increase firms' willingness to borrow. For example, Gorry et al. (2015) provide evidence that the structure of executive compensation is sensitive to taxation. Thus, our results suggest that tax incentives to encourage greater managerial equity ownership can create conditions in which corporate executives will be more willing to increase leverage in response to a monetary policy stimulus.

Another novel feature of this paper is our focus on the Chinese corporate sector. This offers some unique advantages that we discuss more fully below. We examine the evolution of borrowings by Chinese public-listed firms after the announcement of a remarkably large credit stimulus by the government of China in November 2008.[3]

[2]Agarwal et al. (2018) examine the response of household borrowers to the credit expansion in the U.S. They show that consumers' propensity to borrow (i.e. demand for credit) is an important determinant in how much additional credit is obtained by the consumer. Thus, their focus is exclusively on retail household demand for credit stimulus, we focus exclusively on the demand by corporate borrowers.

[3]For example, The Economist (2008) described it as "eye-popping" and reported that it "...would surely represent the biggest two-year stimulus (outside wartime) by any government in history."

This stimulus affords us an interesting natural experiment as it was exceptionally large and essentially unanticipated. Also, as the banking sector is primarily state owned, the Chinese banks had little choice when they were directed by the government to increase the credit supply. In their study of China's 2008 monetary policy stimulus, Deng et al. (2015) state this bluntly: "Beijing ordered state-owned banks to lend and they lent. (p. 55)". This institutional feature of Chinese banking sector, addresses the empirical problems associated with the imperfect transmission of credit policy when risk-averse or poorly capitalized banks refuse to expand credit. Thus, the "supply" side problem of credit expansion studied in the bank lending channel literature is not a major factor in China.

We believe the Chinese stimulus was both exceptionally large and not well anticipated by the investors. To illustrate the scale of this stimulus, total loan quotas, which are the lending targets that Chinese bank officials are expected to meet, were increased from \$4.9 trillion CNY in 2008 to almost \$10 trillion CNY in 2009 (Cong et al. 2017). At the same time, the Central Bank dramatically lowered banks' reserve requirements and expanded money supply. Ouyang and Peng (2015) note that "this was the biggest stimulus program in the world, equal to about the three times size of the U.S. effort (p. 548)". The literature also suggests that this large credit stimulus was not widely anticipated (Naughton 2009 and Deng et al. 2015).

Our key empirical measure of managerial ownership is the fraction of total equity of firm owned by its executives. [4] We exploit the cross-sectional differences in the executive ownership at the time when the credit stimulus is announced. In our empirical tests, we control for other factors that may drive the cross-sectional differences in

[4]This measure is commonly employed in studies of managerial ownership. For example, Panousi and Papanikolau (2012) use this measure for U.S. data to show that the negative effect of idiosyncratic risk on investment is stronger when risk-averse executives hold a higher fraction of the firm's equity.

leverage.[5] We also include firm and industry fixed effects. We report two main results. First, the level of leverage and CEO's variable share of compensation are negatively correlated in the cross-section of Chinese firms. On average, one standard deviation increase in managerial ownership is associated with three percent lower leverage. This suggests that a CEO's risk-aversion is an important factor in her leverage choices. Our findings are in line with the theoretical predictions of John and John (1993) and Carlson and Lazrak (2010). Our second main finding confirms the role of executive ownership as a key determinant of how firms respond to a credit stimulus. In the year immediately following the 2008 credit push, the firms with a higher managerial ownership increased their leverage significantly more compared to firms with lower managerial ownership. Given our first result of lower leverage for higher managerial ownership, this is a striking result. Thus, we show that the structure of executive compensation has a significant influence on how firms react to the credit stimulus.

We conduct a battery of robustness test to validate our findings. We conduct a parallel trends analysis that shows that the credit stimulus had a widely different impact on firms with high pay-for-performance sensitivity. While pre-2008 the leverage ratio for this group of firms was consistently lower than that of the firms with low pay-for-performance sensitivity, there is a sharp break immediately after the 2008 stimulus announcement. In the post-stimulus period the executives of firms with higher ownership increase their leverage ratios dramatically. These trends provide additional evidence for the causal relationship between credit expansion and the role of executive incentives on how much additional debt a firm borrows. We address the possibility that levels of executive ownership may be endogenous - the same factors that influence ownership by a firm's managers may also affect the leverage choices made by the

[5] These include whether the firm is a state-owned-enterprise, return-on-assets, book-to-market ratios, firm's size, the concentration of the ownership structure, the institutional ownership and the share of fixed assets in the total assets of the firm.

firm. We employ the propensity score matching (PSM) methodology to overcome the concerns due to confounding characteristics. We designate the firms in top quartile of managerial ownership as "treatment" group. We match each of these treated firms with another firm that was predicted to have the similar level of managerial ownership but in fact did not. This matched set of firms is the "control" group. Again, we find that holding all else constant at the sample means, the top quartile firms increase their leverage significantly more. We re-estimate our results by excluding all state owned enterprises (SOEs) as the credit stimulus could have had a disproportionately large impact on these firms (Deng et al. 2015). Again our results continue to hold. We also employ an alternative measure of managerial pay-for-performance sensitivity by using the ratio of value of equity owned by the executives and the cash salary. This also yields similar results. Finally, we conduct a placebo test in which we randomly designate 2011 as the year of credit stimulus. In the following year (i.e. 2012) we find there is no effect of executive ownership on changes in leverage. This suggests we are identifying the effects of the credit stimulus correctly. Taken together, these results suggest that the structure of managerial compensation plays a significant role in how the firm reacts to a credit expansion.

The paper proceeds as follows. Section 1.2 discusses the contribution to the literature. Section 1.3 describes the sample and the 2008 Chinese Credit Push. Section 1.4 has the empirical analysis. Section 1.6 summarizes robustness tests. Section 1.7 concludes. The appendix describes the variables.

1.2 Related Literature

Our paper is related to three streams of existing research, namely: theoretical and empirical papers that explore the relationship between a firm's executive compensation policy and its capital structure; work that studies credit policies; and newly emerging research on the Chinese corporate sector. The theoretical underpinnings of how a firm's leverage is related to the compensation structure of its executives has been studied by John and John (1993) and Carlson and Lazrak (2010). John and John (1993) show that shareholders reduce variable pay in the firms with higher leverage to minimize the cost of debt. In a more recent paper, Carlson and Lazrak (2010) show that risk-averse managers when exposed to a greater pay-for-performance sensitivity will choose lower leverage. To the best of our knowledge, we are the first ones to show that expansionary credit policies unambiguously cause a *positive* correlation between change in leverage and variable compensation.[6]

We also bring together two strands of prior research. The first set of studies focuses on the interplay between a firm's pay-for-performance sensitivity of its top executives and its financial policy. Recent works in this area include Cheng, Hong and Scheinkman (2015), Milidonis (2014), Panousi and Papanikolau (2012) and Shue and Townsend (2017). The second stream of empirical research that our paper complements is the recent literature that examines which lenders react more to monetary and credit policies (see Gambacorta and Marques-Ibanez 2011 for a survey). While the supply side (i.e. lender-related) factors that affect credit stimulus transmission have been the focus of a number of studies (Ioannidou, Ongena and Peydró 2015 or Dell'Ariccia, Laeven and Suarez 2016 for example) our paper focuses on the unexplored area of how different borrowers react to a credit stimulus. Our findings show that the pay-for-performance feature has a significant effect on how firms react to credit stimulus.

[6]Gete and Gomez (2017a) study whether it is better to regulate leverage or compensation in a model with exogenous credit spreads, risk neutral agents and the complementarity between effort and leverage.

Finally, our paper also adds to the growing literature on issues related to the Chinese corporate sector. The previous studies have focused either on the drivers of executive compensation (Firth, Fung and Rui 2006; Chen, Ezzamel and Cai 2011; and Conyon and He 2011) or on the drivers of the capital structure (Li, Yue and Zhao 2009; Firth, Lin and Wong 2008) separately. To the best of our knowledge, ours is the first paper to study compensation structure and firm-leverage of Chinese corporations jointly.

1.3 The 2008 Credit Push

In this section we provide a brief description of the 2008 Chinese credit stimulus and of our sample.

The rapid increase in losses from sub-prime mortgages made in the Unites States is considered as the primary catalyst that precipitated the worst global recession since the 1930s (International Monetary Fund 2009). On November 9, 2008, the Chinese State Council announced a massive fiscal and monetary stimulus package. The fiscal component entailed a spending of four trillion CNY (equivalent to US$586 billion) by end of 2010. Bai et al. (2016) provide the detailed discussion of the stimulus and claim that it was roughly equivalent to 12% of China's annual GDP. The monetary stimulus was aimed primarily at increasing the bank lending by increasing the lending quotas for banks, reducing the reserve ratio and cutting the base lending rate.[7] This monetary policy intervention provides an unexpected and remarkably large shock to the credit supply. The impact of this policy adoption is illustrated in Figure 1.1, in which we plot the ratio of credit-to-GDP for several years before and after the 2008 stimulus. As can be seen in the figure, this ratio is quite is stable at around 150%

[7]Some of the papers that discuss the monetary stimulus include Deng et al. (2015), Ouyang and Peng (2015), and Cong et al. (2017).

up to December of 2008. However, in 2009 the ratio shot up to almost 182%. This represents an increase of over 20% in a single year from a fairly stable baseline.

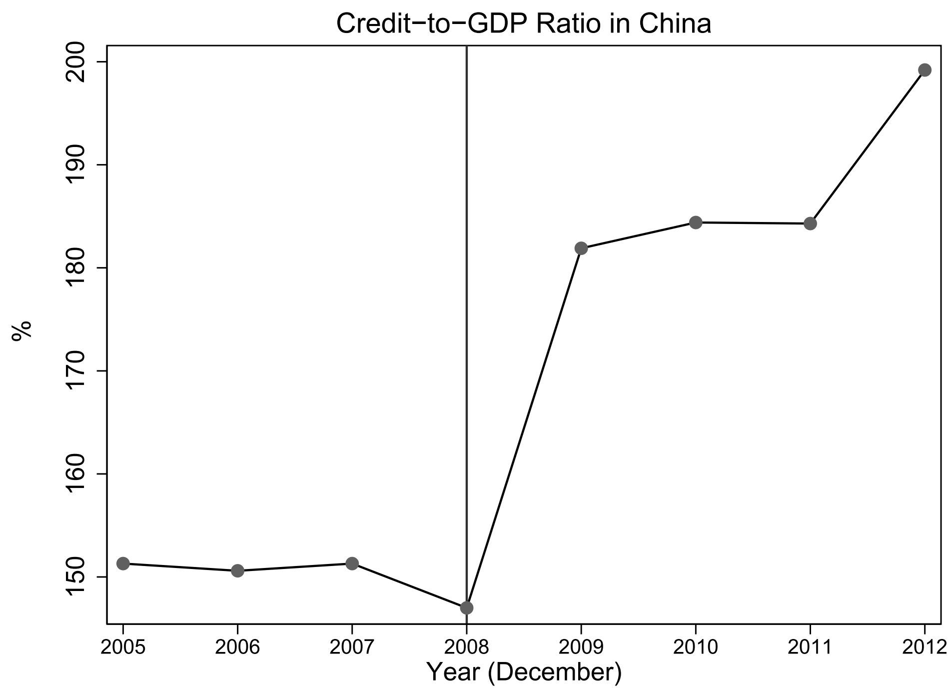

Figure 1.1. The Credit-to-GDP Ratio for the Non-financial Sector.
The vertical line is November 2008, which is the month when the credit stimulus was announced by the Chinese government. Source: Bank for International Settlements and CSMAR database.

Given this sharp discontinuity in 2008, for a number of our empirical tests, we restrict our sample period to two years: 2008, which captures the baseline leverage and compensation structure before the credit push, and 2009, which incorporates the change in these variables subsequent to the large credit expansion.

Figure 1.2 plots the policy rate in China and the average borrowing cost for the firms in our sample of public-listed Chinese firms. The borrowing cost for an individual firm is the ratio of reported interest expenses for year to the total reported debt. The figure shows that both the policy rate and the average borrowing costs decreased sharply after the 2008 credit push.

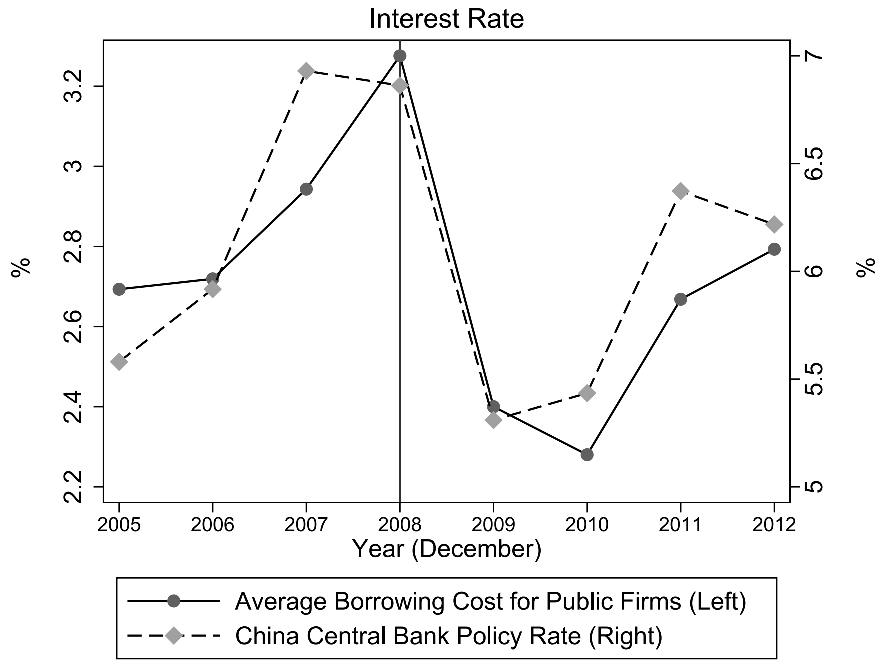

Figure 1.2. Borrowing Costs in China.
This figure plots the policy rate of China's Central Bank (dashed line) and the average cost of debt for the Chinese public firms (solid line). The vertical line is November 2008, which is the month credit stimulus was announced by the Chinese government. Source: Wind database.

Figure 1.3 consists of two graphs, the top graph illustrates the cost of borrowing for the period before and after the credit push. It is a binned scatterplot - we rank order all firms according to their book leverage as reported at the end of 2008 and divide them into 20 bins of roughly 70 firms each. Thus, each bin can be viewed as an equally-weighted portfolio of firms that have similar level book leverage. We construct a scatterplot of the average borrowing costs for each bin (y-axis) and the average book leverage (the x-axis). The solid black dots represent our calculations for 2008. The solid black line is the fitted regression for these 20 bins. As expected, the upward sloping regression line implies that the borrowing costs are increasing in leverage. We repeat this exercise for 2009. The gray dots represent the relationship between leverage and borrowing cost in 2009. For each of the 20 leverage ratios, the gray dots (i.e. 2009) lie below the black dots (2008). The fitted dotted line for 2009 is also below the solid line (2008) and the difference is almost one percentage point in borrowing costs across the entire leverage spectrum. This top graph provides visual evidence that the 2008 credit stimulus led to a significant drop in borrowing costs for Chinese firms regardless of the level of leverage. The bottom graph of Figure 1.3 shows the same analysis but compares 2007 to 2010. Again the figure shows that pre-stimulus period had consistently higher borrowing costs compared to 2010 at every leverage level.

1.4 Empirical Results

1.4.1 Main Variables

We utilize two main sets of data: the China Stock Market & Accounting Research (CSMAR) dataset, and the Wind Financial database. CSMAR is the leading database for accounting and market information about Chinese corporations. It has been used in a number of recent research studies such as Conyon and He (2011), Giannetti, Liao and Yu (2015), Jiang and Kim (2015), Liao, Liu and Wang (2014), and Piotroski and Zhang (2014). Wind is the other major data source for Chinese firms and has been used by Li et al. (2011) and Chen et al. (2012).

Following the capital structure literature, we exclude financial firms given the significant differences in leverage and regulation of financial firms relative to other

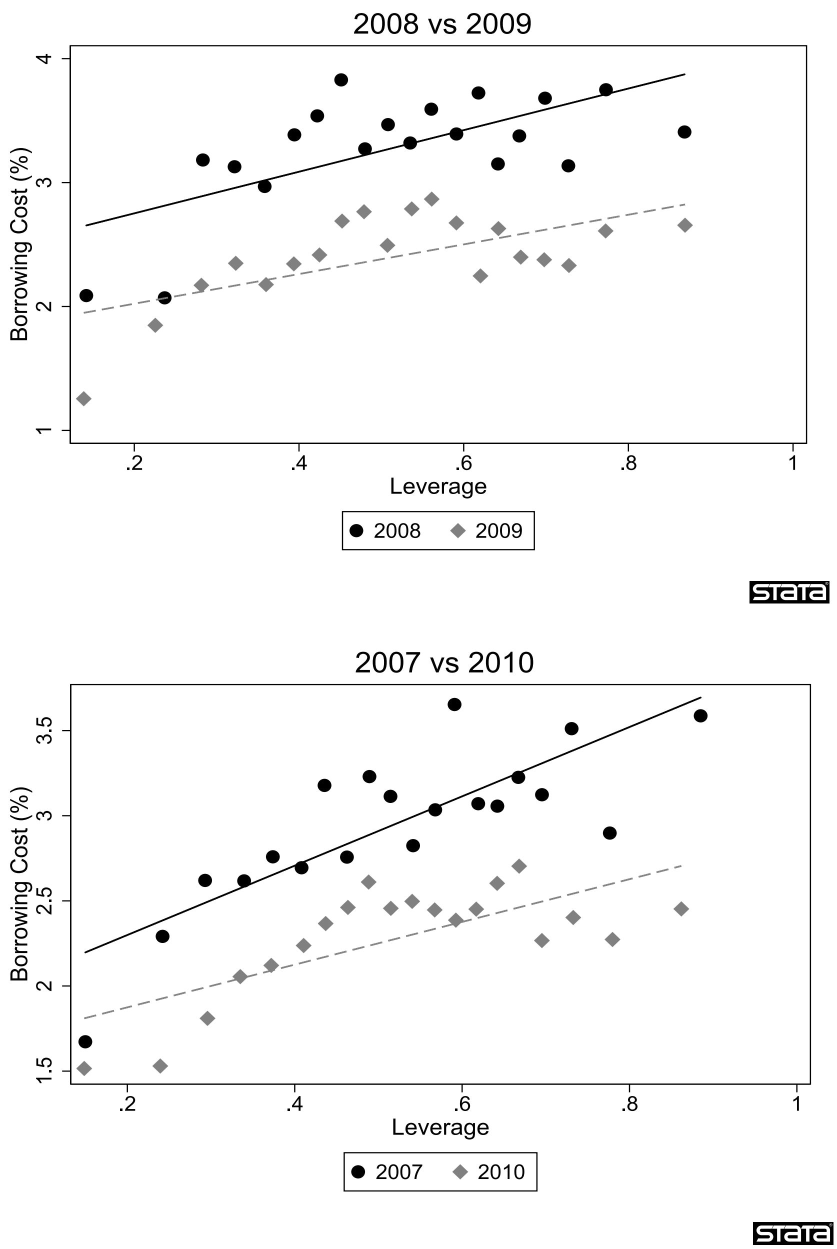

Figure 1.3. Borrowing Cost Versus Leverage for Public Non-financial Firms in China Before and After the 2008 Credit Push.

The figure in the upper panel compares 2008 vs 2009. The figure in the bottom panel compares 2007 vs 2010. For ease of appearance, the points are grouped into 20 bins of around 70 observations each. The lines are the fitted regressions for each year. Source: CSMAR database.

industries.[8] We also restrict our sampling universe to those firms which were publicly-listed before 2008 and had a book value of equity greater than zero.

Since our main analysis explores the relationship between, managerial ownership and firm leverage, we require empirical measures for both of these variables. For the executive ownership of the firm, we create a continuous measure similar to the insider-holding variable used for U.S. based studies (see for example Panousi and Papanikolau 2012). This measure takes the total number of shares owned by the firm's executives and divides it by the number of shares outstanding, we denote it as $Executive\,Ownership$. Our other main variable of interest is the firm's leverage level. Following the commonly used methodology outlined in Berger, Ofek, and Yermack (1997), we measure the level of leverage at the end of the fiscal year using two continuous variables:

$$Book\ Leverage = \frac{Total\ Debt\ (Book\,Value)}{Total\ Assets\ (Book\,Value)}. \tag{1.1}$$

and

$$Market\ Leverage = \frac{Total\ Debt\ (Book\,Value)}{Total\ Debt\ (Book\,Value) + Equity\ (Market\,Value)}. \tag{1.2}$$

We estimate a number of regression models that include several control variables widely employed in other capital structure and executive compensation studies such as firm profitability, firm size and other firm level characteristics. We include detailed definitions of all of these variables in the appendix. However, there is one specific firm characteristic that is unique to our sample which merits more discussion. Unlike most developed economies, a large fraction of publicly listed firms in China are state-owned enterprises (SOEs) that undertook the share issue privatization process. Many empirical studies focusing on China explicitly acknowledge this by including a control

[8] See, for example, Garvey and Hanka (1999), Malmendier, Tate and Yan (2011) or Lemmon, Roberts and Zender (2008).

for SOEs (see for example Piotroski and Zhang 2014). We follow their approach and in all our regression tests we include a dummy variable that equals one if the firm is a SOE and zero otherwise. In our robustness tests, we re-estimate our empirical models on a subsample that excludes SOEs.

Table 1.1 summarizes the key variables in our sample which is a two-year (2008 and 2009) panel of publicly-listed Chinese firms. We have data on 1,530 firms. We start by reporting the leverage and compensation proxies which are at the center of our empirical analysis. The average book leverage is 0.50, implying that roughly half the book value of total assets is accounted for by debt. For comparison, Giannetti, Liao and Yu (2015) also report an average leverage ratio of 0.5 for their sample of Chinese firms over the 1999-2009 sample period. Piotroski and Zhang (2014) report a similar level (0.52) for the sample period 2005-2007. The average market leverage ratio for our sample is 0.30, which is much lower than the book leverage. The average executive ownership in our sample is 1.85% which is similar to the middle quintile insider holding of 1.01% that Panousi and Papanikolau (2012) report for their sample of U.S. firms.

Panel C of Table 1.1 reports the descriptive statistics of the control variables that we use in our regressions. These are broadly consistent with existing studies of Chinese corporations (see Chen et al. 2012 and Liao, Liu and Wang 2014). SOEs makeup roughly half of our firm-year observations.

1.4.2 Parallel Trends

Our empirical strategy examines the post-2008 *change* in leverage for firms with different levels of executive ownership. As we discussed earlier, the Chinese credit stimulus was followed by a sharp decline in interest rates and we need to be careful in interpreting the change in corporate behavior following the stimulus. We employ

Table 1.1. Summary Statistics

Variable	*# Obs*	*# Firms*	*Mean*	*Median*	*SD*	*Min*	*Max*
A. Main Variables							
Book Leverage	3007	1530	0.5	0.51	0.19	0.05	1
Market Leverage	3007	1530	0.3	0.26	0.19	0.01	0.81
Executive Ownership	3007	1530	0.02	0	0.07	0	0.63
Equity-to-Salary	2999	1529	61.43	0	275.07	0	2801.08
Interest Expense (%)	1956	1180	2.89	2.78	1.76	0.01	8.18
B. Other Control Variables							
ROA (net)	3007	1530	0.05	0.05	0.08	-0.42	0.39
Size (ln($sale\, in\, RMB$))	3007	1530	21.04	20.98	1.48	14.4	28
Market Book	3007	1530	1.79	1.36	1.52	0.14	10.8
Asset Tangibility	3007	1530	0.28	0.25	0.19	0	0.92
Dividend (Dummy)	3007	1530	0.54	1	0.5	0	1
Positive Net Profit (Dummy)	3007	1530	0.87	1	0.34	0	1
SOE	3007	1530	0.51	1	0.5	0	1
Stock Holding Concentration	3007	1530	0.18	0.15	0.12	0	0.76
Institution Ownership	3007	1530	0.07	0.03	0.1	0	0.68
Bank Holding (Dummy)	3007	1530	0.03	0	0.17	0	1
Foreign Holding (Dummy)	3007	1530	0.06	0	0.24	0	1
CEO Turnover (Dummy)	3007	1530	0.19	0	0.4	0	1
CEO Chairman (Dummy)	2921	1510	0.85	1	0.36	0	1
Comp. Committee (Dummy)	3007	1530	0.85	1	0.36	0	1
Board Size	2957	1526	9.19	9	1.89	4	18
Board Independence	2957	1526	0.36	0.33	0.05	0.09	0.71

This table reports the summary statistics of the 1,530 public-listed Chinese firms for the 2008-2009 period. The unit of observation is the firm-year. The data sources are the China Stock Market & Accounting Research (CSMAR) dataset, and the Wind Financial database. All the continuous variables are winsorized at 1% and 99% level. All variables are described in detail in the Appendix.

a difference-in-differences (DiD) approach to isolate the impact of credit push across our two sub-groups (high versus low executive ownership firms). Angrist and Krueger (1999) note that the DiD approach is especially useful for estimating the effect of sharp changes in government policy. This matches our setting of Chinese credit stimulus. However, the DiD identification rests on a key assumption that absent of the policy change, the observed difference-in-differences would be zero. This assumption is frequently referred to as "parallel trend" assumption. In our setting, the parallel trends assumption requires that leverage ratio of high as well as low managerial ownership firms follow a similar trend in the pre-stimulus period. Below we discuss why we believe that the parallel trends assumption is a valid one for our sample.

Figure 1.4 examines this issue by plotting the leverage ratios for these two groups for several years before and after the 2008 stimulus. First, we first rank-order all firms based on $Executive\,Ownership$ as estimated at the end of 2008. We denote, all firms in which the executives own less than the median level of executive ownership as "Low Ownership" firms, while all firms above the median are denoted as "High Ownership". Next, we calculate the average book leverage for both of these groups for every year starting in 2005 to 2012. Finally, in Figure 4 we plot the evolution of the leverage ratio for these two groups over this 8-year period. The solid black line represents the leverage ratio for the low ownership group while the dashed line represents the leverage ratio of the high ownership group.

Figure 1.4 shows that for the four year period leading up to 2008, the leverage ratios for both groups appear to be following a similar trend. The leverage of low executive ownership firms is always larger than that of the high executive ownership firms. However, immediately after the 2008 credit stimulus, the leverage ratio of the high ownership group increases sharply and within two years it becomes larger than that of the low ownership group. The sharp break in the leverage ratio pattern in 2008 motivates the DiD empirical strategy that we employ in the next section.

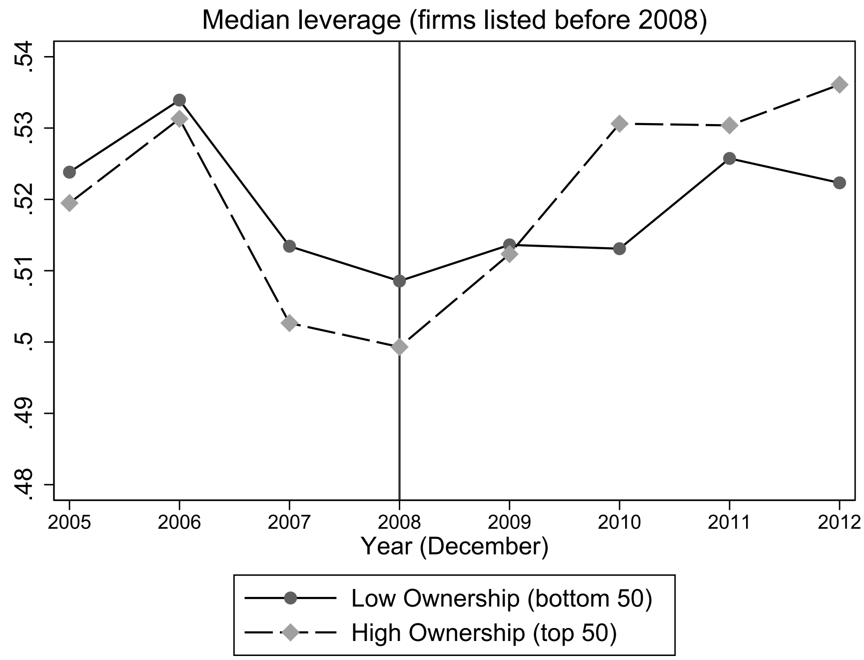

Figure 1.4. The Median Book Leverage Ratio for the Non-financial Public Firms.
The vertical line is November 2008, which is the month when the credit stimulus was announced by the Chinese government. The solid line is the median leverage for the group of firms with top 50 percentile executive ownership in 2008 and the dashed line is median leverage for the group of firms with bottom 50 percentile executive ownership in 2008. Source: CSMAR database.

1.4.3 Baseline Results

We estimate how the *change* in a firm's leverage after the credit expansion is related to the ownership by its executives. Our empirical strategy consists of estimating panel regression models where the dependent variable $Leverage\,Ratio$ is either $Book\,Leverage$ or $Market\,Leverage$ as defined in equations (1.1) or (1.2) respectively. The benchmark model that we estimate is a traditional difference-in-differences regression described below:

$$\begin{aligned} Leverage\,Ratio_{it} = \beta_0 + \beta_1 Executive\,Ownership_{it} + \beta_2 Credit\,Push_t + \\ + \beta_3 Executive\,Ownership_{it} \times Credit\,Push_t + \\ + \Sigma\beta_k Controls_{itk} + \alpha_{ijt} + u_{it}. \end{aligned} \tag{1.3}$$

where i indexes firms, t indexes years, and j indexes industry. $Leverage\,Ratio_{it}$ is the leverage ratio (book or market) of the firm i at the end of year t, $Executive\,Ownership$, is the fraction of total shares owned by the top executives of a firm i at the end of year t.[9] $Credit\,Push$ is a dummy variable that equals one if the observation occurs after 2008 and zero otherwise. $Controls$ are characteristics of firm i at the time t. We control for several variables commonly employed in the literature to explain leverage and compensation structure such as firm's operating performance (return-on-assets), growth opportunities (book-to-market ratio), firm's size (natural log of sales), the concentration of the ownership structure, the institutional ownership and the asset composition (ratio of fixed assets to total assets). We also include SOE, a dummy variable, that equals one for firms in which the government is the largest shareholder. α_{ijt} is a set of firm i, industry j and year t fixed effects. We also adjust the standard errors by clustering at the individual firm level.

[9] This definition is the same as the one used by Panousi and Papanikolaou (2012) who use the executive ownership as the proxy for the pay-performance sensitivity.

The main variable of interest is the interaction term ($Executive\,Ownership \times Credit\,Push$) as it allows us to estimate how the effect of the credit push translates into leverage choices across firms with varying level of executive ownership. Specifically, we are interested in the size and significance of coefficient β_3 which captures the average change in leverage from 2008 to 2009 for varying levels of executive ownership.

Table 1.2 describes the results of our baseline regression. Panel A reports the estimates of based on $Book\,Leverage$ as the dependent variable while Panel B presents the estimation results based on $Market\,Leverage$. In column 1 of Panel A we present the results of our simplest specification where we control for the firm characteristics but do not include any fixed effects. The coefficient for $Executive\,Ownership \times Credit\,Push$ is 0.206 and it is significant at the one percent level. This implies that higher ownership by the executives is significantly more likely to be associated with a larger increase in debt following a government-initiated credit expansion. Thus, a one standard deviation increase in executive ownership corresponds to an increase of 0.014 in the absolute level of $Book\,Leverage$ (0.206×0.07). Since the sample average of book leverage is 0.5, this is an economically significant increase of almost three percent. This increase in book leverage is in addition to the predicted increase of 0.061 in book leverage for *all firms* after the credit expansion (based on the coefficient of 0.0614 for $Credit\,Push$).

The coefficient for $Executive\,Ownership$ (β_1) is negative and significant at the one percent level. This result is consistent with well-studied theory of risk-averse of the managers which predicts that executive ownership and firm leverage have a negative relationship. This is consistent with the argument that risk-averse executives with a higher level of stock-holding will tend to choose lower levels of debt as their compensation is more exposed to the default of the firm. Interestingly, Huang et al. (2006) also report similar findings using data on Chinese firms from 1994 to 2003.

Table 1.2. Effect of Executive Ownership on Firm Leverage After the Credit Push of 2008

Panel A. Book Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Credit Push$_t$	0.206***	0.185***	0.188***
	(0.000)	(0.000)	(0.000)
Executive Ownership$_{i,t}$	-0.222***	-0.179***	-0.180***
	(0.000)	(0.001)	(0.001)
Credit Push$_t$	0.0614***	0.0550***	0.121***
	(0.000)	(0.000)	(0.003)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	3007	3007	3007
R^2	0.354	0.391	0.393

Panel B. Market Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Credit Push$_t$	0.361***	0.343***	0.327***
	(0.000)	(0.000)	(0.000)
Executive Ownership$_{i,t}$	-0.255***	-0.229***	-0.220***
	(0.000)	(0.000)	(0.000)
Credit Push$_t$	-0.0507***	-0.0580***	0.0382*
	(0.000)	(0.000)	(0.094)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	3007	3007	3007
R^2	0.604	0.636	0.640

This table reports the panel regression estimation of equation 1.3 and reports how the executive ownership is related to changes in firm leverage from the end of year 2008 (Pre-Credit Push) to end of year 2009 (Post-Credit Push). The sample consists of 1,530 public-listed Chinese firms. Executive Ownership$_{i,t}$ is number of shares owned by the executives divided by shares outstanding. Credit Push$_t$ denotes whether $t = 2009$. We use book leverage as the dependent variable for Panel A and market leverage as the dependent variable for Panel B. The controls are return to assets, size of the firm, market-to-book ratio, assets tangibility, dividend, positive net profit, state owned enterprise, ownership concentration, institutional ownership, bank holding and foreign holding (see the appendix for details). We also include industry fixed effects and industry-by-year fixed effects. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. The p-values are clustered at the firm level.

This negative relation is also consistent with the results from other studies using U.S. data (for example, Carlson and Lazrak 2010, Morellec, Nikolov and Schurho 2012, and Glover and Levine 2015). Thus, holding all else equal, higher ownership by a firms' executives is associated with lower book leverage.

While the results in column 1 are after controlling for observable firm characteristics, there may be unobservable industry characteristics (both time-invariant and-time variant) that can bias the coefficient estimates. In columns 2 through 3 of Panel A, we re-estimate our benchmark regression specification by introducing an increasingly restrictive set of fixed effects. In column 2, we include industry fixed effects to control for any time-invariant unobserved differences across different industries. In column 3 we replace the industry fixed effects by industry-by-time fixed effects. This specification allows us to control for *time-varying* industry level unobserved heterogeneity. These specifications provide a strong control for any omitted variables bias in our estimations. Examining the coefficients for $Executive\, Ownership \times Credit\, Push$ shows that both the size and significance remains essentially unchanged when we introduce industry or industry-by-year fixed effects (columns 2 and 3).

We repeat the analysis outlined in Panel A using $Market\, Leverage$ instead of $Book\, Leverage$ as the dependent variable in equation (1.3). The results are described in Panel B and closely mirror the results reported in Panel A. The coefficients are, in fact, larger and the economic significance is even greater. For example, the coefficient for $Executive\, Ownership \times Credit\, Push$ (β_3) in the most restrictive specification (column 3 of Panel B) is 0.361 and significant at the one percent level. For the post-credit expansion, this implies an absolute increase of 0.025 in the market leverage for one standard deviation increase in the managerial-ownership. Since the sample mean of market leverage is 0.30, this translates into an economically large increase of over 8%. As in Panel A, the coefficient for $Executive\, Ownership$ continues to be negative and significant. The coefficient for $Credit\,Push$ is *negative*, implying a decrease in market leverage from 2008 to 2009. This finding is driven largely by the remarkable recovery of the stock prices by the end of 2009 from the extremely low levels at the end of 2008. To put this in perspective, the Shanghai composite index closed at a level of 1,821 on December 31, 2008 but had climbed to 3,277 by end of 2009, that is, an increase of 77%. Since our market leverage ratio is calculated at the end of 2008 and 2009, the huge increase in stock prices in 2009 increases the denominator in equation (1.2) leading to a mechanically lower level of $Market\,Leverage$ following the credit push.

Taken together, the results reported in Panel A and Panel B of Table 1.2 provide strong evidence that high ownership by managers is associated with lower debt levels. However, a government-sponsored credit stimulus creates significantly more incentive for managers with larger ownership to take on greater debt. Thus, an increase in executive ownership (and the resulting increase in pay-for-performance sensitivity of compensation) for a risk-averse CEO will induce her to reduce leverage, while an increase in subsidized credit via a monetary stimulus will induce her to *increase* leverage. The interaction term $Executive\,Ownership \times Credit\,Push$ (β_3) is significantly positive for both the book leverage ratio and the market leverage specifications.

1.4.4 Firm fixed effects

The industry and industry×year fixed effects provide robustness check for our estimation in Table 1.2. However, there may be unobservable firm characteristics (e.g. corporate culture) which may introduce omitted variable bias in our estimated coefficients. In this section, we describe our results using the firm fixed effects into our regression model equation (1.3). For each firm, we want to see the how differences in the executive ownership affects the leverage choices made by the managers. By using the firm fixed effect, we control for all time-invariant firm-specific characteristics, yielding coefficient estimates that are less likely to be contaminated by omitted variables bias.

Table 1.3 reports the results of our panel regressions that include firm fixed effects. As in the previous table, Panel A of Table 1.3 describes our estimation results using book leverage as the dependent variable. Column 1 reports the estimation results in which we only include firm-fixed effects (no other firm level controls). This specification assumes that any change in leverage from 2008 to 2009 for a specific firm is entirely due to managerial ownership, the credit push and the interaction of these two factors. The coefficient for $Executive\,Ownership \times Credit\,Push\,(\beta_3)$ is positive and significant at 5% level for book leverage. Thus, even for the same firm, an increase in executive-ownership implies a significantly larger increase in leverage following the credit push. In column 2 we include all the time variant firm characteristics that we had included for estimation reported in Table 1.2 in addition to firm fixed effects. Column 3 reports estimation of a model which also includes industry-by-year fixed effects. Both the size and the significance of the coefficient for $Executive\,Ownership \times Credit\,Push\,(\beta_3)$ remains largely unchanged. The results reported in Panel B employ market leverage as the dependent variable. The results are even stronger - the coefficient for $Executive\,Ownership \times Credit\,Push\,(\beta_3)$ is positive and significant at the one percent level. The estimated values of the β_3 are consistently above 0.20 in all specifications (column 1 to column 3).

1.5 Propensity Score Matching

Our results so far have examined the demand-side effects on firm's willingness to take on more debt based on different levels of managerial-ownership. It is possible

Table 1.3. Effect of Executive Ownership on Firm Leverage After the Credit Push of 2008: Firm Fixed Effects

Panel A. Book Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Credit Push$_t$	0.0626**	0.0617**	0.0646**
	(0.039)	(0.042)	(0.035)
Executive Ownership$_{i,t}$	0.0262	0.0523	0.0521
	(0.751)	(0.476)	(0.477)
Credit Push$_t$	0.00984***	0.0163***	0.0201
	(0.000)	(0.000)	(0.237)
Firm's Controls	No	Yes	Yes
Industry× Year FE	No	No	Yes
Firm FE	Yes	Yes	Yes
Observations	3007	3007	3007
R^2	0.021	0.149	0.156

Panel B. Market Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Credit Push$_t$	0.220***	0.210***	0.209***
	(0.000)	(0.000)	(0.000)
Executive Ownership$_{i,t}$	-0.130**	-0.104**	-0.0962**
	(0.011)	(0.025)	(0.046)
Credit Push$_t$	-0.128***	-0.124***	-0.0742***
	(0.000)	(0.000)	(0.000)
Firm's Controls	No	Yes	Yes
Industry× Year FE	No	No	Yes
Firm FE	Yes	Yes	Yes
Observations	3007	3007	3007
R^2	0.664	0.696	0.703

This table reports the panel regression estimation of equation 1.3 and reports how the executive ownership is related to changes in firm leverage from the end of year 2008 (Pre-Credit Push) to end of year 2009 (Post-Credit Push). The sample consists of 1,530 public-listed Chinese firms. Executive Ownership$_{i,t}$ is number of shares owned by the executives divided by shares outstanding. Credit Push$_t$ denotes whether $t = 2009$. We use book leverage as the dependent variable for Panel A and market leverage as the dependent variable for Panel B. The controls are return to assets, size of the firm, market-to-book ratio, assets tangibility, dividend, positive net profit, state owned enterprise, ownership concentration, institutional ownership, bank holding and foreign holding (see the appendix for details). All the specifications include firm fixed effects. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. The standard errors are clustered at the firm level.

that the difference in executive ownership across firms may itself be driven by certain firm-specific characteristics. In this section we describe our analysis using an alternative approach of comparing the leverage choices made by high managerial ownership firms (the treatment group) to the borrowing decisions of a propensity-score-matched sample of low managerial ownership firms (the control group). This approach helps mitigate concerns that firms with high managerial ownership may differ systematically from firms with low managerial ownership.

The key idea underlying the propensity score matching (PSM) methodology is to create a control group of firm who are similar to the treated firms when compared to several pre-treatment *observable* characteristics. For our setting, the treated firms are those with a high level of executive ownership. Ideally we would like to compare the response to credit stimulus of this group to the response of an ex-ante similar control group that did *not* have high managerial ownership. For the creation of this control group, we employ the nearest neighbor matching of propensity scores, developed by Rosenbaum and Rubin (1983). [10]

We start the matching process by creating the treatment group based on executive ownership at the end of 2008. All firms with ownership levels in the top quartile in 2008 are assigned to the high ownership (treated) group. Specifically, we create a dummy variable $Top25\,Owership$ which equals one if the firm ranks in the top 25% firms based on the executive ownership in 2008 and zero otherwise. In the second step, we estimate a probit regression model using the *Top25 Ownership* as the dependent variable and a large set of observable firm characteristics which include all firm-level control variables for our benchmark regression in the equation (1.3) and additional controls: CEO turnover, whether the CEO and the Chairman of the board is the

[10]A number of recent papers in economics and finance have used the PSM methodology. These include Michaely and Roberts (2012), Dahiya Iannotta and Navone (2017) and D'Acunto and Rossi (2017)

same person, whether the firm has a compensation committee, the size of the board and the fraction of independent director in the board. The choice of these additional control variables for the executive ownership is motivated by their use in prior studies of determinant of incentive pay for the managers (Bettis and et al. 2010; Dittmann, Maug and Spalt 2010; Kato and et al 2005; Bertrand and Mullainathan 2001).

We estimate a probit model for the sample of 375 of firms classified as $Top25\, Owership$ and the remaining 1,135 firms which are not in the top quartile of managerial ownership in 2008. This allows us to estimate the predicted probability of a particular firm being in the top quartile of managerial ownership based on various firm-characteristics. In the next step, we use the predicted probabilities, (i.e. propensity scores) to match each of the high managerial ownership firms to the nearest neighbor from the control group. We employ a one-to-one match without replacement procedure. After the matching process, each firm in the treatment group (top 25% executive ownership) is paired with a firm from the control firm that has the closest propensity score. To ensure that our matching procedure creates similar firms in each pair we follow the process outlined by D'Acunto and Rossi (2017). We calculate the difference in the propensity score for each matched pair. If the propensity score difference between the matched firms is larger than one quarter of the standard deviation of the executive ownership in our sample we exclude that pair from our analysis. We also exclude all matched pairs that are not in the common support (whose propensity score is higher than the maximum or less than the minimum propensity score of the controls of our sample). After applying these exclusions we are left with a final sample of 301 treated and 301 control firms for our PSM tests.

We use the propensity score matched sample to estimate the following regression:

$$
\begin{aligned}
Leverage\,Ratio_{it} = {} & \beta_0 + \beta_1 Top25\,Ownership_{i,2008} + \beta_2 Credit\,Push_t + \\
& + \beta_3 Top25\,Ownership_{\,i,2008} \times Credit\,Push_t + \\
& + \Sigma\beta_k Controls_{itk} + \alpha_{ijt} + u_{it},
\end{aligned} \tag{1.4}
$$

The difference-in-differences model described above is similar to the equation (1.3) with one modification. We use the dummy variable $Top25\ Ownership$ instead of $Executive\ Ownership$. Again the main coefficient of interest is β_3 which is roughly the average change in leverage from pre-credit push year (2008) to the post credit push year (2009) for the treatment group (top quartile ownership) minus the same change in leverage for the control group.

The results from estimating equation 1.4 are presented in Table 1.4. In the Panel A, the first column is the baseline specification that includes the firm characteristics as control variables but does not include fixed effects. The coefficient β_3 for the interaction term is 0.0231 and is significant at the one percent level. It implies that if the firm is in the top quartile of executive ownership in 2008, on average, it increases book leverage by 0.0231 more compared to a similar firm (based on observable characteristics) that was not in the top quartile of managerial ownership. It is equivalent to the around 4.6% $(0.0231 \div 0.5)$ increase in book leverage for firms with top-quartile executive ownership. In columns 2 and 3 of the Panel A, we add the industry fixed effect and industry-by-year fixed effects respectively. Both the size and the significance of the coefficient β_3 remains essentially unchanged.

In the Panel B of the Table 1.4 we present the results using the market leverage as the dependent variable in equation 1.4. Column 1 (firm controls included but no fixed effects) shows that the coefficient β_3 of the interaction term $Top25\,Ownership_{\,i,2008} \times Credit\,Push_t$ is 0.0186 and significant at the five percent level. This is equivalent

Table 1.4. Effect of Executive Ownership on Firm Leverage After the Credit Push of 2008: Propensity Score Matching Estimation

Panel A. Book Leverage

	(1)	(2)	(3)
Top25 $\text{Share}_{i,2008}$ × Credit Push_t	0.0231***	0.0222***	0.0233***
	(0.006)	(0.007)	(0.005)
Top25 $\text{Share}_{i,2008}$	-0.0300**	-0.0313**	-0.0318**
	(0.017)	(0.011)	(0.010)
Credit Push_t	0.0498***	0.0431***	0.0714***
	(0.000)	(0.000)	(0.002)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	1204	1204	1204
R^2	0.371	0.410	0.412

Panel B. Market Leverage

	(1)	(2)	(3)
Top25 $\text{Share}_{i,2008}$ × Credit Push_t	0.0186**	0.0177**	0.0187**
	(0.031)	(0.035)	(0.023)
Top25 $\text{Share}_{i,2008}$	-0.0195*	-0.0196**	-0.0203**
	(0.055)	(0.046)	(0.040)
Credit Push_t	-0.0577***	-0.0657***	-0.0211
	(0.000)	(0.000)	(0.329)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	1204	1204	1204
R^2	0.627	0.658	0.665

This table reports the panel regression estimation of equation 1.4 and reports how the executive ownership is related to changes in firm leverage from the end of year 2008 (Pre-Credit Push) to end of year 2009 (Post-Credit Push). The sample consists of 602 public-listed Chinese firms representing 301 firms with executive ownership in the top 25% (Treated group) and a matched sample of 301 firms (control group) which had similar probability (i.e. propensity) of being in the top quartile of executive ownership but were not. The matched firms were chosen by the propensity score based on the 2008 values of the control variables and was done based on the nearest neighbor approach of Rosenbaum and Rubin (1983). Executive $\text{Ownership}_{i,t}$ is number of shares owned by the executives divided by shares outstanding. Credit Push_t denotes whether $t = 2009$. We use book leverage as the dependent variable for Panel A and market leverage as the dependent variable for Panel B. The controls are return to assets, size of the firm, market-to-book ratio, assets tangibility, dividend, positive net profit, state owned enterprise, ownership concentration, institutional ownership, bank holding and foreign holding (see the appendix for details). The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. The standard errors are clustered at the firm level.

to around 6.2% ($0.0186 \div 0.3$) increase in market leverage after the credit stimulus for top quartile managerial ownership firms. This result is robust to adding of the industry fixed effect (column 2) and the industry-by-year fixed effect (column 3).

The PSM results described in the Table 1.4 provide additional evidence for our baseline results reported earlier in tables 1.2 and 1.3. To ensure that our finding that executive ownership is a significant factor in how firms respond to credit push, we perform a number of robustness tests. In the following section we outline these tests and report their results.

1.6 Robustness Tests

In this section we discuss a number of robustness tests to validate our main findings.

1.6.1 Private Firms Only, Excluding State Owned Enterprises

Almost half of our sample consists of State Owned Enterprises (SOE). Since the government has a significant ownership in these firms, their managerial decision making (e.g. the choice of leverage levels that we study in this paper) may not reflect traditional factors such as the executive ownership, risk-averseness of the CEO etc. For example, Deng et al. 2015 argue that a significant fraction of credit push mandated by the government was aimed at pushing state owned banks to lend to state owned enterprises. Since the executive ownership is likely to be low for SOEs, if the credit push was largely focused on SOEs, our tests are biased against finding a significant relationship between leverage and executive ownership. However we control for this issue by following the approach of Piotroski and Zhang (2014) and include an indicator variable for SOEs in all the estimations discussed in Section 1.4 (Tables 1.2 through 1.4). To ensure that our results are not sensitive to the inclusion of SOEs, we rerun our benchmark panel regression for subsamples in which we exclude all SOEs. We classify a firm to be a SOE if the government is the largest shareholder.[11] The results are described in Table 1.5.

The coefficient for $Executive\,Ownership \times Credit\,Push$ continues to be positive and significant for both measures of leverage. The other variables of interest continue to have coefficients that are of same sign and significance as reported in our main results of Table 1.2. Thus, our main result showing that heterogeneity in managerial compensation structure is systematically related to changes in firm's leverage, continues to hold for the sample that excludes SOEs.

1.6.2 Equity-to-Salary Ratio as Alternative

Our primary measure of managerial incentives in this paper is the fraction of firm's equity owned by its executives. This measure captures the accumulated stock holding of a firm's managers. An alternative approach to measuring the executive pay-performance sensitivity is to use the ratio of the value of the stock ownership to the annual fixed cash compensation. We re-estimate our baseline specification using this alternative pay-performance sensitivity measure, denoted as *Equity-to-Salary Ratio*. This ratio is defined as:

$$\textit{Equity-to-Salary} = \frac{\textit{Market Value of the Equity} \times \textit{Executive Ownership}}{\textit{Cash Salary of the Executives}}, \qquad (1.5)$$

Where $Market\,Value\,of\,the\,Equity$ is market value of the firm at the end of the year and the $Executive\,Ownership$ is executive ownership of the firm. So, the numerator

[11]The government is the listed as the ultimate controller for these firms.

Table 1.5. Effect of Executive Ownership on Firm Leverage After the Credit Push of 2008: Non-SOE Sample

Panel A. Book Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Credit Push$_t$	0.167***	0.158***	0.157***
	(0.000)	(0.001)	(0.002)
Executive Ownership$_{i,t}$	-0.224***	-0.183***	-0.182***
	(0.000)	(0.002)	(0.003)
Credit Push$_t$	0.0571***	0.0508***	0.0953**
	(0.000)	(0.000)	(0.040)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	1469	1469	1469
R^2	0.372	0.405	0.406

Panel B. Market Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Credit Push$_t$	0.283***	0.267***	0.240***
	(0.000)	(0.000)	(0.000)
Executive Ownership$_{i,t}$	-0.266***	-0.225***	-0.209***
	(0.000)	(0.000)	(0.000)
Credit Push$_t$	-0.0492***	-0.0568***	0.0356
	(0.000)	(0.000)	(0.168)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	1469	1469	1469
R^2	0.597	0.629	0.634

This table reports the panel regression estimation of equation 1.3 and reports how the executive ownership is related to changes in firm leverage from the end of year 2008 (Pre-Credit Push) to end of year 2009 (Post-Credit Push). The sample consists only of the public-listed Chinese firms which are not directly controlled by the Government (Non-SOE firms). Executive Ownership$_{i,t}$ is number of shares owned by the executives divided by shares outstanding. Credit Push$_t$ denotes whether $t = 2009$. We use book leverage as the dependent variable for Panel A and market leverage as the dependent variable for Panel B. The controls are return to assets, size of the firm, market-to-book ratio, assets tangibility, dividend, positive net profit, state owned enterprise, ownership concentration, institutional ownership, bank holding and foreign holding (see the appendix for details). The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. The standard errors are clustered at the firm level.

is market value of the stock held by the executives. The *Cash Salary of the Executives* is the cash salary of the top three executives for the firms.[12]

We modify the baseline specification of equation (1.3) above by replacing *Executive Ownership* by *Equity-to-Salary*:

$$\begin{aligned} Leverage\,Ratio_{it} = \beta_0 + \beta_1 Equity\text{-}to\text{-}Salary_{it} + \beta_2 Credit\,Push_t + \\ + \beta_3 Equity\text{-}to\text{-}Salary \times Credit\,Push_t + \\ + \Sigma\beta_k Controls_{itk} + \alpha_{ijt} + u_{it}. \end{aligned} \tag{1.6}$$

The results from estimation of various regression models are described in Table 1.6. Again we use both the book leverage (Panel A) as well as Market Leverage (Panel B) as our dependent variable. The first column of both panels shows that the firms with higher *Equity-to-Salary* ratio increased their leverage ratio significantly more in response to the credit push. The coefficient on the interaction term is positive and significant at the one percent level in both panels. Columns 2 and 3 provide estimations of expanded regressions that include industry and industry-by-year fixed effects. The size and statistical significance remain essentially unchanged. Thus, our finding that managerial incentives have a significant impact on how firms respond to monetary stimulus is robust to this alternative definition of pay for performance sensitivity of executives.

1.6.3 Placebo Test

A possible concern about our findings is the validity of our natural experiment. Although Figure 1.4 shows a clear discontinuity around 2008, to establish a stronger claim for causality, we design a falsification test in which we designate 2012 as a

[12]Ideally we would have liked using the ownership value of the top three executives as the numerator to estimate this ratio, however data on executive ownership for Chinese firm is only available as an aggregate measure.

Table 1.6. Effect of Executive Ownership on Firm Leverage After the Credit Push of 2008: Equity-to-Salary Ratio as an Alternative Proxy

Panel A. Book Leverage

	(1)	(2)	(3)
Equity-to-Salary$_{i,t}$ × Credit Push$_t$	0.0000545***	0.0000447***	0.0000446***
	(0.000)	(0.002)	(0.002)
Equity-to-Salary$_{i,t}$	-0.0000445**	-0.0000318*	-0.0000315*
	(0.012)	(0.060)	(0.066)
Credit Push$_t$	0.0632***	0.0565***	0.122***
	(0.000)	(0.000)	(0.002)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	2999	2999	2999
R^2	0.351	0.389	0.391

Panel B. Market Leverage

	(1)	(2)	(3)
Equity-to-Salary$_{i,t}$ × Credit Push$_t$	0.0000783***	0.0000706***	0.0000654***
	(0.000)	(0.000)	(0.001)
Equity-to-Salary$_{i,t}$	-0.0000568***	-0.0000489**	-0.0000445**
	(0.009)	(0.015)	(0.033)
Credit Push$_t$	-0.0482***	-0.0557***	0.0387*
	(0.000)	(0.000)	(0.092)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	2999	2999	2999
R^2	0.601	0.634	0.637

This table reports the panel regression estimation of equation 1.6 and reports how the executive ownership is related to changes in firm leverage from the end of year 2008 (Pre-Credit Push) to end of year 2009 (Post-Credit Push). The sample consists of 1,530 public-listed Chinese firms. Equity-to-Salary Ratio$_{i,t}$ is the ratio of market value of shares held by the executives to the annual cash compensation for executives. Credit Push$_t$ denotes whether $t = 2009$. We use book leverage as the dependent variable for Panel A and market leverage as the dependent variable for Panel B. The controls are return to assets, size of the firm, market-to-book ratio, assets tangibility, dividend, positive net profit, state owned enterprise, ownership concentration, institutional ownership, bank holding and foreign holding (see the appendix for details). All the specifications include firm fixed effects. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. The standard errors are clustered at the firm level.

placebo "post-credit push" year by assigning a fake credit push at the end of 2011. We rerun all our tests on the 2011 and 2012 panel data, effectively simulating a two year period around the fake credit stimulus. Since there was no major monetary policy shift in this period, we expect to see the placebo *Credit Push* period of 2012 to have no explanatory power. This is indeed what we find. The results of this placebo test are presented in Table 1.7. For both the book leverage and the market leverage, the coefficient for $Executive\,Ownership \times Placebo\,Credit\,Push$ is statistically insignificant.[13]

1.6.4 Pre-Credit Push Compensation

The results discussed so far show a significant relationship between contemporaneous levels of executive ownership with firm leverage. A possible concern that remains is that firms can react rapidly by adjusting the compensation of their executives in response to the credit stimulus. We address this concern that shareholders may react rapidly to the credit stimulus and modify the compensation contract in 2009. A rapid adjustment of compensation structure in response to the credit stimulus biases our tests towards not finding any significant effects. Thus, this concern is unlikely to be a critical one. Nevertheless, we re-estimate our baseline specification in which we fix the compensation structure proxies at their 2008 values. Since these contracts were in place before the announcement of the credit push, it is reasonable to argue that they were unaffected by the monetary policy shift announced in November of 2008. The results reported in Table 1.8 show that our original findings remain robust to this alternative specification.

[13] The coefficient of the *Executive Ownership* however, is still negative for the placebo test. This is consistent with the theoretical predictions of negative relation between executive ownership and leverage during normal times.

Table 1.7. Effect of Executive Ownership on Firm Leverage After the Credit Push of 2008: Placebo Test on 2011 and 2012

Panel A. Book Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Post2012	0.0150	0.0250	0.0309
	(0.766)	(0.602)	(0.527)
Executive Ownership$_{i,t}$	-0.156**	-0.119*	-0.122*
	(0.022)	(0.063)	(0.057)
post2012	-0.00735**	-0.00691**	0.0783
	(0.015)	(0.021)	(0.106)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	3001	3001	3001
R^2	0.322	0.377	0.377

Panel B. Market Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Post2012	0.00505	0.0207	0.0186
	(0.913)	(0.622)	(0.659)
Executive Ownership$_{i,t}$	-0.132**	-0.0906*	-0.0904*
	(0.028)	(0.087)	(0.084)
post2012	-0.000562	-0.000137	0.121***
	(0.804)	(0.950)	(0.000)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	3001	3001	3001
R^2	0.590	0.657	0.657

This table reports the panel regression estimation of equation 1.6 and reports how the executive ownership is related to changes in firm leverage from the end of year 2011 (Placebo Pre-Credit Push) to end of year 2012 (Placebo Post-Credit Push). Executive Ownership$_{i,t}$ is number of shares owned by the executives divided by shares outstanding. Post2012 denotes whether $t = 2012$. We use book leverage as the dependent variable for Panel A and market leverage as the dependent variable for Panel B. The controls are return to assets, size of the firm, market-to-book ratio, assets tangibility, dividend, positive net profit, state owned enterprise, ownership concentration, institutional ownership, bank holding and foreign holding (see the appendix for details). The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. The standard errors are clustered at the firm level.

Table 1.8. Effect of Executive Ownership on Firm Leverage After the Credit Push of 2008: Ownership Fixed at 2008 level

Panel A. Book Leverage

	(1)	(2)	(3)
Executive Share$_{i,2008}$ × Credit Push$_t$	0.159***	0.142***	0.143***
	(0.000)	(0.000)	(0.000)
Executive Share$_{i,2008}$	-0.233***	-0.189***	-0.189***
	(0.000)	(0.001)	(0.001)
Credit Push$_t$	0.0619***	0.0554***	0.120***
	(0.000)	(0.000)	(0.003)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	3007	3007	3007
R^2	0.355	0.392	0.393

Panel B. Market Leverage

	(1)	(2)	(3)
Executive Share$_{i,2008}$ × Credit Push$_t$	0.341***	0.326***	0.310***
	(0.000)	(0.000)	(0.000)
Executive Share$_{i,2008}$	-0.267***	-0.240***	-0.231***
	(0.000)	(0.000)	(0.000)
Credit Push$_t$	-0.0507***	-0.0580***	0.0377*
	(0.000)	(0.000)	(0.099)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	3007	3007	3007
R^2	0.604	0.636	0.639

This table reports the panel regression estimation of equation 1.3 and reports how the executive ownership is related to changes in firm leverage from the end of year 2008 (Pre-Credit Push) to end of year 2009 (Post-Credit Push). The sample consists of 1,530 public-listed Chinese firms. Executive Ownership$_{i,2008}$ is number of shares owned by the executives at the end of year 2008 divided by shares outstanding at the end of year 2008. Credit Push$_t$ denotes whether $t = 2009$. We use book leverage as the dependent variable for Panel A and market leverage as the dependent variable for Panel B. The controls are return to assets, size of the firm, market-to-book ratio, assets tangibility, dividend, positive net profit, state owned enterprise, ownership concentration, institutional ownership, bank holding and foreign holding (see the appendix for details). We also include industry fixed effects and industry-by-year fixed effects. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. The p-values are clustered at the firm level.

1.6.5 Larger Sample

The sample period of all of our tests has been the two year period 2008-2009. This choice was driven by our belief that the *ceteris paribus* assumption is more likely to be true over this short period. However, we re-estimate our panel regression over a longer, four year period (2007-2010). We report these results in Table 1.9. Again, for both the book leverage (Panel A) as well as the market leverage (Panel B), we find that the interaction term $Executive\,Ownership \times Credit\,Push$ has a positive and significant (at the one percent level) coefficient, similar to our main results reported in Table 1.2 for the 2008-2009 sample.

Table 1.9. Effect of Executive Ownership on Firm Leverage After the Credit Push of 2008: Longer Sample Period of 2007 to 2010

Panel A. Book Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Credit Push$_t$	0.160***	0.145***	0.139***
	(0.000)	(0.001)	(0.001)
Executive Ownership$_{i,t}$	-0.253***	-0.207***	-0.183***
	(0.000)	(0.000)	(0.000)
Credit Push$_t$	0.00986***	0.00908***	0.0520
	(0.002)	(0.003)	(0.271)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	5898	5898	5898
R^2	0.310	0.348	0.364

Panel B. Market Leverage

	(1)	(2)	(3)
Executive Ownership$_{i,t}$ × Credit Push$_t$	0.134***	0.125***	0.137***
	(0.000)	(0.000)	(0.000)
Executive Ownership$_{i,t}$	-0.115***	-0.0899**	-0.116***
	(0.006)	(0.022)	(0.003)
Credit Push$_t$	-0.0223***	-0.0236***	0.0538*
	(0.000)	(0.000)	(0.091)
Firm's Controls	Yes	Yes	Yes
Industry FE	No	Yes	No
Industry× Year FE	No	No	Yes
Observations	5898	5898	5898
R^2	0.584	0.613	0.642

This table reports the panel regression estimation of equation 1.3 and reports how the executive ownership is related to changes in firm leverage from pre-Credit Push period of 2007 and 2008 to to the post-Credit Push period of 2009 and 2010. Thus, the sample period covers four years; 2007-2010. The sample consists of 1,530 public-listed Chinese firms. Executive Ownership$_{i,t}$ is number of shares owned by the executives divided by shares outstanding. Credit Push$_t$ denotes whether $t \geq 2009$. We use book leverage as the dependent variable for Panel A and market leverage as the dependent variable for Panel B. The controls are return to assets, size of the firm, market-to-book ratio, assets tangibility, dividend, positive net profit, state owned enterprise, ownership concentration, institutional ownership, bank holding and foreign holding (see the appendix for details). We also include industry fixed effects and industry-by-year fixed effects. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. The p-values are clustered at the firm level.

Taken together, the results from our robustness test provide strong support for a meaningful relationship between incentives faced by a firm's managers and the leverage choices those managers make in response to a government sponsored credit push.

1.7 Conclusions

How the private sector reacts to a large government-initiated credit stimulus is an important topic for economists as well as policy makers. After all, the ultimate goal for expansionary credit policies is to induce greater borrowing by households and corporations. However, when faced with increased credit supply, not all firms will respond in a similar manner. This paper focuses on one important source of heterogeneity across firms: the compensation structure of the top executives.

We focus on the Chinese government's exceptionally large and unanticipated credit expansion announced in November 2008. The Chinese setting offers a unique advantage as the government exercises almost complete control over the banking sector. This implies that demand, rather than supply, largely drives the observed changes in firms' borrowing as the banks have little discretion in *not* increasing the credit supply.

Our results provide empirical support for the idea that in normal economic times, debt and compensation structure as proxied by executive ownership are substitute mechanisms for inducing managerial effort. However, when a large, government-subsidized credit expansion is in place, the executives with higher ownership (i.e. higher pay-for-performance sensitivity) will take on more debt.

The findings of this paper can motivate future research on how credit expansion policy may produce different responses across countries as well as across different industries within a country. For example, our results may point to possible explanations of why the expansionary credit policies in Japan and to a certain extent in Europe did not lead to significantly more borrowing by the corporate sector.

Chapter 2

A Comprehensive Model of Leverage and Executive Compensation

2.1 Introduction

How much and in what form should a firm's owners pay a manager hired to run the firm? How will the compensation structure affect the manager's risk-taking through incurring debt to expand the firm's size? These questions are central in corporate finance research. John and John's (1993) seminal paper has triggered a large literature studying the relationship between the level and structure of executive compensation and risk-taking. The empirical studies, however, have reported conflicting results as discussed by Tosun (2016). For example, Berger, Ofek, and Yermack (1997) document a positive relationship between risk-taking proxied by firm-leverage and CEO equity ownership. In contrast, Bryan, Hwang, and Lilien (2000) report that higher variable compensation is associated with lower firm-leverage. The theory models used in prior studies assume either the compensation or the leverage or the borrowing spreads to be exogenous. Edmans and Gabaix (2016) highlight this shortcoming in their survey of the executive compensation literature.

In this paper, we analyze the links between executive compensation and leverage in a model that avoids the shortcomings of previous models. In our model the CEO's risk aversion, effort supplied, risk-taking, as well as endogenous costs of borrowing, are jointly determined. We show that allowing for endogenous compensation and endogenous leverage fully rationalizes the conflicting findings of the empirical literature. Moreover, we uncover new insights that we discuss below.

We consider a firm owned by a shareholder who has access to an investment project but lacks the skills to exploit this opportunity. Thus, she hires a CEO possessing the required skills to manage the firm. The model also has a lender from whom the CEO can borrow. The CEO can be risk-averse while the shareholder and the lender are risk-neutral. The firm's cash flows are stochastic and increasing in the amount invested. The expected cash flow is also increasing in the CEO's effort. The CEO is averse to effort, as it is costly.

Following the approach outlined in John and John (1993) and Carlson and Lazrak (2010), the shareholder offers a compensation contract featuring two components. The first component is a fixed amount paid to the CEO regardless of the final cash flow realized by the firm. The second component is a share of the cash flow realized by the firm (hereafter "variable component"). A larger variable component implies that the CEO compensation has a higher pay-for-performance sensitivity. After accepting the contract, the CEO chooses her effort level as well as how much debt to take on. Larger debt expands the scope of the firm and can potentially lead to a larger cash flow. However, as discussed later, the CEO is risk-averse and faces conflicting incentives on how much to borrow.

We employ the financial contract framework of Bernanke, Gertler, and Gilchrist (1999) to model the debt contract. The lender is risk-neutral and she prices the debt by charging a spread over her own cost of funds. This spread is determined endogenously and reflects the risk of default for the borrowing firm.

The model assumes symmetric information among all players when the contracts (compensation and leverage) are written. However, a key variable, the effort supplied by the CEO, is not verifiable by outsiders. This rules out the possibility of writing an explicit compensation contract conditioned on the effort of the CEO. We also rule out any possibility of renegotiating with the lender if the cash flow is below the amount owed to the lender (default state).

Our model has four main implications for the relationship between executive compensation and capital structure. First, we show that a CEO's risk aversion implies a *negative* relationship between leverage and the CEO's ownership of the firm. This finding confirms the results of earlier theoretical models (e.g. Carlson and Lazrak 2010) and some of the empirical findings (e.g. Bryan, Hwang, and Lilien 2000). When the CEO is risk-averse, there is a trade-off between variable compensation and how much the CEO borrows. This trade-off arises because the CEO's total compensation has a higher variance when either the pay-for-performance sensitivity is high or when the firm's leverage is larger. Thus, a CEO who is more exposed to her firm's risk reduces the firm-leverage to lower that risk.

However, Carlson and Lazrak's (2010) result is based on a model with exogenous compensation. It is reasonable to argue that the shareholders will ex-ante offer a contract taking into account the CEO's risk-aversion and her leverage choices. Once we allow shareholders to optimally choose the CEO's compensation, we uncover a novel mechanism that can explain why the empirical literature has reported conflicting findings about the cross-sectional correlation between CEO compensation and firm leverage.

For a shareholder, the firm's leverage and the CEO's effort are complements. That is, greater effort makes higher future cash flow more likely, and this allows the firm to sustain a higher level of leverage. This implies that the shareholders of firms desiring a higher level of debt will include a *larger* variable component in the CEO compensation contract to encourage the CEO to exert more effort.[1] Thus, the optimal action of shareholders can generate a *positive* cross-sectional relationship between the level of leverage and the degree of pay-for-performance sensitivity (i.e. variable component) of CEO compensation.

Our second result is the novel prediction that the optimal level of *total compensation* is increasing in leverage.[2] The shareholder in a leveraged firm wants to elicit high effort from the CEO, and thus offers a large share of the firm's ownership. However, in order to reduce the CEO's aversion to leverage, the shareholder also has to offer a higher fixed component in the CEO compensation. Thus, the optimal compensation contract requires that *both* the compensation components, fixed as well as variable, need to be increased if the shareholder wants the CEO to increase effort and leverage at the same time (for example to profit from better investment opportunities).

Our third result is that leverage and the ratio of variable-to-fixed compensation are *positively* correlated. The optimal variable pay grows faster than the fixed pay.

Finally, we study the dynamic implications of the model. We analyze how expansions of credit supply affect the debt uptake of firms managed by CEOs with varying compensation structures. Policy makers often try to stimulate economic activity by promoting growth in credit to the corporate sector. Most of the previous literature that has examined the impact of such credit expansions has focused on how this

[1]There are several factors in the model that can explain the observed differences in leverage and compensation across the *cross-section* of firms. These include different degrees of idiosyncratic risk of the firms as well as varying monitoring costs for the lender.

[2]Cheng, Hong, and Scheinkman (2015) show that the total compensation will be higher if the overall risk of the firm increases. However, the firm-risk is exogenous in their model. In our model, the risk induced specifically by the increased leverage is chosen by the CEO. Jaggia and Thakor (1994) propose a model that also yields results similar to ours. However, in their model the highly-levered firms need to pay higher compensation in order to induce employees to invest in acquiring skills that are specific to that firm. Golan, Parlour, and Rajan (2015) show that greater product market competition can also impact compensation level. Since we want to focus primarily on the relationship between leverage and compensation, we exclude product market considerations in our model.

policy is transmitted through the banks' lending decisions, i.e. the "supply" of credit. To the best of our knowledge, we are the first to show that the structure of executive compensation can also affect the "demand" for borrowing.

Our model predicts that the relationship between the *change* in leverage and variable compensation is unambiguously *positive* after an expansionary shift in the credit supply. This occurs because the variable component allows the CEO to capture a larger fraction of the cash flow generated by the firm. Since the government credit subsidy increases the value of the borrowing firm, its CEO will borrow more if she is promised a larger share of the firm (i.e. higher variable compensation).

Our paper connects two strands of theoretical literature on executive compensation and firm leverage. The first group of models takes executive compensation as exogenous and studies a firm's leverage choices. Papers following this approach include John and John (1993), Carlson and Lazrak (2010) or Panousi and Papanikolaou (2012). The second group of models solves for the optimal compensation, but with exogenous leverage decisions with no default and no endogenous credit spreads. This group includes Dittmann, Maug, and Spalt (2010), Dittmann, Yu, and Zhang (2017), He (2011), Bolton, Mehran, and Shapiro (2015) and Gete and Gomez (2017). We find that when compensation, leverage and the cost of leverage are all endogenous, we generate novel insights.

Furthermore, we also show how the compensation structure affects a firm's response to expansions of credit supply. This mechanism complements the large literature on the bank lending channel.[3] This result is closely related to Agarwal et al. (2018) who examine the response of retail (credit card) borrowers to the credit expansion in the U.S.. They show that consumers' propensity to borrow (i.e. demand for credit) is an important determinant in how much additional credit is obtained

[3] Gambacorta and Shin (2016) provide a survey.

by the consumer. We complement their study by focusing on the uptake of credit by corporate borrowers.

Our results suggest that maximizing the impact of credit policies requires combining them with policies that increase firms' willingness to borrow. For example, tax incentives that encourage higher managerial equity ownership may result in corporations reacting more to credit expansions if the tax incentives lead to greater managerial ownership.[4] This result complements papers such as Bebchuk and Goldstein (2011), who study policies for economies in which banks abstain from lending to firms with good projects.

The paper proceeds as follows. In section 2.2 we present the model. Section 2.3 describes our main results. Section 2.4 concludes. The Appendix B has additional results and the first order conditions of the model.

2.2 Model

Our model considers a firm operating a project that generates risky cash flows. We model the cash flow risk by incorporating a stochastic shock to the firm's productivity. At the start of the period (date 0) the firm invests and the returns are realized at the end of the period (date 1). There are three agents: a shareholder, a CEO and a lender. The shareholder lacks the ability to operate the firm and must hire an outside CEO with the required skills.

At date 0, the shareholder offers the CEO a mutually acceptable compensation contract. After being hired, the CEO chooses to borrow an amount B and invests the newly borrowed amount in the project (firm already has N of equity investment,

[4] Gorry et al. (2017) provide evidence that the structure of executive compensation is sensitive to taxation.

made by the shareholder).[5] The lender prices this debt by charging a spread over its own cost of funds. At date 1, the project generates a cash flow. Apart from the realized cash flow, the firm has no other assets of any value. Thus, the final value of the firm (denoted by Y) equals the total cash flow generated by the project. This value is both observable and verifiable at date 1.

To operate the project, the CEO expends costly effort which we denote as p. The CEO's effort increases the expected future cash flow that will be generated by the firm. Following the typical setup employed in the compensation literature (see Gayle, Golan and Miller 2015 for example), we assume that the effort supplied by the CEO is private information and cannot be observed directly by the shareholder. This makes it impossible to write a compensation contract based on the level of effort supplied by the CEO. The compensation contract has two components: a fixed component (denoted by A) and a variable component (denoted by v) that is a fraction of the realized cash flow of the firm at date 1. Figure 2.1 recapitulates our model's time-line.

2.2.1 The Firm

At date 0, the firm has a pre-determined level of equity (N) and the CEO can borrow B to expand the size of the project,

$$K = B + N. \tag{2.1}$$

Capital (K) is the total investment of the firm. Conceptually, one can think of the equity N either in terms of cash investment or operating assets already in place contributed by the shareholder.

[5] We limit the new capital to be in form of debt. This allows us to abstract away from issues related to equity dilution as well as information frictions between different equity holders.

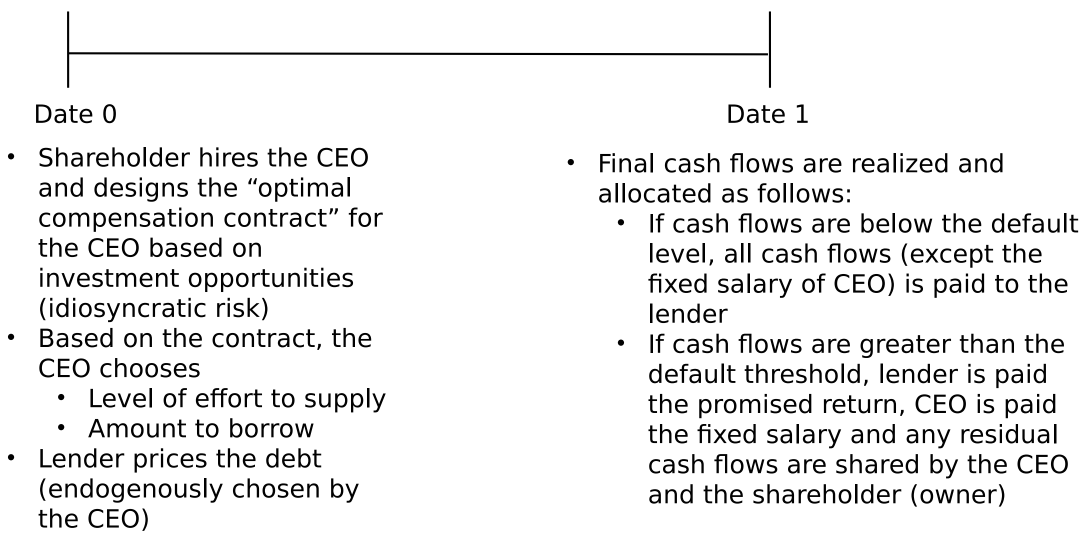

Figure 2.1. Time-line of the Actions of Shareholder, CEO and Debt Lender.

The firm's cash flow Y at date 1 is stochastic and depends both on the capital employed and on the shock to productivity,

$$Y(\omega, K) = \omega R_k K,$$

where R_k is a constant and ω is the productivity shock. The productivity shock ω follows a lognormal cumulative density function. This setup mirrors the specification in Bernanke, Gertler, and Gilchrist (1999) where ω represents the idiosyncratic risk of a specific firm while R_k is the aggregate return to capital.

In our model, the CEO's effort (p) has an impact on the final realized value via the productivity shock ω. We model the expected mean of the associated lognormal distribution of ω as a function of the CEO's effort:

$$\omega \sim \ln \mathcal{N}(\omega; \mu(p), \sigma), \tag{2.2}$$

$$\mu(p) = \psi p^{\varepsilon} - \frac{\sigma^2}{2}, \tag{2.3}$$

where σ is the idiosyncratic uncertainty of the productivity shock, $\psi > 0$ and $\varepsilon < 1$ are respectively the level and the shape parameters for the effect of the CEO's effort on the productivity shock.

From (2.2) and (2.3) it follows that the firm's expected productivity is increasing and concave in effort. That is,

$$\mathbb{E}[\omega] = e^{\mu(p)+\frac{\sigma^2}{2}} = e^{\psi p^{\varepsilon}}.$$

We denote the cumulative density function of ω by $F(\omega; p)$ to stress that the expected value of the productivity shock (ω) is a function of the CEO's effort p.

2.2.2 The Lender

The lender faces a cost of funds $R_B(1-\tau)$. The parameter $\tau \geq 0$ is a government credit subsidy that shifts credit supply, as we explain in more detail below. There are several ways to interpret this parameter. For example, Jeske, Krueger, and Mitman (2013) refer to it as a loan guarantee. It can also be thought as a monetary policy or government's subsidies lowering the lender's cost of funds.

Following Bernanke, Gertler, and Gilchrist (1999), we model the financial contract as a default threshold $\hat{\omega}$ and a loan size B such that when the firm receives a shock ω above the threshold $\hat{\omega}$ then it pays $\hat{\omega} R_k K$ to the lender. When the shock ω is below the threshold $\hat{\omega}$ then the firm defaults and the lender seizes the firm's assets after paying a proportional foreclosure cost, $\gamma > 0$. The endogenous lending rate R_L is implicitly defined as

$$R_L B = \hat{\omega} R_k K. \tag{2.4}$$

The lender's participation constraint requires that the lender must expect to break even:

$$\int_{\hat{\omega}}^{\infty} R_L B \, dF(\omega; p) + \int_0^{\hat{\omega}} (1-\gamma)\, \omega R_k K \, dF(\omega; p) = R_B(1-\tau)B. \tag{2.5}$$

The first integral in the left hand side of (2.5) is the expected revenue for the lender when the firm repays (the area where ω is above the threshold $\hat{\omega}$). The second integral is the lender's expected revenue in the case of the firm's default. That is, the value of the firm's assets net of foreclosure costs. The right hand side of (2.5) is the cost of funds for the lender.

Equation (2.5) determines the endogenous lending spreads. Since the firm's productivity shock (and the resulting cash flows) are not known ex-ante (at date 0), the lender needs to set the lending rate higher than his cost of funds to compensate him for the probability of default and for the foreclosure costs. Using (2.1), (2.4) and (2.5) we get:

$$\int_0^{\hat{\omega}} (1-\gamma)\, \omega R_k (B+N) \, dF(\omega; p) + \int_{\hat{\omega}}^{\infty} \hat{\omega} R_k (B+N) \, dF(\omega; p) = R_B(1-\tau)B. \tag{2.6}$$

The equation (2.6) describes the lender's participation constraint when it is binding.

2.2.3 The Compensation Contract

Similar to the approach of John and John (1993) and Carlson and Lazrak (2010), we study compensation contracts with both a fixed component ($0 \leqslant A$) and a variable component denoted as a share $0 \leqslant v \leqslant 1$ of the firm's value at date 1. The total payoff for the CEO is $s(\omega)$,

$$s(\omega) = \begin{cases} A + v\left[Y(\omega, K) - R_L B\right] & \text{if} \quad \omega \geq \hat{\omega}, \\ A & \text{if} \quad \omega < \hat{\omega}. \end{cases} \tag{2.7}$$

That is, when the firm defaults ($\omega < \hat{\omega}$) the CEO only receives the fixed compensation A. When the firm repays $(\omega \geq \hat{\omega})$, the CEO gets the fixed salary A, and a share v of the firm's final cash flow net of payments to the lender.

2.2.4 The CEO

The CEO bears the cost of effort denoted by $c(p)$,

$$c(p) = \phi p^{\rho}, \tag{2.8}$$

which we assume is increasing and convex. That is, $\phi > 0$ and $\rho > 1$.

Given the compensation contract, the CEO, decides her effort p and the firms' borrowing contract $(B,\ \hat{\omega})$ to maximize her expected utility subject to the lender's participation constraint. That is, the CEO solves:

$$\max_{\{\hat{\omega}, p, B\}} \int_{\hat{\omega}}^{\infty} u\left(A + v\left(Y(\omega, K) - R_L B\right) - c(p)\right)\, dF(\omega; p) + \int_{0}^{\hat{\omega}} u\left(A - c(p)\right)\, dF(\omega; p) \tag{2.9}$$

$$\text{subject to } (2.6)\,.$$

2.2.5 The Shareholder

The shareholder makes a take-it-or-leave-it offer to the potential CEO taking into account that the compensation contract will affect the CEO's effort and borrowings. Thus, the shareholder chooses the compensation contract (A, v) to maximize the firm's cash flow net of payments to the lender and the CEO:

$$\max_{\{A,v\}} \int_{\hat{\omega}}^{\infty} \left[(1-v)\left(Y\left(\omega, K\right) - R_L B\right) - A\right] dF(\omega; p) \tag{2.10}$$

subject to the CEO's effort, default threshold and borrowings determined by the FOCs of the CEO's problem defined by (2.9).

2.2.6 Calibration

The model does not have closed-form solutions and we solve it numerically assuming that the CEO has the standard CRRA preferences:[6]

$$u(C) = \frac{C^{1-\eta}}{1-\eta}, \tag{2.11}$$

where the CEO's consumption C is the wage payments $s(\omega)$ defined in (2.7) minus the cost of effort,

$$C = s(\omega) - c(p). \tag{2.12}$$

The parameter η is the coefficient of risk aversion. For $\eta > 0$, $\eta \neq 1$ there is positive risk aversion. The risk-neutral case is $\eta = 0$.

We use the same coefficient of risk aversion (η) as Carlson and Lazrak (2010), the foreclosure cost (γ) follows Bernanke, Gertler, and Gilchrist (1999), and the scale parameter (σ) of the lognormal productivity shocks follows Gete (2016). Since we

[6] Calibration exercises with CRRA preferences include Dittmann, Maug, and Spalt (2010) and Hall and Murphy (2000) among others. We verified that the results also hold for constant absolute risk aversion (CARA) preferences. Given the strong intuition behind the theory, we believe that the results will also hold for other preference types such as Epstein-Zin.

also analyze the impact of credit supply expansion on changes in leverage across firms with different CEO compensation contracts, we use the monetary stimulation implemented by China as our test case.[7] For the cost of lenders' funds (R_b) we use a 2% rate, which is the average return on deposits between 2007 and 2010 in China. For the remaining parameters, we select them to match moments from the Chinese credit stimulus studied in Dahiya, Ge, and Gete (2017). We select the credit stimulus parameter (τ) to match the decrease in interbank rates that the Chinese Central Bank implemented in 2008. Table 1 contains the parameters of the model and Table 2 reports the moments that we match.

Table 2.1. Parameters

Exogenously Determined		
Parameter	Value	Description
η	1.1	Coefficient of risk aversion
σ	0.40	Scale parameter productivity shock
γ	0.12	Foreclosure cost
τ	0.01	Credit subsidy to lenders
R_b	1.02	Cost of lenders' funds
Endogenously Determined		
ψ	0.045	Level parameter of benefits from effort
ε	0.315	Shape parameter of benefits from effort
R_k	1.04	Parameter return of capital
ϕ	0.0012	Level parameter of costs of effort
ρ	2.2	Shape parameter of costs of effort

[7] The Chinese government announced a \$568 billion stimulus package combined with a dramatic easing of monetary policy as described by Deng et al. (2015). The announcement received extensive media coverage much of which was devoted to the relatively large size of the Chinese stimulus. For example, *Forbes* magazine compared the \$568 billion Chinese stimulus to policy initiatives of other countries and stated "... The sums involved are substantial. By comparison, the U.S. pumped \$100 billion into its economy in the summer via tax rebate checks. Germany has just announced a \$65 billion stimulus package. Both economies are larger than China's."

Table 2.2. Model Moments and Targets (Annualized)

Description	Targets	Model
Leverage	0.50	0.50
Default rate	5.1%	5.57%
Lender lending rate	3%–6%	3.44%
Net ROA	4-6%	4%
Net ROE	7%–9%	8.47%

In the next section we discuss the qualitative results that are robust across the parameter space.

2.3 Results

First, we analyze the cross-sectional implications of the model for exogenous compensation, like Carlson and Lazrak (2010). Next, we study the case where all the key variables are endogenous. Finally, we analyze the dynamic effects of credit policy shifts.

2.3.1 If Compensation is Exogenous

The panels in Figure 2.2 plot the leverage and effort choices of a risk-averse and a risk-neutral CEO as a function of the variable and fixed payments. That is, different compensation components are exogenously changed within the model holding all else constant.

The first insight is gained by comparing figures 2a and 2c which plot respectively the choice of leverage and effort made by a risk-neutral CEO (solid line) and a risk-averse CEO (dashed line) as a function of variable pay, holding all else constant. Figure 2.2c shows that, for both the risk-neutral CEO and the risk-averse CEO, higher

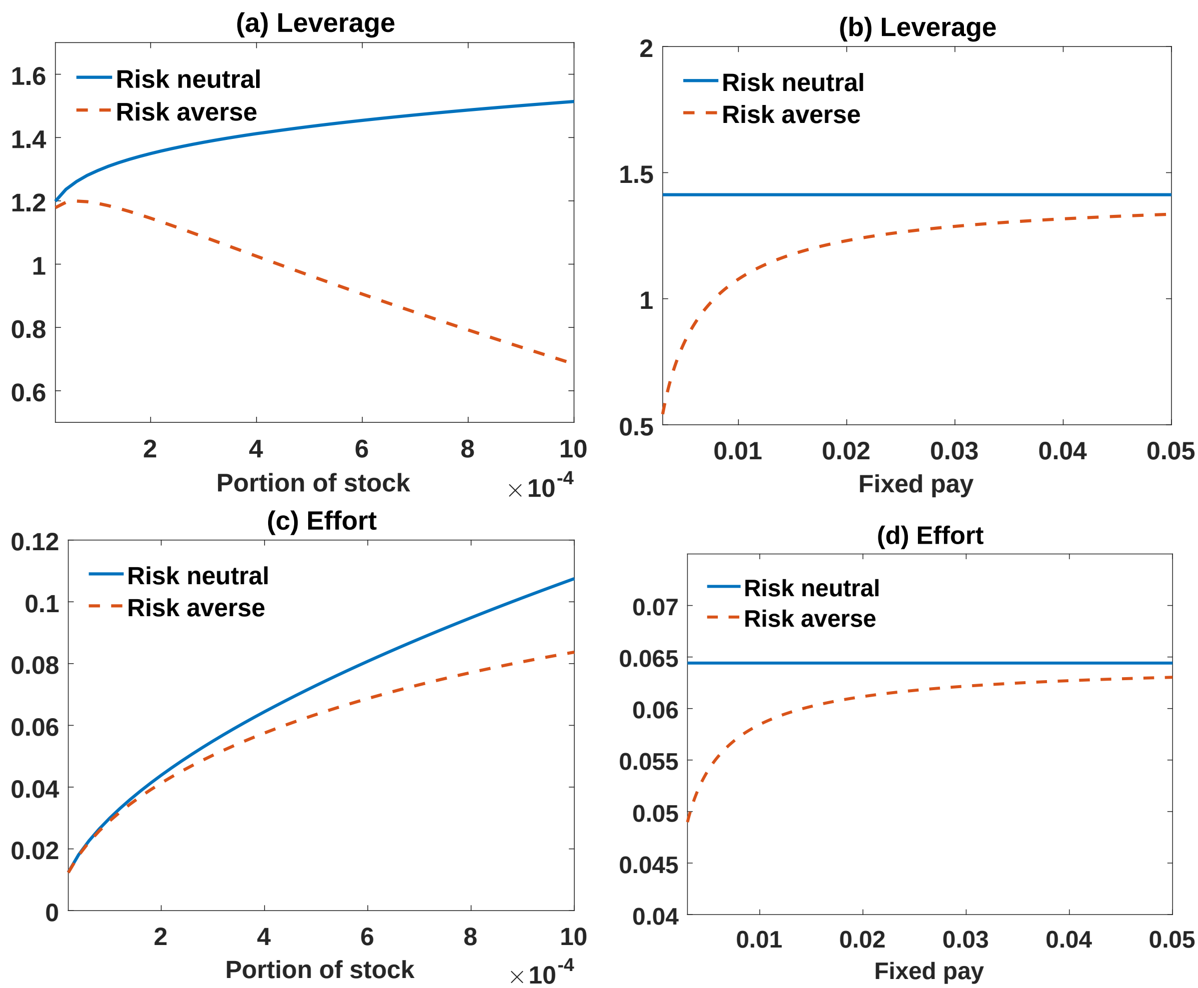

Figure 2.2. Leverage, Effort and the Structure of CEO Compensation for a Risk-averse and a Risk-neutral CEO.

This figure plots firm's leverage and effort as a function of CEO's variable (v) and fixed compensation (A) when the CEO is risk-averse and when she is risk-neutral. Leverage is defined as debt-to-equity $(\frac{B}{N})$.

variable compensation encourages effort which, in turn, increases the firm value and the value of the CEO's ownership.

When the CEO is risk-neutral, Figure 2.2a shows that leverage increases for the risk-neutral CEO as the variable compensation increases. This result arises because higher effort makes negative productivity shocks less likely and effort and leverage are complements.

When the CEO is risk-averse, Figure 2.2a shows that a compensation contract with a larger performance-based component discourages leverage. That is, the CEO trades off variable compensation and leverage because both increase the variance of her total compensation and her exposure to default risk. Figure 2.2a shows that this channel generates a negative cross-sectional correlation between leverage levels and variable compensation.

Figures 2.2b and 2.2d show the role of fixed compensation. Higher fixed pay makes the CEO less risk averse as there is a large guaranteed payout even if the firm suffers an adverse productivity shock. This encourages the CEO to increase leverage, which in turn also motivates her to supply greater effort to reduce the likelihood of bad shocks. Figures 2.2b and 2.2d show that this channel is irrelevant for a risk-neutral CEO, because she is only motivated by the variable part of her compensation.

2.3.2 Both Compensation and Leverage are Endogenous

Figure 2.3 plots the optimal compensation that the shareholder chooses. Optimal compensation (represented by the dot on the surface) implies that an optimal contract will include both variable pay $(v > 0)$ and fixed compensation $(A > 0)$. The variable pay elicits the CEO's effort and increases the value of the firm. However, variable compensation makes the CEO more risk-averse and encourages under-investment. By paying fixed compensation, the shareholder encourages the risk-averse CEO to

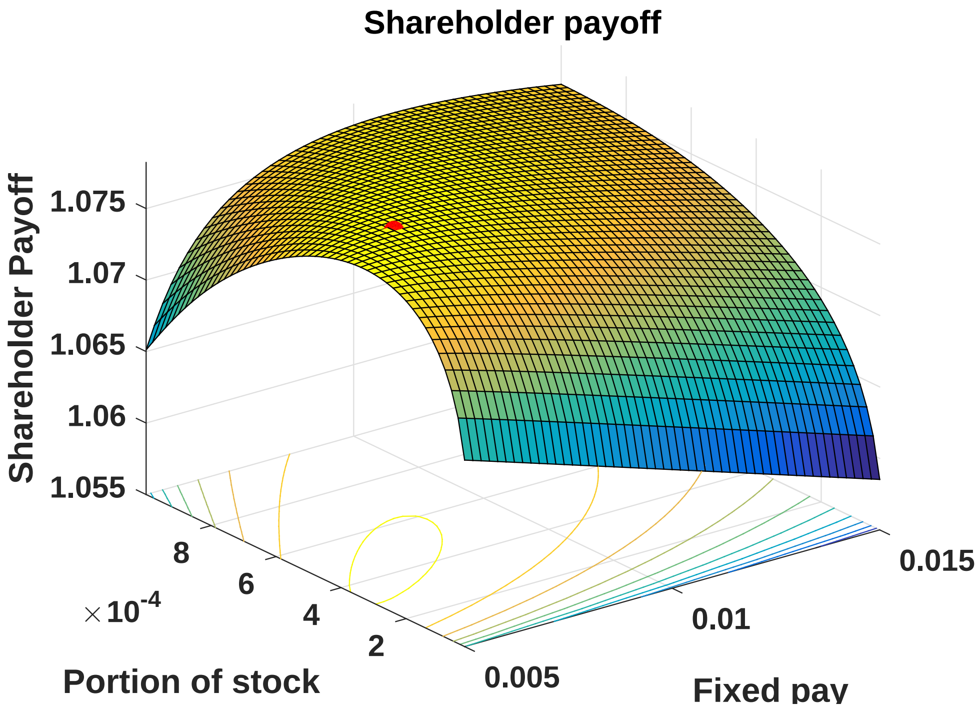

Figure 2.3. Shareholder Payoff as a Function of CEO Compensation. This figure plots the shareholder's payoff (equation 2.10) as a function of the variable (v) and fixed (A) compensation paid to CEO. The optimal combination (v, A) is the dot on the top of the surface.

increase leverage. Thus, the optimal compensation package is a combination that provides enough motivation for the CEO to provide costly effort and enough insurance to encourage risk-taking.

To generate cross-sectional heterogeneity, the firms need to differ on some parameter. In the Appendix B we show that differences in idiosyncratic volatility (σ) or in the monitoring cost parameter (γ) generate observationally equivalent cross-sectional heterogeneity in leverage. Given this result, we focus our discussions only on idiosyncratic volatility (σ) . This choice is motivated by the approach taken by Panousi and Papanikolau (2012). They show that higher idiosyncratic risk lowers investment

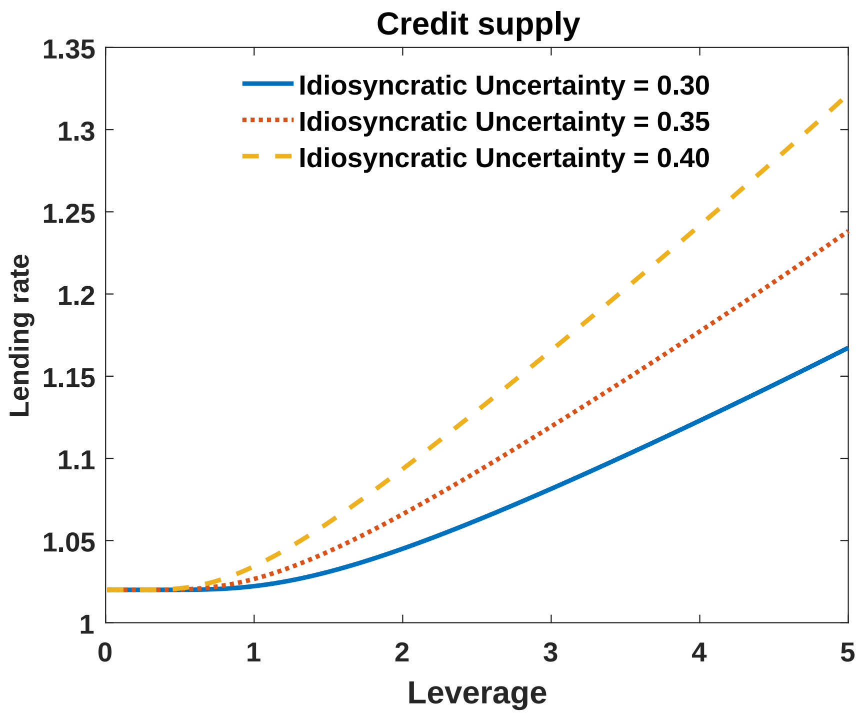

Figure 2.4. Credit Supply as a Function of Firm's Idiosyncratic Uncertainty.
This figure plots credit supply (equation 2.5) for firms with different degrees of idiosyncratic uncertainty (σ).

especially when a risk-averse CEO holds a higher fraction of the firm's equity. To understand why cross-sectional heterogeneity in idiosyncratic volatility (σ) translates into cross-sectional heterogeneity in leverage, Figure 2.4 plots the lender's participation constraint (equation 2.6) for firms with different idiosyncratic volatility (σ). Figure 2.4 shows that lenders charge higher spreads to riskier firms. The following two mechanisms are driving this result: 1) Volatility is bad for lenders because debt contracts imply concave payoffs. That is, high risk firms have higher default risk; and 2) Volatile firms encourage less effort from their risk-averse CEOs. Thus, Figure 2.3

shows that, all things being equal, less volatile firms face lower borrowing costs and, as a consequence, shareholders of such firms will desire a higher level of leverage.

Figure 2.5 shows how firms with different idiosyncratic volatility (σ) choose leverage and executive compensation when all variables are endogenous and optimally selected. Figures 2.5a, 2.5c and 2.5d show that there are positive cross-sectional correlations between variable, fixed and total compensation with leverage. The reason is that from the shareholder's perspective, leverage and CEO's efforts are complementary. Shareholders in low-volatility firms need to offer higher fixed payments to encourage their CEOs to leverage, and higher variable pay to motivate the CEO to provide high effort.

Moreover, Figure 2.5b shows that for reasonable degrees of risk-aversion the variable compensation grows faster than the fixed component. As a consequence, the ratio of variable to fixed compensation ($\frac{\int_{\hat{\omega}}^{\infty} v[Y(\omega,K)-R_L B]dF(\omega;p)}{A}$) increases in leverage.

Thus, to recap, this section outlines different mechanisms that explain why the empirical literature reports conflicting findings on whether performance-based compensation and firm-leverage are positively or negatively correlated.

2.3.3 Dynamic Results

In this section, we study how firms change their leverage in response to an expansionary shift in credit supply. How the corporate sector responds to a large government-initiated credit stimulus is an important issue for economists as well as policy-makers. After all, a major objective for expansionary credit policies is to induce greater borrowing by households as well as corporations. The academic literature on this topic focuses on the impact of such policies on the "supply" of credit typically

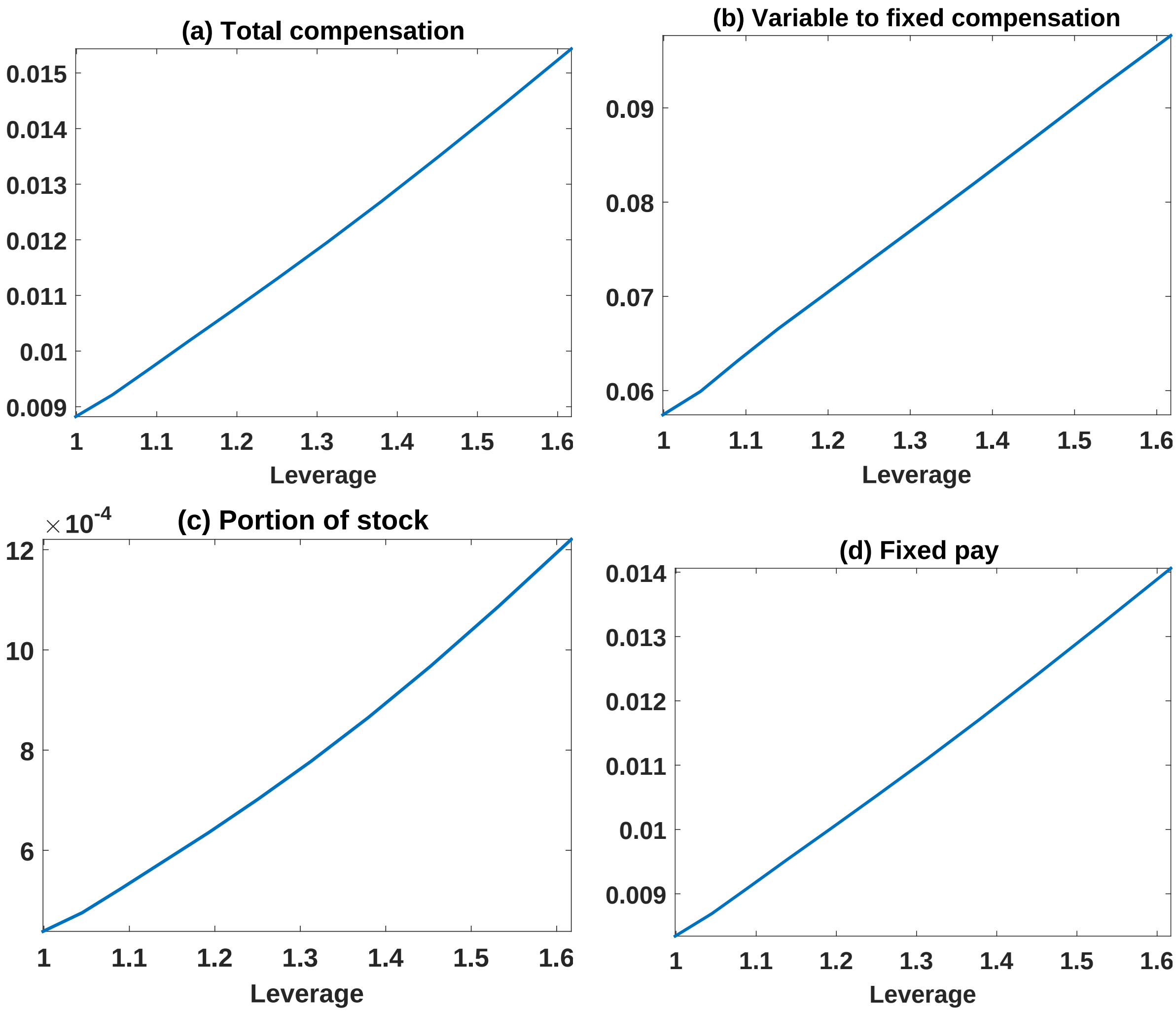

Figure 2.5. The Cross-section of Compensation Variables and Leverage (Benchmark).
This figure plots the compensation variables versus the firm's leverage. All variables change because the degree of idiosyncratic uncertainty (σ) changes.

through the banking channel.[8] Few studies have examined how a credit stimulus interacts with the factors that affect the “demand" for borrowing.

We show that the structure of executive compensation plays a critical role in how corporations choose to borrow more when there is an outward shift in credit supply. Firms with a higher managerial equity ownership (i.e., stronger incentives) increase leverage more. Our results suggest that maximizing the impact of credit policies requires combining them with policies that increase firms' willingness to borrow. For example, tax incentives that encourage higher managerial equity ownership may result in corporations reacting more to credit expansions if the tax incentives lead to greater managerial ownership.

Specifically, in our model we capture the policy intervention by making our τ variable take on a strictly positive value. This is consistent with Agarwal et al. (2018), who model credit expansions as changes in banks' cost of funds. Figure 2.6a shows that the credit supply, which is the lender's participation constraint (2.6), shifts right and the cost of leverage decreases when $\tau > 0$.

The Figure 2.6b illustrates the key cross-sectional implication of our model after the credit stimulus. The x-axis represents firms with different levels of executive ownership and the y-axis represents the growth of the leverage after the credit stimulus previously depicted in Figure 2.6a. Figure 2.6b shows that firms whose CEOs have larger equity ownership react more to the credit supply shift. Thus, a CEO with high ownership is predicted to increase firm-leverage more compared to another CEO with lower firm ownership. Intuitively, high ownership implies that the CEO will share a larger portion of the rewards from leverage and is therefore more receptive to the credit stimulus. Thus, higher variable compensation induces greater changes in leverage.

[8]Gambacorta and Shin (2016) provide a recent survey of this stream of work.

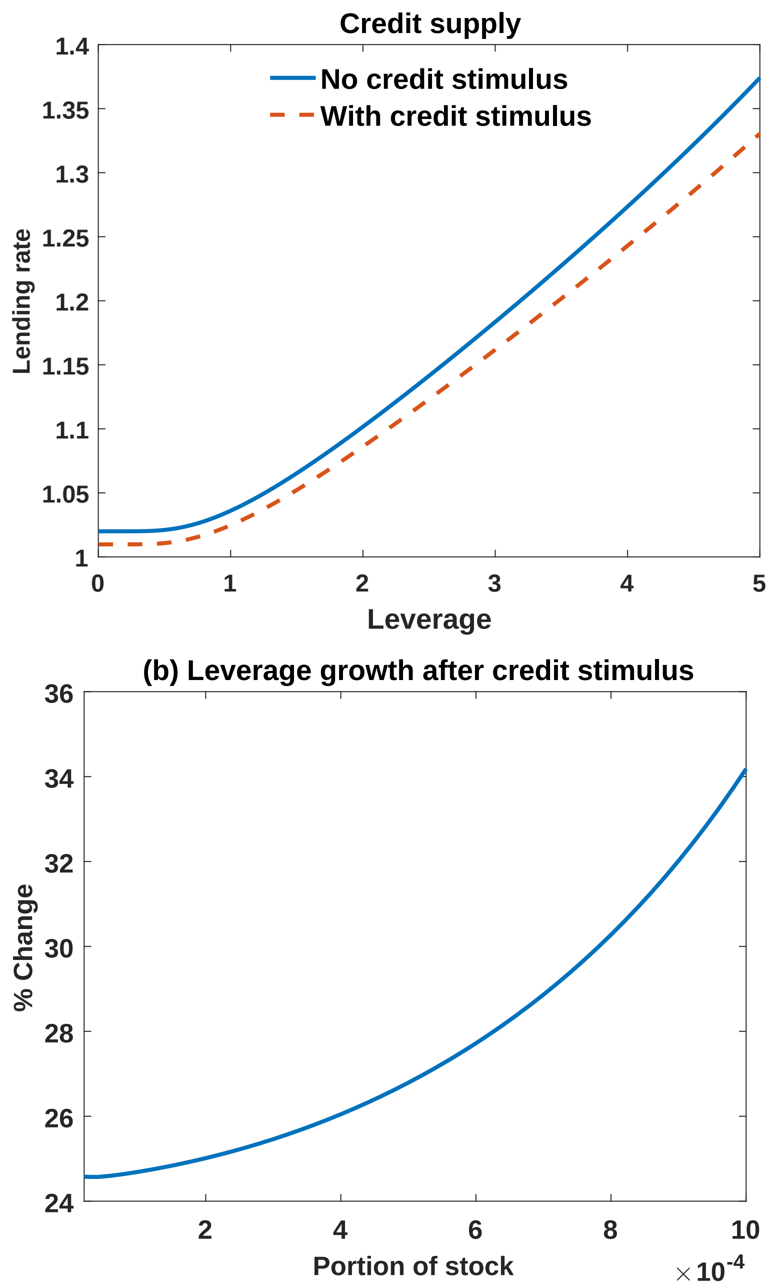

Figure 2.6. The Effects of a Credit Stimulus on Credit Supply and Firm's Leverage.

The top panel plots credit supply (equation 2.5) before and after a government subsidy to lenders' cost of funds. The bottom panel plots the change in firm's leverage for firms with different level of variable compensation (v) after the credit supply shift reported in the top panel.

2.4 Conclusions

This paper studies a model with endogenous compensation contracts and leverage choices. We show that multiple channels are at play and the cross-sectional links between leverage and variable compensation are ambiguous and much in line with the empirical findings.

Our model shows that the optimal compensation package is a combination of fixed and variable components that provides enough motivation for a CEO to exert costly effort, and enough insurance to encourage risk-taking. From the perspective of the shareholder, leverage and CEO's effort are complements. Thus, to encourage both of these two elements, compensation packages need to have total pay increasing in leverage.

Finally, we show that the compensation structure of the CEO affects the demand for credit. A key cross-sectional implication arising from our model is that firms with high CEO ownership will react more (i.e. they will borrow more) in response to a credit supply expansion. This result uncovers a potential channel which can play an important role in the effectiveness of credit policies.

Chapter 3

Natural Disasters and Housing Markets. The Tenure Choice Channel

3.1 Introduction

The threats posed by climate change and rising sea levels have the potential to damage housing values on an enormous scale. For example, Rao (2017), the Risky Business Project (an organization co-chaired by Michael Bloomberg, Henry Paulson, and Thomas Steyer) estimates that between $66 billion and $160 billion worth of real estate is expected to be below sea level by 2050 (The Risky Business Project 2014). An important policy question is to understand how will housing markets react to the higher risk of natural disasters. Further to understand how the higher risk of natural disasters affect the choices of low income, middle and high income households. This is the question that we study in this paper.

We gather and analyze a new database of natural disasters in the United States that we integrate with real estate and mortgage variables. Our database is novel because it provides the damage and intensity of the different natural disasters at the local levels; it creates the opportunity for us to compare the different kinds of disasters in different places. Together with information of the housing rents, housing prices, mortgage, etc. from Zillow database and HMDA database, we can unveil the natural disasters' impacts on the housing market.

We uncover several new facts: (1) Housing rents permanently increase following the disaster. The effects on housing prices are ambiguous; (2) Conforming mortgage applications for low-mid size homes fall while jumbo applications increase. Approval standards do not change; (3) Homeownership rates decline. The previous facts are consistent with a tenure choice channel in which low-mid income households hedge natural disaster by moving from the ownership to the rental market. Wealthy households expand their housing holdings.

Section 3.2 describes the related literature. Section 3.3 talks about the theory of how disaster risk affects the housing market. Section 3.4 introduces our data sources and variables. Section 3.5 are the benchmark results for the real estate market reactions. Section 3.6 are reactions of the different wealth levels households. Section 3.7 analyzes the impacts from different types of disasters as the sensitivity tests. Section 3.8 is the conclusion.

3.2 Related Literature

This paper contributes to three strands of the natural disasters, housing market and credit reactions literature. First, our work is related to the papers studying the impacts of the natural disasters on the housing values. Second, it is related to the papers one mortgage reactions after external shocks. Third, it is related to the papers on heterogeneous reactions of households with the different wealth to the external shocks.

Technically, we need to find the way to compare the impacts of the different types of disasters to the housing market across the different locations around the US. To overcome these two difficulties in measurement, we use the methods from the Cortes and Strahan (2017) for the cross-regional comparison of the impacts of the natural disasters. At the same time, we use the methods from the Gete and Reher (2018) for the cross regional comparison for the housing rents, housing prices and other local housing market variables. Below we will introduce you these two relevant studies and also others relevant studies in detail.

First, we study the natural disaster's impact on the expanding gulf between the housing rents and housing prices. There are large group of literature on the housing prices and natural disasters (Harrison et al. 2001, Bin and Polasky 2004, Hallstrom and Smith 2005, Morgan 2007, Bin et al. 2008, Daniel et al. 2009, Bin and Landry 2013 and Boustan et al. 2017). Almost all of them focus only on the housing prices of individual properties on one county or region. These studies use the hedonic price model to evaluate the negative impact of the natural disasters on the individual housing values. Among these studies, Harrison et al. (2001) compare the housing prices between two groups of households in Alachua County Florida: one group is within the areas with high natural disasters risk (flood zones) and another group is outside. They show that there exist the pricing differences between the areas with low risk and with high risk of the natural disasters. Furthermore, Bin and Polasky (2004) use houses in Pitt County, North Carolina show that these prices difference between high risk areas and low risk areas became larger after the hit of a huge natural disaster. Their results are consistent with the conventional thinkings that the natural disasters are detrimental to the housing values and larger disasters can change households expectations for the housing market.

Here is our difference between previous studies of housing prices and natural disasters on individual property pricing. We push further the topics to study the impacts of the natural disasters on whole local level by comparing housing market variables across 242 MSAs all around United States. Also we study more than just housing prices that we also study housing rents, and more importantly, the growing gap between housing rents and housing prices, which indicates the households perception of risks of natural disasters in holding the units. We will discuss this issue in detail in the theory section below.

Also, our research is similar to the Boustan et al. (2017) that both our studies try to answer how the natural disasters influence the real estate on the market level by comparing the different locations. To answer this question, both our studies need to find a common proxy of the natural disasters to compare the intensity of the different disaster across different locations. Boustan et al. (2017) use the American Red Cross and the Federal Emergency Management Agency datasets to identify the large natural disasters by using the number of causalities to proxy the impact of the natural disasters. Their results show that the even severe disaster has little impact to the change of the housing rents and housing prices and only the super-severe disasters with more than 10 deaths can lead to the drop of both the housing rents and housing prices. In our studies, we capture all sized disasters and intensity from the StormEvent Database, which including the different types of disasters and their property damage. We use the summation of all property damages of the natural disasters within one year in one MSA to evaluate the damage of the natural disasters. The property damage is the intermediary for our study to compare the intensity of the different types of natural disasters across different regions and years. Also, Boustan et al. (2017) study the housing prices and rents change for every 10 years limited by its dataset. We study the annual changes of the housing prices, housing rents and distance between rents and prices, so we have more fine and detailed reactions of the housing market to the impacts of the natural disasters.

Second, our study is related to the literature of credit reactions and housing market. Gete and Reher (2018) show that at the MSA level, tighter credit standards have increased demand for rental housing, leading to higher rents. Especially, Cortes and Strahan (2017), Wix and Schuwer (2016), Lambert et al. (2015), Morse (2011) have proven that the natural disasters can have significant impact on the households credit demand. Among them, Cortes and Strahan (2017) study how financially integrated banks respond to natural disasters from the supply side. Our research focuses on the demand side of the mortgage market that how the households' mortgage demand reacts to the natural disasters. For the cross disasters comparison, they use property damage data from the SHELDUS and only keep the large disasters with state of emergency declaration to the FEMA because the banks react more to the huge disasters. Our dataset StormEvent is the primary sources for the SHELDUS dataset. So, the measurement of the intensity of natural disasters of our study and Cortes and Strahan (2017) have some similarities. Also, Beraja et al. (2017) show that the regional risk can be reflected in the mortgage rate of the local credit market. In our study, we want to see whether, after the shocks of the natural disasters, the households will react by reducing their home purchase mortgages and turning to the rental market to avoid the future disasters.

Third, by using broader data, our study adds insights to previous literature that the households with different wealth backgrounds will react to the shocks differently. Especially for the shocks of natural disasters, Smith et al. (2006) use the household level data in one location Dade County, Florida to show that the households with different react differently after the hit of the hurricane Katrina. Low-income household react by moving into low-rent housing in the affected areas and mid-income households move out of the area to avoid the risk. However, the wealthy households are insensitive to the shock and they remain the same of their housing choices as post-disaster. The single area household level results from Smith et al. (2006) are consistent with our nation-level results that the low and mid income households react more to the natural disasters and the wealthy households are resistant to the shocks. In their research, they also raise the question about generalization of their one county results to all markets in US. Our research answers their questions and study reaction of different wealth level households after natural disasters in different markets by controlling for local economic and demographic characteristics.

In addition, D'Acunto and Rossi (2017) discovery that the increased cost of the financial regulation around 2011 tends to have redistribution effects through the mortgage market. The wealthy households tend to get more housing mortgage, mid-income households tend to get less mortgage, and the low-income households are unaffected. Here, we find the appealing similarities of the households reactions after the shocks of the natural disasters. The low-income households tend to decrease their applications of the mortgage slightly and mid-income households will decrease their applications most. More interesting, high-income households go against the tide and increase their mortgage applications. In this way, although we are taking from the different perspectives, our findings are consistent with Smith et al. (2006) and D'Acunto and Rossi (2017) that low and mid-income are among the most sensitive groups to the negative external shocks or changes. While, the wealthy group are resistant to the negative shocks or changes, and sometimes can even benefit from them.

3.3 Theory

In this section, we explain how the natural disasters have impacts on the housing market through the tenure conversion channel. This channel is derived from the risk of housing damage during natural disasters. The owner of the housing will take more responsibility for the damage after the natural disasters.

Households are heterogeneous in wealth. As implied by standard portfolio theory, low wealth households have lower willingness to take risks. In housing and mortgage markets, this translates into less willingness to own housing in the areas exposed to natural disaster risk. Thus, as a consequence, we expect that natural disasters should cause households to move from the ownership to the rental market. Rents should increase and mortgage applications should fall for the loans associated with low-mid wealth households. Lower demand for ownership but higher rents make unclear what happens to prices. However, the gap between housing rents and housing prices should increase. Finally, we do not expect changes in denial rates. High income households, instead, have high willingness to take risks, meaning they are more resistant to the risk of natural disasters. In addition, the high income households also tend to seize opportunities of increased rent growth after natural disasters, which explains their increased applications for housing mortgages after the natural disasters.

Next, we describe our dataset and test the predictions described above.

3.4 Data

Currently, we use property damage of all the relevant disasters as our benchmark measure of the disaster impacts. Our data of the natural disasters is from the StormEvent compiled by NOAA's National Weather Service (NWS). This dataset has detailed impacts of the natural disasters such as property damage, crop damage, the intensity of each disaster and also the location information. We choose 25 disasters with the significant influence and damage to the real estates out of all 51 types of the natural disasters from the StormEvent dataset. The 25 types of the disasters account for around 98% all the property damage of all 51 types of the natural disasters[1].

The advantage of using the property damage as the proxy of the intensity for natural disasters is the convenience to compare different disasters. The property damage can let us compare the between the different kinds of disasters in different places. For example, we can compare the wildfire in California and the hurricane in Florida. It

[1]All our results are robust when we include all 51 types of the natural disasters.

helps us to disentangle the impact of the damage of the different disasters in the across different regions. Table 3.1 report the disasters properties damage in millions dollar

Table 3.1. Natural Disasters, 2010 to 2014

Disaster Type	Aggregate property damage	# Events (MSA level)
Coastal Flood	21,112	135
Tornado	16,734	2,237
Flood	11,199	2,588
Hail	8,926	2,398
Flash Flood	6,003	4,213
High Wind	4,324	1,541
Wildfire	3,052	544
Thunderstorm Wind	1,762	19,017
Storm Surge/Tide	797	41
Winter Storm	587	694
Tropical Storm	279	145
Blizzard	248	121
Hurricane	235	18
Lightning	219	2,174
Ice Storm	192	185
Heavy Snow	145	246
Strong Wind	82	2,383
Debris Flow	71	64
Tsunami	58	8
Landslide	41	46
Heavy Rain	26	280
Dust Storm	6	43
Avalanche	0.6	11
Dust Devil	0.5	39
Total	76,097	39,171

This table summarizes the natural disasters in the database. The sample covers 2010 to 2014. Aggregate property damage is in millions of US dollars.

value and total counts of the afflicted events at county and MSA levels within that year. We rank them by total property damage in the first column. The second column is the number of the events at the MSAs level. One thing comes to our attention is the damage of the flood related disasters. The flood related disasters such as coastal flood, flood, flash flood, storm surge and hurricane are among the top of the damage lists. For the coastal flood along, the property damage in our dataset is more than \$ 21 billion. This is consistent with the fact that the government sponsored National Flood Insurance Program (NFIP) has began to lost money, and in the last fifteen years, it lost a lot (McMillan 2007). For example, in 2013 the NFIP was technically insolvent and had \$24 billion in debt (Newman 2013). The second thing comes to our attention is that besides the flood related disasters, there are different types of the disasters contribute to the damage such as tornado (around \$17 billions), hail (around \$9 billions), wildfire (\$3 billions) and etc. When we analyze the impacts of the natural disasters on the housing market and household reactions, we want to include all impacts of the various natural disasters. So, we use the reported property damage as a proxy to evaluate the impact of the naturals disasters in each MSA. Here, we use the logarithm of the damage of the natural disasters in each MSA $Disasters\,Damage_{i,t+1-k}$ to measure annual impact of the natural disasters. Table 3.2 reports the statistics of the variables using for this research. We totally have 242 MSAs for 5 years panel from 2010 to 2014. We divide them into four sections. The section a) of the Table 3.2 is the logarithm of the natural disasters, which we mentioned in the last paragraph. The section b) of the Table 3.2 are real estate variables, they include the growth rates of the rent-to-price ratio, the housing rents, housing prices, number of the housing units and number of the owner-occupied units. The section c) of the Table 3.2 includes the credit variables including growth rates of the number of mortgage applications, the number of mortgage originations, the number of the mortgage denials. We also includes these growth rates for the jumbo loans and conforming loans respectively for the analysis of the credit reactions for households with different wealth levels. The section d) includes our MSA level control variables, which we include the growth rates

Table 3.2. Data Description, 2010 to 2014

Variable	N	MSAs	Mean	SD	P25	Median	P75	Min	Max
a. Natural Disasters									
Disasters Damage	1079	242	13.359	2.586	11.695	13.313	14.958	6.215	21.826
b. Real Estate Variables									
$\Delta log(Rent/Price)$	1079	242	0.023	0.081	-0.023	0.023	0.072	-0.283	0.588
$\Delta log(Rent)$	1079	242	0.025	0.060	-0.003	0.027	0.054	-0.292	0.570
$\Delta log(Price)$	1079	242	0.001	0.060	-0.035	0.000	0.035	-0.259	0.280
$\Delta log(Owner\_Occ\_Units)$	1079	242	0.022	0.078	0.000	0.000	0.005	-0.552	1.301
$\Delta log(Units)$	1079	242	0.027	0.087	-0.001	0.000	0.015	-0.556	1.433
c. Credit Variables									
$\Delta log(Applications)$	1079	242	0.050	0.139	-0.047	0.040	0.145	-0.621	1.610
$\Delta log(Originations)$	1079	242	0.054	0.145	-0.044	0.045	0.150	-0.570	1.596
$\Delta log(Denials)$	1079	242	-0.020	0.150	-0.104	-0.020	0.061	-0.986	0.592
$\Delta log(Applications\_Conforming)$	1079	242	0.047	0.139	-0.050	0.036	0.143	-0.629	1.586
$\Delta log(Originations\_Conforming)$	1079	242	0.051	0.145	-0.048	0.042	0.148	-0.582	1.577
$\Delta log(Denials\_Conforming)$	1079	242	-0.021	0.150	-0.101	-0.021	0.067	-0.989	0.594
$\Delta log(Applications\_Jumbo)$	1033	241	0.213	0.502	0.000	0.223	0.457	-1.946	2.944
$\Delta log(Originations\_Jumbo)$	1004	239	0.231	0.509	0.000	0.251	0.483	-1.946	2.552
$\Delta log(Denials\_Jumbo)$	729	194	-0.040	0.610	-0.368	-0.055	0.293	-2.327	1.974
d. MSA Controls									
$\Delta log(Income)$	1079	242	0.010	0.034	0.000	0.013	0.026	-0.148	0.141
$\Delta log(Population)$	1079	242	0.020	0.062	-0.002	0.000	0.010	-0.147	0.435
$\Delta log(Uemployment)$	1079	242	0.005	0.023	-0.011	0.001	0.019	-0.065	0.088
$\Delta log(Age)$	1079	242	0.005	0.022	-0.003	0.005	0.013	-0.117	0.170
$Units\_Per\_Person$	1079	242	0.365	0.049	0.342	0.365	0.383	0.242	0.887
$log(Income)$	1079	242	11.022	0.145	10.917	11.020	11.118	10.527	11.469
$log(Population)$	1079	242	12.758	0.976	11.926	12.629	13.392	10.961	15.580
Denial Because DTI	1079	242	0.0011	0.001	0.0004	0.0007	0.0014	0	0.0088
Denial Because Employment	1079	242	0.0002	0.0003	0	0.0001	0.0002	0	0.0034
Denial Because Credit	1079	242	0.0016	0.0015	0.0006	0.0011	0.002	0	0.0134
Denial Because Collateral	1079	242	0.1146	0.0341	0.0903	0.1126	0.1342	0.0339	0.4256
$Big4Share_{2008}$	1079	242	0.154	0.103	0.076	0.140	0.217	0.001	0.579
$Big4Branch_{2008}$	1079	242	0.185	0.182	0.059	0.142	0.235	0.000	0.875

This table presents summary statistics of the key variables in our sample. All variables are at the MSA level. *Disasters Damage* is the logarithmic dollar value of the property damage caused by the natural disasters. $\Delta log(Rent/Price)$, $\Delta log(Rent)$ and $\Delta log(Price)$ denote growth rates of the rent-to-price ratio, rent and housing price. based on HMDA data. $Big4Share_{2008}$ and $Big4Branch_{2008}$ are, respectively the branch deposit share of the Big-4 banks in 2008 and the branch numbers share of the Big-4 banks. Wages are the median hourly wage in the MSA. Age and Income refer to the median in the MSA. All the variables are from 2010 to 2014. The *Disasters Damage* and MSA controls are one period lag variables, so they are from 2009 to 2013. The Data Appendix has more details.

of the MSA median income, the MSA population, MSA median age. We also include the lagged level of the ratio of units per person, logarithm of income, logarithm of population, denial rate because of the DTI, denial rate because of the employment, denial rate because of credit score, denial rate because of the collateral. In addition, we also include the market share of big-4 banks in term of the deposits and bank branches in 2008, which control for the supply of the mortgage market locally.

3.5 Aggregate Effects

3.5.1 Housing Prices and Rents

To see how the natural disasters influence the real estate, we first use an econometric model with the current year plus five previous years natural property damage on the right-hand side. In this way, we want to see how natural disasters change the rent cost over time.

$$\Delta log(Y_{i,t}) = \beta_0 + \sum_{k=1}^{6} \beta_k Disasters\,Damage_{i,t+1-k} + \\ + \eta_i + \eta_t + \mu_{i,t}, \tag{3.1}$$

where i denotes the MSA and t denotes the year. The dependent variables $Y_{i,t}$ are $\Delta log(Rent/Price_{i,t})$, $\Delta log(Rent_{i,t})$ and $\Delta log(Price_{i,t})$. $\Delta log(Rent_{i,t})$ is the growth of the Zillow rent index. $\Delta log(Price_{i,t})$ is the growth of the Zillow price index. $\Delta log(Rent/Price_{i,t})$ the growth of the rent to price ratio from the Zillow. Our measurement of the disaster is $Disasters\,Damage_{i,t-1}$ which is the logarithmic dollar value of the property damage caused by the natural disasters. η_i and η_t are the MSA fixed effects and year fixed effects.

Figure 3.1 plots the coefficient of the β_t which denotes the impact of natural disasters at the current period and previous period. $t = 0$ is the year of the damage

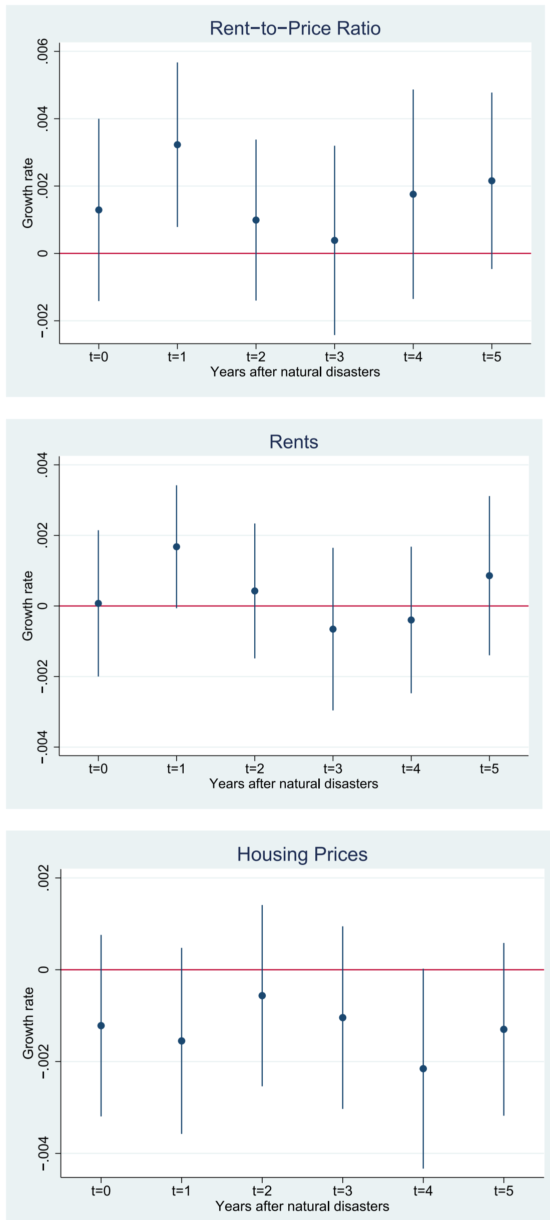

Figure 3.1. Growth Rate of Rent-to-price, Housing Rents and Housing Prices After the Natural Disasters.

This figure plots the coefficients of the disaster damage (β_1) of the equation (3.1) to the growth rates of the rent-to-price ratio, housing rents and housing prices as the dependent variables respectively. The vertical bars are the 95% confidence interval of the coefficients. $t = 0$ is the year the damage of the natural disasters occur.

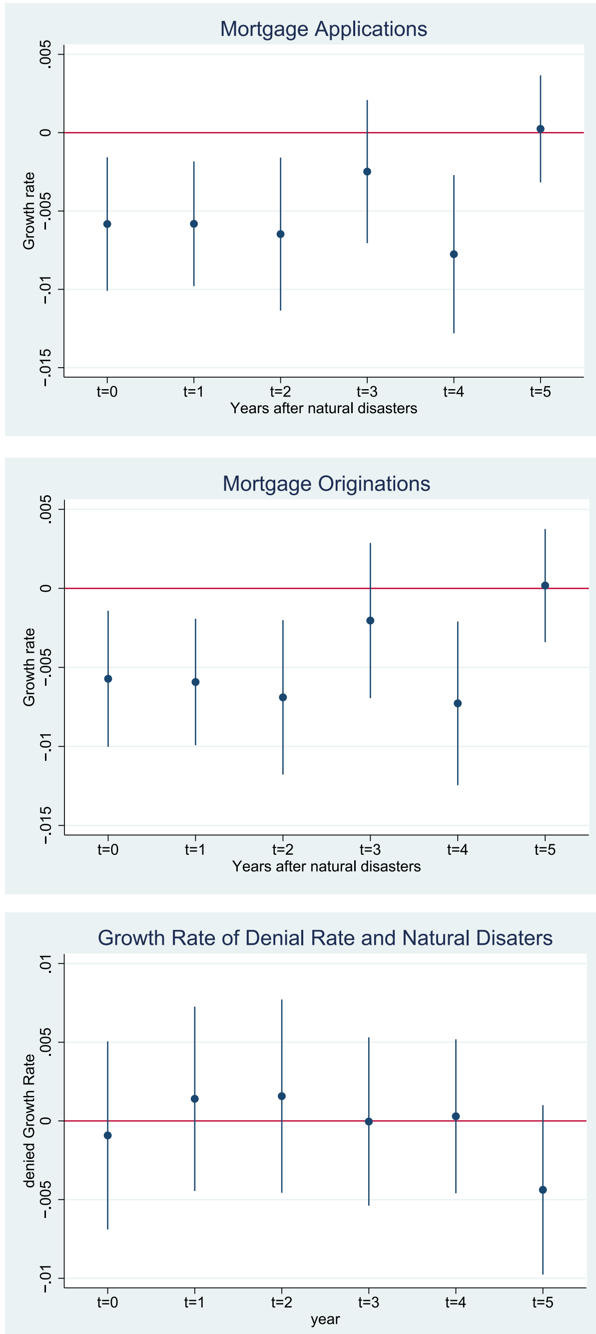

Figure 3.2. The Growth of the Loan Applications, Originations and Denials After the Natural Disasters.
This figure plots the coefficients of the disaster damage (β_1) of the equation (3.1) to the growth rates of the mortgage applications, originations and denials as the dependent variables respectively. The vertical bars are the 95% confidence interval of the coefficients.

incurred. We can see that the impact of natural disaster at current year does not have significant influence to the rent-to-price ratio. It needs time for the housing market and household to react to shock. The looks the impact to the next year ($t = 1$), we see that the natural disasters contribute to significant rent-to-price growth. More interesting is that this growth seems permanent that we do not see significant return of the rent-to-price in the future ($t = 2+$) and significant drop. In other words, the impact of the natural disasters on the rent-to-price is permanent. It indicates that the evidence is more inclined to say that the natural disasters change household preference toward to the housing rent market instead of just short period housing destruction or mis-allocations. In the sections below, we will dissect the reasons why how the natural disasters fuel up the growth of the gap between housing rents and housing prices.

Here we show how the natural disaster's damage will push up the rent cost. It follows our theory that the natural disasters change the taste of the household between the purchase and rent. For the MSA level rent dynamics, we follow the specification from the [41]. For the impact of the natural disaster on the rent, price and rent-to-price ratio, we have the models below:

$$\Delta log(Rent/Price_{i,t}) = \beta_0 + \beta_1 Disasters\,Damage_{i,t-1} + \gamma\,Control_{i,t-1} + \eta_i + \eta_t + \mu_{i,t}, \tag{3.2}$$

$$\Delta log(Rent_{i,t}) = \beta_0 + \beta_1 Disasters\,Damage_{i,t-1} + \gamma\,Control_{i,t-1} + \eta_i + \eta_t + \mu_{i,t}, \tag{3.3}$$

$$\Delta log(Price_{i,t}) = \beta_0 + \beta_1 Disasters\,Damage_{i,t-1} + \gamma\,Control_{i,t-1} + \eta_i + \eta_t + \mu_{i,t}, \tag{3.4}$$

where i denotes the MSA and t denotes the year. $\Delta log(Rent_{i,t})$ is the log change of the Zillow rent index. $\Delta log(Price_{i,t})$ is the log change of the Zillow price index. $\Delta log(Rent/Price_{i,t})$ the log change of the rent to price ratio from the Zillow.

$Control_{i,t-1}$ is the MSA controls such as growth and level of: the MSA average income, unemployment rate, population growth and etc.

Table 3.3. Rent-to-Price Ratio, Rents and Housing Prices

Δlog in	Rent-to-Price		Rents		Prices	
	(1)	(2)	(3)	(4)	(5)	(6)
Disasters Damage$_{i,t-1}$	0.00288***	0.00368***	0.00238***	0.00252***	-0.000498	-0.00115
	(0.003)	(0.001)	(0.002)	(0.005)	(0.470)	(0.138)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.275	0.265	0.081	0.039	0.475	0.493
Observations	1079	1079	1079	1079	1079	1079

The dependent variables Δlog(Rent-to-Price), $\Delta log(Rents)$ and $\Delta log(Prices)$ are respectively, the growth rates of the rent-to-price ratio, rents and housing prices. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

Column (1) and (2) of Table 3.3 report the results of equation (3.3) shows the impact of the natural disaster's damage on the rent-to-price ratio. We want to see how the natural disasters widen the gap between the rent and housing value. The column (1) is the estimation without the MSA fixed effects. We can see the coefficient $Disasters\,Damage_{i,t-1}$ (β_1) reached 0.00288 with the significance level of 1%. The average growth of the rent-to-price ratio is 0.023. So, one standard deviation impact of the natural disasters will lead to additional 0.0071 to the rent-price ratio and it can contribute to around 31% of overall annual rent-to-price growth. In the column (4), we add the MSA fixed effects to the estimation. The idea is to see the how the disaster damage above MSA average level has impacts on the rent growth. For example, we want to whether an unexpected large scale natural disaster has impact on the rent growth. The coefficient of $Disasters\,Damage_{i,t-1}$ (β_1) is 0.00368 and also significant at 1% level, which implies that one standard deviation of the damage can contribute to 34% of the overall annual rent-to-price ratio growth. So, for both specifications, the impact of natural disasters' to the gap between rents and housing prices are significant and huge.

Column (3) and (4) of Table 3.3 report the results of equation (3.3) shows the impact of the natural disaster's damage on rent cost. Column (3) estimates the impact of natural disaster to growth of the rent without the MSA fixed effects. The coefficient of the previous year disasters property damage $Disasters\, Damage_{i,t-1}$ (β_1) is 0.00238 and significant at 1% level. So, one standard deviation change of the damage can lead to 0.0063 increase to the rent growth. Considering the average of the rent growth is 0.025, the one standard deviation of the damage (2.53) can contribute to 25% of the overall annual rent growth. The coefficient of $Disasters\, Damage_{i,t-1}$ (β_1) is 0.00252 and also significant at 1% level, which implies that one standard deviation of the damage can contribute to 26% of the overall annual rent growth.

Column (5) and (6) of Table 3.3 reports the results of equation (3.4) and shows the impact of the natural disasters damage on housing price. From the coefficient $Disasters\, Damage_{i,t-1}$ (β_1) both specification, we can see the natural disasters have overall negative impacts on the housing value. However, none of the these specifications are significant. So, for each MSA, the natural disasters do not have clear pattern of its housing value.

In this section, we can clearly see that the natural disasters have magnificent and significant impacts to the growth of both the rent and the gap between the rent and the housing value. It is enough evidence to show that the natural disasters shift the household portfolio choices from purchasing the houses towards renting the houses. However, for the housing value, although we cannot see clear patterns. Here comes the question. The traditional story tells us that the housing value is equivalent to the future cash flow of the rents. How can we see the increase of the rent but not the value of housing. To solve this puzzle, we need to turn to demand and supply of the housing market in the section 3.5.3.

3.5.2 Housing Supply and Homeownership

To see the decrease of the housing supply, we focus on the growth rate of the housing units in each MSA.

$$\Delta log(Units_{i,t}) = \beta_0 + \beta_1 Disasters\, Damage_{i,t-1} + \gamma\, Control_{i,t-1} + \eta_i + \eta_t + \mu_{i,t}, \tag{3.5}$$

where the $\Delta log(Units_{i,t})$ the growth rate of housing units in MSA i and in year t. Other elements are defined same as above. Column (1) and (2) of Table 3.4 report the

Table 3.4. Housing Units and Owner-Occupied Units

Δlog in	Units		Owner Occ Units	
	(1)	(2)	(3)	(4)
Disasters Damage$_{i,t-1}$	-0.000767	-0.00153**	-0.000759	-0.00157**
	(0.309)	(0.039)	(0.335)	(0.044)
MSA Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes
R^2	0.369	0.365	0.435	0.447
Observations	1079	1079	1079	1079

The dependent variable $\Delta log(Applications)$, $\Delta log(Originations)$ and $\Delta log(Denials)$ are respectively, the growth rates of the number of mortgages applications, number of mortgages originations and number mortgage denials at the MSA level. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

results of the equation 3.5 for the growth rate of all housing units in each MSA. We turn to β_1 for the impact of the natural disasters. columns (1) is without the MSA fixed effect and columns (2) is with the MSA fixed effects. Both columns (1) and (2) indicates a drop in the growth rate of the units from the natural disaster's damage. Especially, β_1 of the column (2) is -0.0016 and significant at 5% level. So, on average, it is equivalent to around 15% drop to average the growth rate of the housing units after one standard deviation natural disaster's damage.

From above and section 3.5.2, we can observe shrinkage the housing purchases market from both demand and supply sides. So, what is the equilibrium results of the natural disasters on the housing purchase market, which can provide us the evidence that there is a household preference shift from the house purchasing to house renting. Here, we turn to the homeownership.

$$\Delta log(Occ\_Units_{i,t}) = \beta_0 + \beta_1 Disasters\, Damage_{i,t-1} + \gamma\, Control_{i,t-1} + \eta_i + \eta_t + \mu_{i,t}, \tag{3.6}$$

where the $\Delta log(Occ\_Units_{i,t})$ the growth rate of owner-occupied units in MSA i and in year t. Other elements are defined same as above.

Column (3) and (4) of Table 3.4 report the results of the equation 3.6 for the growth rate of all owner-occupied units in each MSA. Column (3) is without the MSA fixed effect and column (4) is with the MSA fixed effects. Both column (3) and (4) indicate a drop in the growth rate of the owner-occupied units from the natural disaster's damage. Among them, the β_1 is -0.00166 and significant at 5% level. Based on the estimation of the envelope method, it is equivalent to around 19% drop to the average growth rate of the housing units after one standard deviation natural disasters damage.

In this way, we have shown that both the supply and demand of the housing purchase market drop and it leads to drop of the equilibrium results. The ownership of the housing also drops.

3.5.3 Mortgage Market

In this part, we show both demand and supply of the house purchase drop after the natural disaster damage. They are the reason why we can see the shrinkage of the house purchase, but we cannot see the significant change of the housing prices. The demand drop of the houses can be reflected from the loan applications, loan originations.

$$\Delta log(Application_{i,t}) = \beta_0 + \beta_1 Disasters\,Damage_{i,t-1} + \gamma\,Control_{i,t-1} + \eta_i + \eta_t + \mu_{i,t}, \tag{3.7}$$

$$\Delta log(Origination_{i,t}) = \beta_0 + \beta_1 Disasters\,Damage_{i,t-1} + \gamma\,Control_{i,t-1} + \eta_i + \eta_t + \mu_{i,t}, \tag{3.8}$$

$$\Delta log(Denials_{i,t}) = \beta_0 + \beta_1 Disasters\,Damage_{i,t-1} + \gamma\,Control_{i,t-1} + \eta_i + \eta_t + \mu_{i,t}, \tag{3.9}$$

where i denotes the MSA and t denotes the year. $\Delta log(Application_{i,t})$ is the growth rate of the number of the mortgage applications. $\Delta log(Origination_{i,t})$ is the growth rate of the number of the mortgage originations. $\Delta log(Denials_{i,t})$ is the growth rate of number of the denied mortgage. Others variables: disaster damage, MSA level controls and fixed effects are defined same as before. Table 3.5 reports the results for the equations (3.7), (3.8) and (3.9). All these three models describe the house purchase loan market which indicates the demand of the house purchase market. Column (1) and (2) of Table 3.5 reports the growth of the housing loan application after the natural disasters. Column (1) is the specification with the MSA fixed effects. The coefficient of the $Disasters\,Damage_{i,t-1}$ (β_1) is -0.0036, which is significant at 1% level. One standard deviation of the property damage will change -0.0091 to the growth of application. This value account for around 19% drop in the housing loan

Table 3.5. Mortgages Applications, Originations and Denials

Δlog in	Applications		Originations		Denials	
	(1)	(2)	(3)	(4)	(5)	(6)
Disasters Damage$_{i,t-1}$	-0.00332***	-0.00401***	-0.00311**	-0.00340**	-0.00285	-0.00307
	(0.006)	(0.008)	(0.021)	(0.042)	(0.199)	(0.287)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.442	0.422	0.415	0.392	0.285	0.261
Observations	1079	1079	1079	1079	1079	1079

The dependent variable $\Delta log(Applications)$, $\Delta log(Originations)$ and $\Delta log(Denials)$ are respectively, the growth rates of the number of mortgages applications, number of mortgages originations and number mortgage denials at the MSA level. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

application. In the column (2), we add the MSA fixed effects and confirm our result. β_1 is -0.004. It indicates that one standard deviation of the natural disaster damage can account for around 21% drop of the loan application growth rate.

Column (3) and (4) of Table 3.5 reports the growth of housing loan originations after the natural disasters. Column (3) is without MSA fixed effects and column (4) is with the MSA fixed effects. The β_1 for the column (3) is -0.00266 and column (4) is -0.00387, both of them are significant at 5% level. Using the envelop method like before, there will be around 13% to 18% drop of the average growth of origination in the MSA with one more standard deviation damage.

Column (5) and (6) of Table 3.5 reports the growth of housing loan denials after the natural disasters. Column (5) is without MSA fixed effects and column (6) is with the MSA fixed effects, where we can see that the natural disasters do not have significant impact to the loan denials.

So, the natural disasters have significant negative effect to the loan applications and originations.

3.6 Results Across Household Groups

The household credit reactions are different depending on their wealth level (D'Acunto and Rossi 2017). Especially, Smith et al. (2006) observes the low-wealth level household are more sensitive to the shock of the hurricane Katrina in Dade County Florida. They also see that the top-wealth group is most insensitive to the shock.

Here, we follow the way of D'Acunto and Rossi (2017) to indicate the credit reactions for the different wealth level households. Our benchmark for the large loan is the jumbo loan. A jumbo mortgage is a large-size home loan weighing in at a dollar amount above the conforming loan limits. The conforming loan limits are different across the counties. [2] We count the number of the conforming loans and jumbo loan in each MSA to see their reactions to the natural disasters respectively. Our conjecture is that the conforming loan borrowed mostly by the middle-to-low wealth families will react more than the jumbo loan borrowed mostly by the high income families. The reason is that the middle-to-low income families are more risk averse than the high wealth families, which are more resistant to the loss and diversified in their investments.

3.6.1 Conforming Loans

First we look to the reactions of the conforming loans. We will revisit the growth of the loan applications, loan originations and loan volume for the conforming loans only

[2] For most of the counties, the limits are defined as $424,100.

by using the equations 3.7, 3.8 and 3.9. The $\Delta log(Application\_Conforming_{i,t})$, $\Delta log(Origination\_Conforming_{i,t})$ and $\Delta log(Denials\_Conforming_{i,t})$ are the growth rates of the loan applications, loan originations and loan denials for the conforming loans in this section and other variables are defined same as before.

Figure 3.6 panel (a) reports the estimation of the conforming loan for the equations 3.7, 3.8 and 3.9. The columns (1) and (2) are for the growth rate of the applications without and with the MSA fixed effects. The coefficients of the $Disasters\,Damage_{i,t-1}$ (β_1) are -0.0037 and -0.0041 for two specifications. Both of them has the 1% significance level. By using the envelope methods, the one standard deviation of the natural disaster's damage can contribute to around 20% to 23% drop to the average growth rate of the conforming loan applications.

The columns (3) and (4) of Table 3.6 panel (a) are for the growth of the loan originations. The coefficients of the $Disasters\,Damage_{i,t-1}$ (β_1) are -0.0035 and -0.0039 for two specifications with and without MSA fixed effects. They are at the significance levels of 1% and 5% respectively. In this way, one standard deviation of the natural disasters damage can contribute to around 17% to 19% drop to the average growth rate of the conforming loan originations.

The conforming loan mostly purchased by the low-middle-income families are seriously influenced by the natural disasters.

3.6.2 Jumbo Loans

Second we turn to the reactions of the jumbo loans. We revisit the same growth rates of the jumbo loans by using the equations 3.7, 3.8 and 3.9. The $\Delta log(Application\_Jumbo_{i,t})$, $\Delta log(Origination_{i,t}^{Jumbo})$ and $\Delta log(Denial\_Jumbo_{i,t})$ are the growth rates of the jumbo loan applications, loan originations and loan denials in this section and other variables are defined same as before.

Table 3.6. Conforming and Jumbo Mortgages

(a) Conforming Mortgages

Δlog in	Applications		Originations		Denials	
	(1)	(2)	(3)	(4)	(5)	(6)
Disasters Damage$_{i,t-1}$	-0.00340***	-0.00413***	-0.00304**	-0.00381**	-0.00292	-0.00322
	(0.006)	(0.007)	(0.025)	(0.020)	(0.184)	(0.262)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.441	0.421	0.426	0.420	0.290	0.265
Observations	1079	1079	1079	1079	1079	1079

(b) Jumbo Mortgages

Δlog in	Applications		Originations		Denials	
	(1)	(2)	(3)	(4)	(5)	(6)
Disasters Damage$_{i,t-1}$	0.0129**	0.0152*	0.00941	0.0105	-0.00222	-0.00201
	(0.041)	(0.060)	(0.168)	(0.233)	(0.819)	(0.876)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.098	0.082	0.103	0.090	0.043	0.025
Observations	1033	1033	1004	1004	729	729

The dependent variable $\Delta log(Applications)$, $\Delta log(Originations)$ and $\Delta log(Denials)$ are respectively, the growth rates of the number of applications, number of originations and number denials for the conforming mortgages at upper panel and for the jumbo mortgages at the lower panel. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

Table 3.6 panel (b) reports the analysis of the jumbo loans for the equations 3.7, 3.8 and 3.9. Columns (1) and (2) is for the jumbo loan applications growth without and with MSA fixed effects; columns (3) and (4) is for the jumbo loan originations growth without and with the MSA fixed effects; columns (5) and (6) is for the jumbo denials without and with MSA fixed effects. The interesting finding is that, unlike the reactions of the conforming loan reported in panel (b) of Table 3.6, the performances of jumbo loans do not drops after the natural disaster's damage. That the damage coefficient β_1 jumbo loan growth rates of the applications and originations do not have significant negative value. On the contrary, these two values even go up slightly.

Our results for the different wealth groups are consistent with the micro-level household experiment in Smith et al. (2006) that the low-middle wealth families are most influenced by the natural disasters and the high wealth families are less influenced by the natural disasters.

3.6.3 Different Sized Mortgage Groups

Instead using the jumbo loan and conforming loan categorization above, we also use the three loan groups to study the mortgage market reactions for the three different wealth level households: low, middle, high. Following the similar classification from D'Acunto and Rossi (2017[24]), we divide the mortgage into three groups by their sizes. The first group is the loan size smaller than 100 thousand USD, which generally standards for the mortgage for the low wealth households. The second group is the loan size larger than 100 thousand USD but smaller than 417 thousand USD, which generally stands for the loan market for the middle wealth households. The third group is the loan size larger than 417 thousands USD, which generally stands for the wealthy households. We divide our sample into these three groups. We test them on of the loan applications and loan originations in equations (3.7) and (3.8). Table 3.7 reports our results.

The panel (a) reports the percentage change of the loan applications and panel (b) reports the percentage change of the loan originations. On both panels, the column (1) and column (2) for the smallest loan sized group (\$0-100K) with and without MSA fixed effects. The natural disasters slightly decrease the mortgage applications and mortgage originations, however in general the impacts are not significant. Then we look to the column (3) and column (4) for middle sized loan group (\$100K-417K) without and with MSA fixed effects, the impacts the natural disasters are significant to both loan applications and loan originations. They indicate that if there is one standard deviation shock of the property damage from the natural disasters, there will be 0.9% to 1.2% decrease to the loan applications. At the same time, there will be 0.8% to 1.1% decrease to the loan originations. The scale is large, considering the average annual growth rate of the loan applications is only around 5% and the loan originations is only around 5.4%. When we turn to the largest loan sized group (\$417K and above) in the columns (5) and (6) in panel (a), the results show that the both the applications of the large sized loans go againist the trends and even increased after the natural disasters. It indicates that the wealth households not only immune to the shocks of the natural disasters, but also increase their mortgage applications to seize the investment opportunities of the increased housing rents afterwards.

3.7 Sensitivity to Types of Disasters

In our previous benchmark specifications in the section 3.5, we have used the property damage to evaluate the severities and intensities of the natural disasters. Here, we test

Table 3.7. Mortgage Applications and Originations per Loan Size

(a) Mortgage Applications per Loan Size

Δlog in	\$ 0-100k		\$ 100k-417k		\$ 417k+	
	(1)	(2)	(3)	(4)	(5)	(6)
Disasters Damage$_{i,t-1}$	-0.00389*	-0.00295	-0.00341**	-0.00451***	0.0123*	0.0135*
	(0.093)	(0.270)	(0.011)	(0.006)	(0.053)	(0.097)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.235	0.109	0.484	0.482	0.095	0.081
Observations	1079	1079	1079	1079	1033	1033

(b) Mortgage Originations per Loan Size

Δlog in	\$ 0-100k		\$ 100k-417k		\$ 417k+	
	(1)	(2)	(3)	(4)	(5)	(6)
Disasters Damage$_{i,t-1}$	-0.00350	-0.00269	-0.00321**	-0.00438***	0.00821	0.00831
	(0.169)	(0.351)	(0.021)	(0.010)	(0.230)	(0.347)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.221	0.123	0.463	0.469	0.093	0.081
Observations	1079	1079	1079	1079	1005	1005

The dependent variables $\Delta log(Applications)$ and $\Delta log(Originations)$ are the growth rates of the number of mortgage applications and originations for the three loan size groups from 0 to \$100 thousands, from \$100 thousand to \$417 thousand, above \$417 thousand. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

the impacts of the fatal disasters, flooding related disasters, frequency of the disasters and locations of the disasters.

3.7.1 Fatal Disasters

When we analyze the impacts from the natural disasters. One of the questions is that how do households perceive the risk of the natural disasters? Instead of using dollar value properties damage, the households also will pay attention to the life-threatening disasters which bring casualties (Boustan et al. 2017). So, we also test whether the disasters with serious casualties can increase the gap between the housing rents and housing prices. So, here we use indicator $Fatal\,Disaster_{i,t-1}$ (β_1) to show the whether the locations has at least one fatal disaster with multiple direct deaths to proxy the risk of the natural disasters. Based on the equations 3.2, 3.3 and 3.4, we use $Fatal\,Disaster_{i,t-1}$ to substitute the $Disasters\,Damage_{i,t-1}$.

The columns (1) and (2) of the Table 3.8 shows the percentage change of the rent-to-price ratio after an hit of the fatal disaster at the previous year. Column (1) is without the MSA fixed effects and column (2) is with the MSA fixed effects. Both specifications show that if there is an fatal disaster in the previous year the rent-to-price ratio will goes up around 2.4%. The column (3) and column (4) are the percentage change of the rents with and without the MSA fixed effect. The fatal disasters still have positive effect on the growth of the rents, however the growth of the rents is not as significant as the impact of all natural disasters. However, the fatal disasters impacts to the housing prices are more significant. column (5) without MSA fixed effects and column (6) with MSA fixed effects show that the percentage change of the housing prices are significant. The specification with MSA fixed effects (column (6)) indicates that the fatal disasters tend to whittle down the prices of the locations by 1.5%.

Table 3.8. Fatal Disasters

Δlog in	Rent-to-Price		Rents		Prices	
	(1)	(2)	(3)	(4)	(5)	(6)
Fatal Disaster$_{i,t-1}$	0.0234***	0.0230**	0.0134*	0.00856	-0.00991*	-0.0145**
	(0.003)	(0.011)	(0.069)	(0.261)	(0.062)	(0.011)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.272	0.260	0.076	0.033	0.476	0.494
Observations	1079	1079	1079	1079	1079	1079

The dependent variable Δlog(Rent-to-Price), $\Delta log(Rents)$ and $\Delta log(Prices)$ are respectively, the growth rates of the rent-to-price ratio, rents and housing prices. The $Fatal\, Disaster_{i,t-1}$ is an indicator to show whether there is at least one fatal disaster with more than 2 deaths in the previous year. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

The impacts of the fatal disasters has similar effects of increasing the gap between the housing rents and housing prices as our results in section 3.5. However, the fatal disasters is more significant in bringing down the housing prices. It is consistent with the facts that people are risk averse to the risks endangering their lives.

3.7.2 Frequencies of the Disasters

Our specifications of the property damage in section 3.5 evaluated the intensity of the natural disasters. Here we want to show whether the frequency of the natural disasters matters. We change the $Disasters\, Damage_{i,t-1}$ of equations 3.2, 3.3 and 3.4 to two indicators of the frequencies of large disasters and the frequency fo the small disasters. $High\, Freq\, Large_{i,t-1}$ (β_1) is the indicator to show that whether the frequency of large disasters (damage $>$ 100 thousand USD) is above the median frequency of the sample. $High\, Freq\, Small_{i,t-1}$ (β_2) is the indicator to show that whether the frequency of small sized disasters (damage is between 1 thousand to 100 thousand USD) is above the median frequency of the sample.

Table 3.9 reports the results of the impacts of the frequency of the natural disasters on the gap between housing rents and housing rents. Column (1) and Column (2) are for the rent-to-price ratio without and with MSA fixed effects respectively. The $High\, Freq\, Large_{i,t-1}$ is significant at 1% for both specifications and the $High\, Freq\, Small_{i,t-1}$ does not show significant impacts to the change of the rent-to-price ratio. If a location has high frequency of the large disasters, the places tend to have 1.5% to 1.8% higher rent-to-price ratio in the subsequent year. The percentage changes of the housing rents (column (3) and column(4)) are also significant to the $High\, Freq\, Large_{i,t-1}$. One thing to be noted is that from the column (5) and column(6), there will be significant drop of the housing prices after the place endures a high frequency of the large disasters. On contrast, the impacts of frequency of small

Table 3.9. Frequency of the Disasters

Δlog in	Rent-to-Price		Rents		Prices	
	(1)	(2)	(3)	(4)	(5)	(6)
High Freq Large$_{i,t-1}$	0.0151***	0.0183***	0.00886**	0.00986**	-0.00624*	-0.00840**
	(0.004)	(0.001)	(0.031)	(0.041)	(0.083)	(0.028)
High Freq Small$_{i,t-1}$	-0.00372	-0.00347	-0.000902	-0.00141	0.00282	0.00206
	(0.517)	(0.666)	(0.844)	(0.837)	(0.399)	(0.648)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.275	0.265	0.077	0.036	0.477	0.495
Observations	1079	1079	1079	1079	1079	1079

The dependent variable Δlog(Rent-to-Price), $\Delta log(Rents)$ and $\Delta log(Prices)$ are respectively, the growth rates of the rent-to-price ratio, rents and housing prices. High Freq Large$_{i,t-1}$ is the indicator to show that whether the frequency of large disasters (damage > 100 thousand USD) is above the MSA median frequency. High Freq Normal$_{i,t-1}$ is the indicator to show that whether the frequency of small sized disasters (damage is between 1 thousand to 100 thousand USD) is above the MSA median frequency. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

disasters ($High\,Freq\,Small_{i,t-1}$) are not significant for columns from (1) to (6) for rent-to-price ratio, housing rents and housing prices.

About the impacts to gap between housing rents and housing prices, our results indicate the frequency of the large sized disasters plays a more important role than the frequency of the small sized disasters.

3.7.3 Flooding Related Disasters

In this section, we show that the flooding related disasters have more significant impacts to the growth of the rent-to-price ratio than other types of the disasters. Why we are interested in the disasters related to the flooding? Because, the common houses insurance does not cover the damage from the floods and they need to purchase extra flood insurance to cover the damage of the floods. It makes the households get exposed to more risk or costs.

Here we focus on the types of the disasters which can incur flooding. Our types of the flood related disasters include coastal flood, flood, flash flood, thunderstorm wind, storm surge/tide, hurricane, winter storm, tropical storm, debris flow, tsunami and heavy rain. We classify other types of the natural disasters as non-flooding related. The $Flood\,Disasters\,Damage_{i,t-1}$ is logarithm of the property damage from the disasters related to the floods[3]. The $Other\,Disasters\,Damage_{i,t-1}$ is logarithm of the property damage from the disasters not related to the floods. We use these two variables to substitute the $Disasters\,Damage_{i,t-1}$ in equations (3.2), (3.3) and (3.4) and have the results below in Table 3.10. Table (3.10) shows the differences between the impacts of the flooding related natural disasters and other types of natural disasters. The $Flooding\,Damage_{i,t-1}$ has more significant impacts than the

[3]The property damage of the flood related in some places some year is 0, so here we use the add number 1 to the property damage.

Table 3.10. Flooding Related Disasters

Δlog in	Rent-to-Price		Rents		Prices	
	(1)	(2)	(3)	(4)	(5)	(6)
Flooding Damage$_{i,t-1}$	0.00101***	0.00139***	0.00107***	0.00138***	0.0000618	-0.0000147
	(0.004)	(0.001)	(0.000)	(0.001)	(0.795)	(0.956)
Other Disasters Damage$_{i,t-1}$	0.00174**	0.00160	0.00127**	0.00110	-0.000466	-0.000506
	(0.039)	(0.103)	(0.029)	(0.131)	(0.408)	(0.446)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.277	0.267	0.087	0.049	0.475	0.492
Observations	1079	1079	1079	1079	1079	1079

The dependent variable Δlog(Rent-to-Price), $\Delta log(Rents)$ and $\Delta log(Prices)$ are respectively, the growth rates of the rent-to-price ratio, rents and housing prices. The $Flood\,Disasters\,Damage_{i,t-1}$ is logarithm of the property damage from the disasters related to the floods plus 1. The $Other\,Disasters\,Damage_{i,t-1}$ is logarithm of the property damage from the disasters not related to the floods plus 1. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

$Other\,Disasters\,Damage_{i,t-1}$ growth in rent-to-price ratio (columns (1) and (2)) and growth in the housing rents (columns (3) and (4)). Whilst, both types of disasters do not show significant impacts to the change of the housing prices and it is consistent with our specifications in section 3.5.

Here, we have shown that the households are more sensitive to the flooding related disasters and the flooding related disasters can bring more significant changes to the gap between housing rents and housing prices.

3.8 Conclusions

It is an interesting question to study that how people react to the change of the risk in their life. We try to answer this question by observing the households' reactions in the housing market after the impacts of the natural disasters. After the disasters, the dynamics of the housing market shows that the local rents go up but prices do not drop much, which leads to a widening gap between rent and price of the house. It is the result of the tenure conversion from house purchasing to house rental after the households' increased perception of the disasters.

In our study of natural disasters, we not only include the large-sized disasters such as flood, hurricane, and tornado, we but also take account others normal and small sized natural disasters such as high wind and heavy snow. We use the total property damage within one year one MSA to proxy the influence of the natural disasters. The idea is that people are sensitive to the impacts of the change of the risk in their life. If there is one common natural disaster occurs, saying flash flood, the households can easily access the information of this natural disaster through the television, newspaper and even social media. This information has the huge negative impact on their choice of the households when they decide to rent or own their housing. Even the size of the natural disaster is not extremely huge, the risk aversion will amplify the households reactions to the natural disasters. In general, there is a tenure conversion from house purchase to house rental, it further pushes up the housing rents.

From the portfolio theory, the low and mid-income households are more sensitive to taking the risk. Their investment in the housing market can be seriously dampened because they have limited access to the investment opportunities diversifying their risk. We can observe this decrease of their housing investment from the shrinkage of their housing purchase mortgage after impacts of the natural disasters. At the same time, the high-income households who can diversify their investments and risk are resistant to the natural disasters. They also tend to take the advantage of the chance of increased rents revenue to increase their investment in the housing market. This can also be observed from their increased applications for house purchase mortgage.

Appendix

Appendix A: Appendix for Chapter 1

Appendix A1. Definition.

We describe the main variables that we use in the paper below. We utilize two main sets of data: the China Stock Market & Accounting Research (CSMAR) dataset, and the Wind Financial database. All the continuous variables are winsorized at the 1% and 99% level.

Main Variables

Book value leverage (Book Leverage) is the ratio of total debt to total assets of the firm.

Market value leverage (Market Leverage) is the ratio of total debt to the sum of market value of the firm's equity and total debt.

The percentage of executives stock-holding (Executive Ownership) is the ratio of shares held by the executives to the total shares of the firm. The executives are the senior executives disclosed in the annual report, including CEO, general manager and other senior managers.

Executive equity to cash salary ratio (Equity-to-Salary) is the ratio of market value of shares held by the executives to the annual cash compensation for executives. The detailed definition is in the section 1.6.2.

Credit Push is a dummy variable equal to one if year$\geqslant$2009 and zero otherwise.

Borrowing cost (Borrowing Cost %) is the ratio of the interest expense to the total debt.

Control Variables

Return-on-assets (ROA) is the ratio of operating income of the firm before taxation and interest expense to the total asset of the firm.

Market-to-book ratio (Market Book) is the ratio of the stock market value of the firm to the book value of the firm's total assets.

Asset tangibility of the firm (Asset Tangibility) is the ratio of the fixed assets to the total assets of the firm.

Positive Net Profit is indicator to show whether the firm's annual net profit after tax and interest expense is positive.

Dividend is a dummy variable equal to one if the firm paid a dividend in that year and zero otherwise.

State-Owned-Enterprises (SOE) is a dummy variable that denotes whether the firm is a state-owned-enterprise.[4] SEO equals one if the firm is directly controlled by the government and zero otherwise.

Size of the firm (Size) is the logarithm of the total sales of the firm.

Concentration of the share structure (Stock Holding Concentration) is the sum of squares of the percent of shares of the five largest shareholders.

Institutional percentage of share (Institution Stock Holding) is the ratio of shares held by the institutional investors to the total shares of the firm.

---

[4]We follow Chen et al. (2012) and Liao, Liu and Wang (2014) and use the ultimate controller of the firms to decide the identities of the SOEs.

Holding by banks (Bank Holding) is an indicator to show whether the stock of the firm is held by the commercial banks.

Holding by foreign investors(Foreign Holding) is an indicator to show whether the stock of the firm is held by the foreign investors.

CEO Turnover indicator (CEO Turnover) is an indicator to show whether the firm has the CEO turnover during the fiscal year.

CEO and Chairman (CEO Chairman) is a dummy variable that equals one if the CEO is also the chairman of the board and zero otherwise.

Compensation Committee is a dummy variable that equals one if the firm has a compensation committee and zero otherwise.

Board Size is the number of directors on the board of the firm.

Board Independence is the ratio of outside directors to the total number of directors in the board.

Appendix A2. Empirical Analysis of Interest Cost

One firm characteristic that deserves a special mention is the Interest Expense Ratio, which captures the borrowing costs of a firm. We estimate this variable following Pittman and Fortin (2004) as the ratio of interest expenses to total debt:

$$Borrowing\,Cost = Interest\,Expense\,Ratio = \frac{Interest\,Expense}{Short\,Term\,Debt + Long\,Term\,Debt}. \tag{10}$$

While the visual evidence provided in Figure 1.3 points to a significant downward shift in borrowing costs, we test this more formally by estimating a regression model of the following form:

$$
\begin{aligned}
Borrowing\,Cost_{it} = \beta_0 + \beta_1 Leverage\,Ratio_{it} + \beta_2\,Credit\,Push_t + \\
+ \beta_3 Leverage\,Ratio_{it} \times Credit\,Push_t + \beta_4\,Controls_{it} + \alpha_j + u_{it}
\end{aligned}
\tag{11}
$$

where the $Borrowing\,Cost$ is the interest expense ratio as defined in (10), $Book\ Leverage$ is as defined in equation 1.1, $Credit\,Push$ is a dummy variable that equals one for 2009 (post-stimulus) and zero for 2008 (pre-stimulus), and α_j is the industry fixed effect.

We report the results in Table A1. The key coefficients of interest are $Credit\,Push$ and its interaction with $Book\ Leverage$. In column 2 of Panel A we present the results where we control for the firm characteristics and include any fixed effects. We obtain a coefficient of -0.30 for $Credit\,Push$. The coefficient for $Credit\,Push \times Book\ Leverage$ is -0.854, and it is significant at the one percent level. Thus, while the credit push lowers the cost of borrowing across all firms, it is especially powerful in reducing the borrowing costs for firms that choose high leverage.

In other Columns from 1 through 4, we re-estimate our benchmark regression specification by introducing industry fixed effects and the using the market leverage as the alternative specifications. Our results hold for these alternative specifications.

Table A1. Cost of Leverage Before and After the 2008 Credit Push

	Interest Expense (%)			
	(1)	(2)	(3)	(4)
Book Leverage$_{i,t}$ × Credit Push$_t$	-0.845***	-0.903***		
	(0.009)	(0.004)		
Book Leverage$_{i,t}$	1.732***	2.201***		
	(0.000)	(0.000)		
Market Leverage$_{i,t}$ × Credit Push$_t$			-0.861**	-0.744**
			(0.021)	(0.039)
Market Leverage$_{i,t}$			2.025***	2.382***
			(0.000)	(0.000)
Credit Push$_t$	-0.301	-0.256	-0.318**	-0.292**
	(0.125)	(0.184)	(0.032)	(0.044)
Firm's Controls	Yes	Yes	Yes	Yes
Industry FE	No	Yes	No	Yes
Observations	1956	1956	1956	1956
R^2	0.117	0.205	0.118	0.203

Note: the sample covers 2008 and 2009. Credit Push$_t$ denotes whether $t = 2009$. This table regresses interest expense on the interaction term of the credit push and book leverage, as in equation 11. The controls are return to assets, size of the firm, market-to-book ratio, state owned enterprise, ownership concentration, institutional ownership, assets tangibility, and bank ownership (see the appendix for details). The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. The standard errors are clustered at the firm level.

Table A2. Decomposition per Sectors

			Mean			
	# obs	% obs	Interest Cost	Book Leverage	Market Leverage	Executive Share
Agriculture	50	1.66%	3.4194	0.4068	0.1847	3.15%
Mining industry	113	3.76%	2.4731	0.4476	0.2175	0.17%
Manufacturing	1732	57.60%	3.0737	0.4809	0.2802	2.56%
Energy industry	157	5.22%	4.0240	0.6002	0.4296	0.02%
Building industry	80	2.66%	1.7846	0.6777	0.4735	1.73%
Wholesale and re	246	8.18%	2.5972	0.5596	0.3302	0.10%
Transportation	123	4.09%	2.8235	0.4435	0.3103	0.01%
Hotel and catering	18	0.60%	2.6862	0.3297	0.1523	0.15%
Information	84	2.79%	2.1412	0.3736	0.1831	6.43%
Real-estate	253	8.41%	2.0776	0.5677	0.3617	0.52%
Leasing and business	32	1.06%	2.5428	0.4595	0.2726	3.22%
Scientific and technology	8	0.27%	0.9568	0.4870	0.1862	0.19%
Environment	29	0.96%	3.3394	0.4848	0.2588	0.03%
Education	2	0.07%	4.4044	0.5625	0.3422	0.04%
Health and social welfare	4	0.13%	0.9948	0.1659	0.0604	0.00%
Culture and sports	31	1.03%	2.2157	0.4847	0.2199	0.22%
Comprehensive	45	1.50%	2.8848	0.5145	0.3254	0.01%
Total	3007	100%	2.8895	0.4982	0.2972	1.85%

Note: this table reports the sample statistics for each sector of the database. Source: CSMAR.

Appendix B: Appendix for Chapter 2

Appendix B1: The CEO Problem

We denote the CEO's payoff when the firm is not in default as:

$$\Omega(\omega, \hat{\omega}, B, p) \equiv A + v\,(\omega - \hat{\omega})\, R^k(B+N) - c(p), \tag{12}$$

and the CEO's payoffs when the firm is in default as:

$$\Psi(p) \equiv A - c(p). \tag{13}$$

Using (12) and (13), the CEO's maximization problem (2.9) becomes:

$$\max_{\{\hat{\omega}, p, B\}} \int_{\hat{\omega}}^{\infty} u\left(\Omega(\omega, \hat{\omega}, B, p)\right) f(\omega; p)\, d\omega + u(\Psi(p))\, F(\hat{\omega}; p) \tag{14}$$

s.t.

$$\int_0^{\hat{\omega}} (1-\gamma)\, \omega R^k(B+N) f(\omega; p)\, d\omega + \hat{\omega} R^k(B+N)\left(1 - F(\hat{\omega}; p)\right) = R^B(1-\tau)B. \tag{15}$$

Denoting the Lagrangian multiplier by λ_m the Lagrangian is

$$\mathcal{L}_m(\hat{\omega}, p, B) = \left\{ \begin{array}{c} \int_{\hat{\omega}}^{\infty} u\left(\Omega(\omega, \hat{\omega}, B, p)\right) f(\omega; p)\, d\omega + u(\Psi(p))\, F(\hat{\omega}; p) + \\ +\lambda_m \left[\begin{array}{l} \int_0^{\hat{\omega}} (1-\gamma)\, \omega R^k(B+N) f(\omega; p)\, d\omega + \\ +\hat{\omega} R^k(B+N)\left(1 - F(\hat{\omega}; p)\right) - R^B(1-\tau)B \end{array} \right] \end{array} \right\},$$

and the FOCs are:

$$\frac{\partial \mathcal{L}_m(\hat{\omega}, p, B)}{\partial \hat{\omega}} = \left\{ \begin{array}{l} -\int_{\hat{\omega}}^{\infty} u'(\Omega) v R^k(B+N) f(\omega; p)\, d\omega + \\ +\lambda_m \left[-\gamma \hat{\omega} R^k(B+N) f(\hat{\omega}; p) + R^k(B+N)\left(1 - F(\hat{\omega}; p)\right) \right] \end{array} \right\} = 0, \tag{16}$$

For effort:

$$\frac{\partial \mathcal{L}_m(\hat{\omega},p,B)}{\partial p} = \left\{ \begin{array}{l} \int_{\hat{\omega}}^{\infty} \left[-u'(\Omega)c'(p)f(\omega;p) + u(\Omega)\dfrac{\partial f(\omega;p)}{\partial p} \right] d\omega + \\ +u(\Psi)\dfrac{\partial F(\hat{\omega};p)}{\partial p} - u'(\Psi)c'(p)F(\hat{\omega};p) + \\ +\lambda_m \left[\begin{array}{l} \int_0^{\hat{\omega}} (1-\gamma)\omega R^k(B+N)\dfrac{\partial f(\omega;p)}{\partial p}\, d\omega + \\ -\hat{\omega}R^k(B+N)\dfrac{\partial F(\hat{\omega};p)}{\partial p} \end{array} \right] \end{array} \right\} = 0, \quad (17)$$

and for debt level:

$$\frac{\partial \mathcal{L}_m(\hat{\omega},p,B)}{\partial B} = \left\{ \begin{array}{l} \int_{\hat{\omega}}^{\infty} u'(\Omega)(\omega-\hat{\omega})vR^k f(\omega;p)\, d\omega + \\ +\lambda_m \left[\begin{array}{l} \int_0^{\hat{\omega}} (1-\gamma)\,\omega R^k f(\omega;p)\, d\omega + \\ +\hat{\omega}R^k\,(1-F(\hat{\omega};p)) - R^B(1-\tau) \end{array} \right] \end{array} \right\} = 0. \quad (18)$$

Appendix B2. The Shareholder's Problem

The shareholder proposes the compensation contract $\{v, A\}$ that maximizes

$$\max_{\{v,A\}} \int_{\hat{\omega}(v,A)}^{\infty} \left[(1-v)(\omega-\hat{\omega}(v,A))R_k(B(v,A)+N) - A\right] f(\omega;p(v,A))\, d\omega, \quad (19)$$

subject to the CEO's decision allocations $\hat{\omega}(v,A)$, $p(v,A)$ and $B(v,A)$ implicitly defined in Section A1. That is, the shareholder solves:

$$\max_{\{v,F,\hat{\omega},p,B\}} \int_{\hat{\omega}}^{\infty} \left[(1-v)(\omega-\hat{\omega})R_k(B+N) - A\right] f(\omega;p)\, d\omega, \quad (20)$$

subject to the first order conditions of the CEO's problem of functions (16), (17) and (18).

Denoting by $\lambda_{\hat{\omega}}$, λ_p and λ_B the Lagrangian multiplier, the shareholder's Lagrangian is

$$
\begin{aligned}
&\mathcal{L}_s(v, A, \hat{\omega}, p, B) = \\
&= \int_{\hat{\omega}}^{\infty} \left[(1-v)(\omega-\hat{\omega})R_k(B+N) - F\right] f(\omega;p)\, d\omega + \\
&+ \lambda_{\hat{\omega}} \left\{ \begin{array}{l} -\int_{\hat{\omega}}^{\infty} vu'(\Omega)R^k f(\omega;p)\, d\omega + \\ +\lambda_m \left[-\gamma\hat{\omega}R^k f(\hat{\omega};p) + R^k\left(1-F(\hat{\omega};p)\right)\right] \end{array} \right\} + \\
&+ \lambda_p \left\{ \begin{array}{l} \int_{\hat{\omega}}^{\infty} \left[-u'(\Omega)c'(p)f(\omega;p) + u(\Omega)\dfrac{\partial f(\omega;p)}{\partial p}\right] d\omega + \\ +u(\Psi)\dfrac{\partial F(\hat{\omega};p)}{\partial p} - u'(\Psi)c'(p)F(\hat{\omega};p) + \\ +\lambda_m \left[\int_0^{\hat{\omega}}(1-\gamma)\omega R^k(B+N)\dfrac{\partial f(\omega;p)}{\partial p}\, d\omega - \hat{\omega}R^k(B+N)\dfrac{\partial F(\hat{\omega};p)}{\partial p}\right] \end{array} \right\} + \\
&+ \lambda_B \left\{ \begin{array}{l} \int_{\hat{\omega}}^{\infty} u'(\Omega)(\omega-\hat{\omega})vR^k f(\omega;p)\, d\omega + \\ +\lambda_m \left[\int_0^{\hat{\omega}}(1-\gamma)\,\omega R^k f(\omega;p)\, d\omega + \hat{\omega}R^k\left(1-F(\hat{\omega};p)\right) - R^B(1-\tau)\right] \end{array} \right\}.
\end{aligned}
\tag{21}
$$

Using Leibniz rule, we obtain the first order conditions:

$$\frac{\partial \mathcal{L}_s(v, A, \hat{\omega}, p, B)}{\partial \hat{\omega}} =$$

$$= -(1-v)R_k(B+N)\left(1-F(\hat{\omega};p)\right)$$

$$+ \lambda_{\hat{\omega}} \left\{ \begin{array}{l} v^2 R^{k\,2}(B+N) \int_{\hat{\omega}}^{\infty} u''(\Omega) f(\omega;p)\, d\omega + v u'(\Psi) R^k f(\hat{\omega};p) + \\ +\lambda_m \left[-\gamma R^k \left(f(\hat{\omega};p) + \hat{\omega} \frac{\partial f(\hat{\omega};p)}{\partial \hat{\omega}} \right) - R^k f(\hat{\omega};p) \right] \end{array} \right\} +$$

$$+ \lambda_p \left\{ \begin{array}{l} v R^k (B+N) c'(p) \int_{\hat{\omega}}^{\infty} u''(\Omega) f(\omega;p)\, d\omega - v R^k (B+N) \int_{\hat{\omega}}^{\infty} u'(\Omega) \dfrac{\partial f(\omega;p)}{\partial p}\, d\omega + \\ -u'(\Psi) c'(p) f(\omega;p) + u(\Psi) \dfrac{\partial f(\omega;p)}{\partial p} + \\ +u(\Psi) \dfrac{\partial f(\hat{\omega};p)}{\partial p} - u'(\Psi) c'(p) \frac{\partial F(\hat{\omega};p)}{\partial \hat{\omega}} + \\ +\lambda_m \left[(1-\gamma) \hat{\omega} R^k (B+N) \dfrac{\partial f(\hat{\omega};p)}{\partial p} - \left(\dfrac{\partial F(\hat{\omega};p)}{\partial p} + \hat{\omega} \dfrac{\partial f(\hat{\omega};p)}{\partial p} \right) R^k (B+N) \right] \end{array} \right\} +$$

$$+ \lambda_B \left\{ \begin{array}{l} \left[\begin{array}{c} -v^2 R^{k\,2}(B+N) \int_{\hat{\omega}}^{\infty} u''(\Omega) \omega f(\omega;p) d\omega + \\ +\hat{\omega} v^2 R^{k\,2}(B+N) \int_{\hat{\omega}}^{\infty} u''(\Omega) \omega f(\omega;p) d\omega \end{array} \right] - v R^k \int_{\hat{\omega}}^{\infty} u'(\Omega) f(\omega;p)\, d\omega + \\ +\lambda_m \left[(1-\gamma)\, \hat{\omega} R^k f(\hat{\omega};p) + R^k \left(1-F(\hat{\omega};p)\right) - R^k \hat{\omega} f(\hat{\omega};p) \right] \end{array} \right\} = 0. \tag{22}$$

For the variable compensation:

$$
\begin{aligned}
&\frac{\partial \mathcal{L}_s(v, A, \hat{\omega}, p, B)}{\partial v} = \\
&= -R_k(B+N)\int_{\hat{\omega}}^{\infty} \omega f(\omega;p)\,d\omega + \hat{\omega}R_k(B+N)\int_{\hat{\omega}}^{\infty} f(\omega;p)\,d\omega + \\
&+ \lambda_{\hat{\omega}} \left\{ \begin{array}{c} -vR^k(B+N)R^k \int_{\hat{\omega}}^{\infty} u''(\Omega)\omega f(\omega;p)\,d\omega + \\ +vu''(\Omega)\hat{\omega}R^k(B+N)R^k \int_{\hat{\omega}}^{\infty} f(\omega;p)d\omega + \\ -R^k \int_{\hat{\omega}}^{\infty} u'(\Omega) f(\omega;p)\,d\omega \end{array} \right\} + \\
&+ \lambda_p \left\{ \begin{array}{c} \left[\begin{array}{c} -R^k(B+N)c'(p)\int_{\hat{\omega}}^{\infty} u''(\Omega)\omega f(\omega;p)d\omega + \\ +\hat{\omega}R^k(B+N)c'(p)\int_{\hat{\omega}}^{\infty} u''(\Omega)f(\omega;p)d\omega \end{array} \right] + \\ + \left[\begin{array}{c} R^k(B+N)\int_{\hat{\omega}}^{\infty} u'(\Omega)\omega \frac{\partial f(\omega;p)}{\partial p}\,d\omega + \\ -\hat{\omega}R^k(B+N)\int_{\hat{\omega}}^{\infty} u'(\Omega)\frac{\partial f(\omega;p)}{\partial p}\,d\omega \end{array} \right] \end{array} \right\} + \\
&+ \lambda_B \left\{ \begin{array}{c} \left[\begin{array}{c} vR^{k\,2}(B+N)\int_{\hat{\omega}}^{\infty} u''(\Omega)\omega^2 f(\omega;p)\,d\omega + \\ -2\hat{\omega}vR^{k\,2}(B+N)\int_{\hat{\omega}}^{\infty} u''(\Omega)\omega f(\omega;p)\,d\omega + \\ +\hat{\omega}^2 vR^{k\,2}(B+N)\int_{\hat{\omega}}^{\infty} u''(\Omega) f(\omega;p)\,d\omega \end{array} \right] + \\ + \left[\begin{array}{c} R^k \int_{\hat{\omega}}^{\infty} u'(\Omega)\omega f(\omega;p)\,d\omega + \\ -\hat{\omega}R^k \int_{\hat{\omega}}^{\infty} u'(\Omega) f(\omega;p)\,d\omega \end{array} \right] \end{array} \right\} = 0. \qquad (23)
\end{aligned}
$$

For the fixed compensation:

$$
\begin{aligned}
&\frac{\partial \mathcal{L}_s(v, A, \hat{\omega}, p, B)}{\partial A} = \\
&= F(\hat{\omega}, p) - 1 + \\
&+ \lambda_{\hat{\omega}} \left\{ -vR^k \int_{\hat{\omega}}^{\infty} u''(\Omega) f(\omega;p)\,d\omega \right\} + \\
&+ \lambda_p \left\{ \begin{array}{l} -c'(p)\int_{\hat{\omega}}^{\infty} u''(\Omega) f(\omega;p)\,d\omega + \int_{\hat{\omega}}^{\infty} u'(\Omega)\frac{\partial f(\omega;p)}{\partial p}\,d\omega + \\ +u'(\Psi)\frac{\partial F(\hat{\omega};p)}{\partial p} - u''(\Psi)c'(p)F(\hat{\omega};p) \end{array} \right\} + \\
&+ \lambda_B \left\{ \left[\begin{array}{c} vR^k \int_{\hat{\omega}}^{\infty} u''(\Omega)\omega f(\omega;p)\,d\omega \\ -vR^k\hat{\omega} \int_{\hat{\omega}}^{\infty} u''(\Omega) f(\omega;p)\,d\omega \end{array} \right] \right\} = 0. \qquad (24)
\end{aligned}
$$

For debt level:

$$
\begin{aligned}
&\frac{\partial \mathcal{L}_s(v, A, \hat{\omega}, p, B)}{\partial B} = \\
&= \left[(1-v) R_k \int_{\hat{\omega}}^{\infty} \omega f(\omega; p)\, d\omega - \hat{\omega}(1-v) R_k \left(1 - F(\hat{\omega}; p)\right) \right] + \\
&+ \lambda_p \left\{ \; \lambda_m \left[(1-\gamma) R^k \int_0^{\hat{\omega}} \omega \frac{\partial f(\omega; p)}{\partial p}\, d\omega - \hat{\omega} R^k \frac{\partial F(\hat{\omega}; p)}{\partial p} \right] \; \right\} = 0.
\end{aligned} \tag{25}
$$

For effort:

$$
\begin{aligned}
&\frac{\partial \mathcal{L}_s(v, A, \hat{\omega}, p, B)}{\partial p} = \\
&= \left[\begin{array}{c} (1-v) R_k (B+N) \int_{\hat{\omega}}^{\infty} \omega \frac{\partial f(\omega;p)}{\partial p}\, d\omega + \\ +(1-v)\hat{\omega} R_k (B+N) \frac{\partial F(\hat{\omega};p)}{\partial p} \end{array} \right] + A \frac{\partial F(\hat{\omega}; p)}{\partial p} + \\
&+ \lambda_{\hat{\omega}} \left\{ \begin{array}{l} -v R^k \int_{\hat{\omega}}^{\infty} u'(\Omega) \frac{\partial f(\omega;p)}{\partial p} d\omega + \\ +\lambda_m \left[-\gamma \hat{\omega} R^k \frac{\partial f(\hat{\omega};p)}{\partial p} - R^k \frac{\partial F(\hat{\omega};p)}{\partial p} \right] \end{array} \right\} + \\
&+ \lambda_p \left\{ \begin{array}{l} \left(c'^2(p) \int_{\hat{\omega}}^{\infty} u''(\Omega) f(\omega;p) d\omega - c''(p) \int_{\hat{\omega}}^{\infty} u'(\Omega) f(\omega;p) d\omega - c'(p) \int_{\hat{\omega}}^{\infty} u'(\Omega) \frac{\partial f(\omega;p)}{\partial p} d\omega \right) + \\ + \left(-c'(p) \int_{\hat{\omega}}^{\infty} u'(\Omega) \frac{\partial f(\omega; p)}{\partial p} d\omega + \int_{\hat{\omega}}^{\infty} u(\Omega) \frac{\partial^2 f(\omega; p)}{\partial p \partial p}\, d\omega \right) + \\ + \left(-u'(\Psi) c'(p) \frac{\partial F(\hat{\omega}; p)}{\partial p} + u(\Psi) \frac{\partial^2 F(\hat{\omega}; p)}{\partial p \partial p} \right) - \\ - \left(-u''(\Psi) c'(p) c'(p) F(\hat{\omega}; p) + u'(\Psi) c''(p) F(\hat{\omega}; p) + u'(\Psi) c'(p) \frac{\partial F(\hat{\omega};p)}{\partial p} \right) + \\ +\lambda_m \left[(1-\gamma) R^k (B+N) \int_0^{\hat{\omega}} \omega \frac{\partial^2 f(\omega; p)}{\partial p \partial p}\, d\omega - \hat{\omega} R^k (B+N) \frac{\partial^2 F(\hat{\omega}; p)}{\partial p \partial p} \right] \end{array} \right\} + \\
&+ \lambda_B \left\{ \begin{array}{l} \left[\begin{array}{c} -v R^k c'(p) \int_{\hat{\omega}}^{\infty} u''(\Omega) f(\omega;p) \omega d\omega + \\ +\hat{\omega} R^k c'(p) \int_{\hat{\omega}}^{\infty} u''(\Omega) f(\omega;p) d\omega \end{array} \right] + \\ + \left[\begin{array}{c} v R^k \int_{\hat{\omega}}^{\infty} u'(\Omega) \frac{\partial f(\omega;p)}{\partial p} \omega d\omega - \\ -\hat{\omega} v R^k \int_{\hat{\omega}}^{\infty} u'(\Omega) \frac{\partial f(\omega;p)}{\partial p} d\omega \end{array} \right] + \\ +\lambda_m \left[(1-\gamma)\, R^k \int_0^{\hat{\omega}} \omega \frac{\partial f(\omega;p)}{\partial p}\, d\omega - \hat{\omega} R^k \frac{\partial F(\hat{\omega};p)}{\partial p} \right] \end{array} \right\} = 0.
\end{aligned} \tag{26}
$$

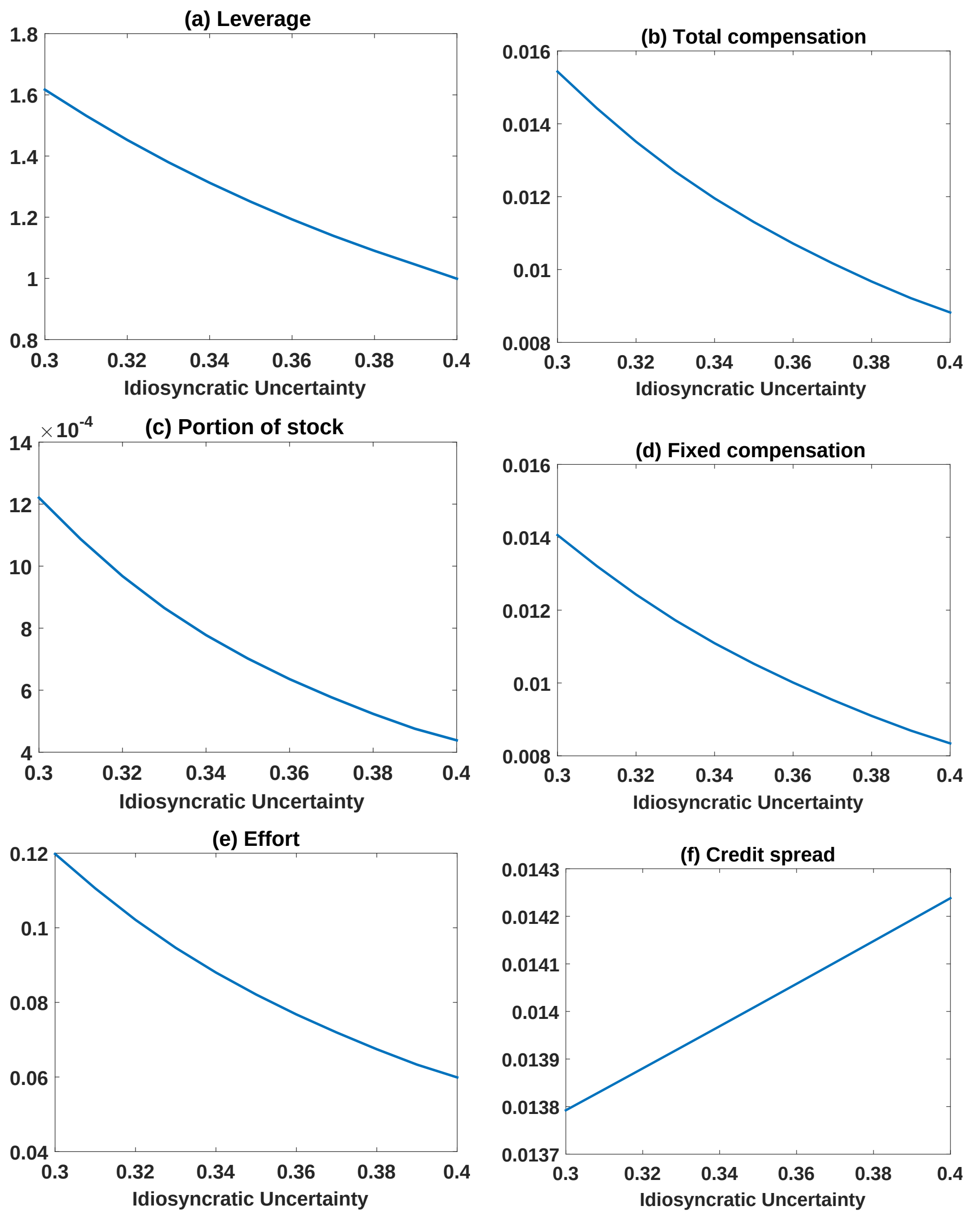

Figure B1. The Compensation Variables, Leverage and Idiosyncratic Uncertainty.

This figure plots the compensation variables and leverage for firms with different levels of idiosyncratic uncertainty (σ).

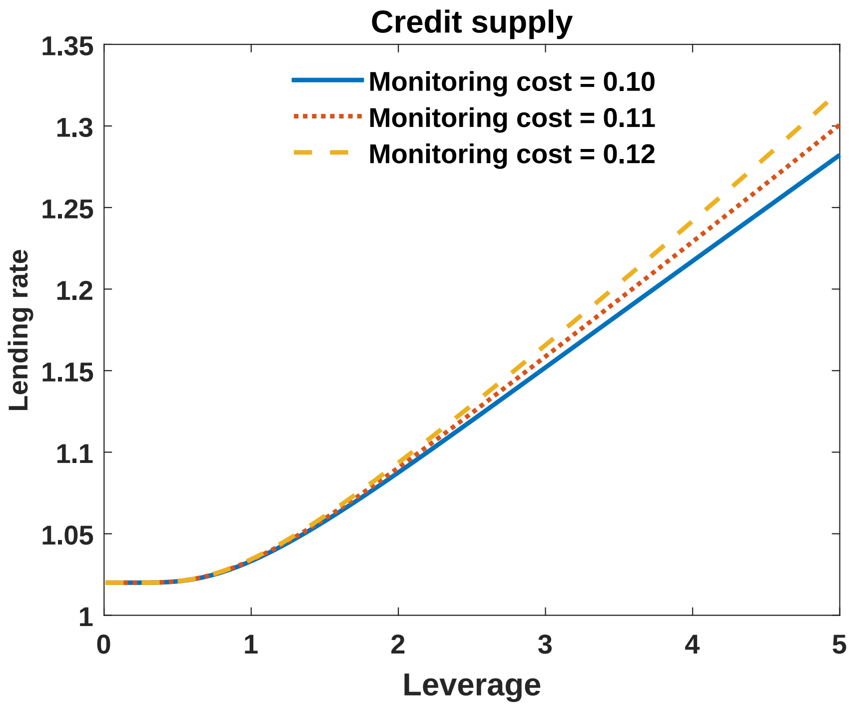

Figure B2. Credit Supply as a Function of Firm's Monitoring Costs.
This figure plots credit supply (equation 2.5) for firms with different degrees of monitoring cost (γ).

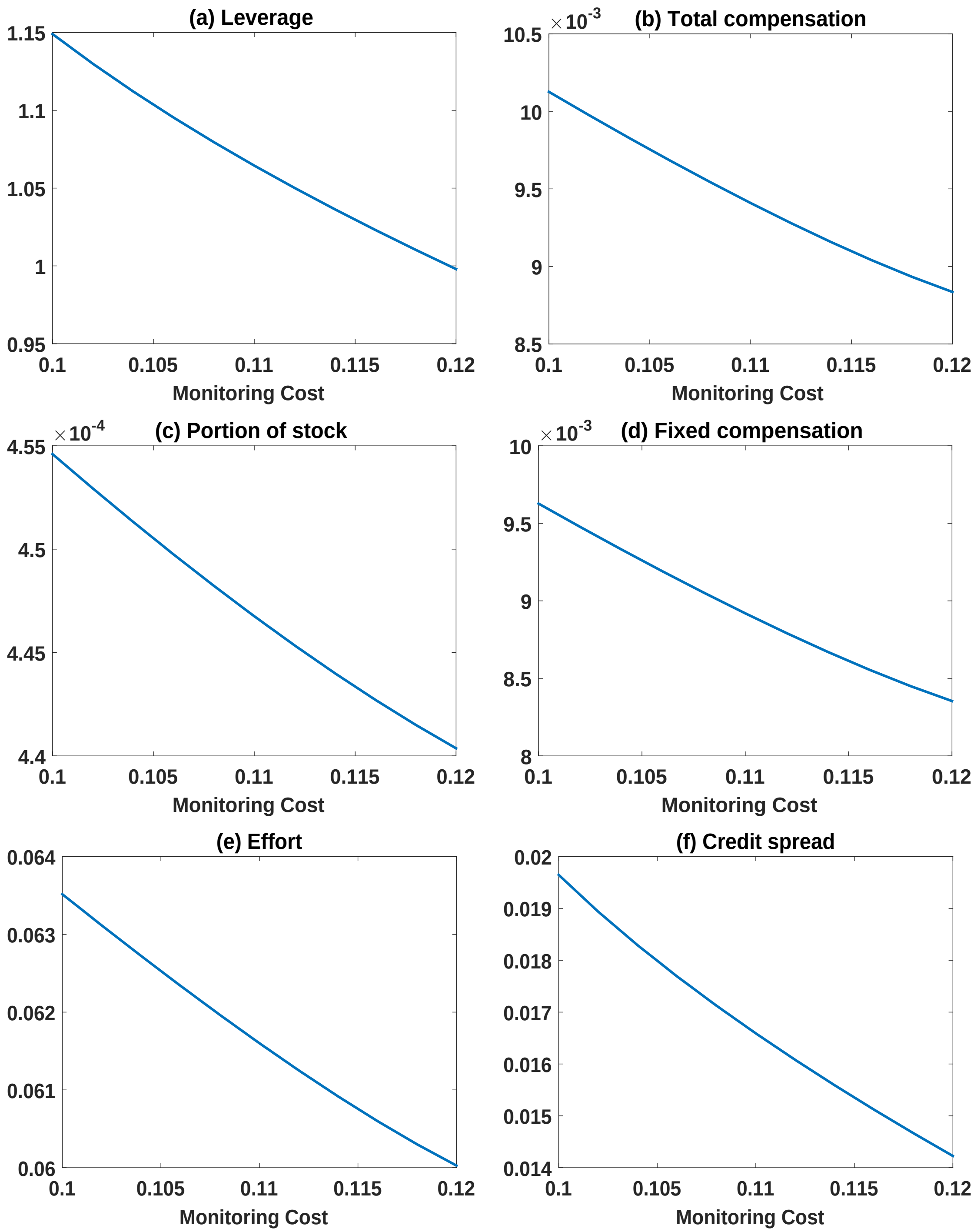

Figure B3. The Compensation Variables, Leverage and Monitoring Cost. This figure plots the compensation variables and leverage for firms with different levels of monitoring cost (γ).

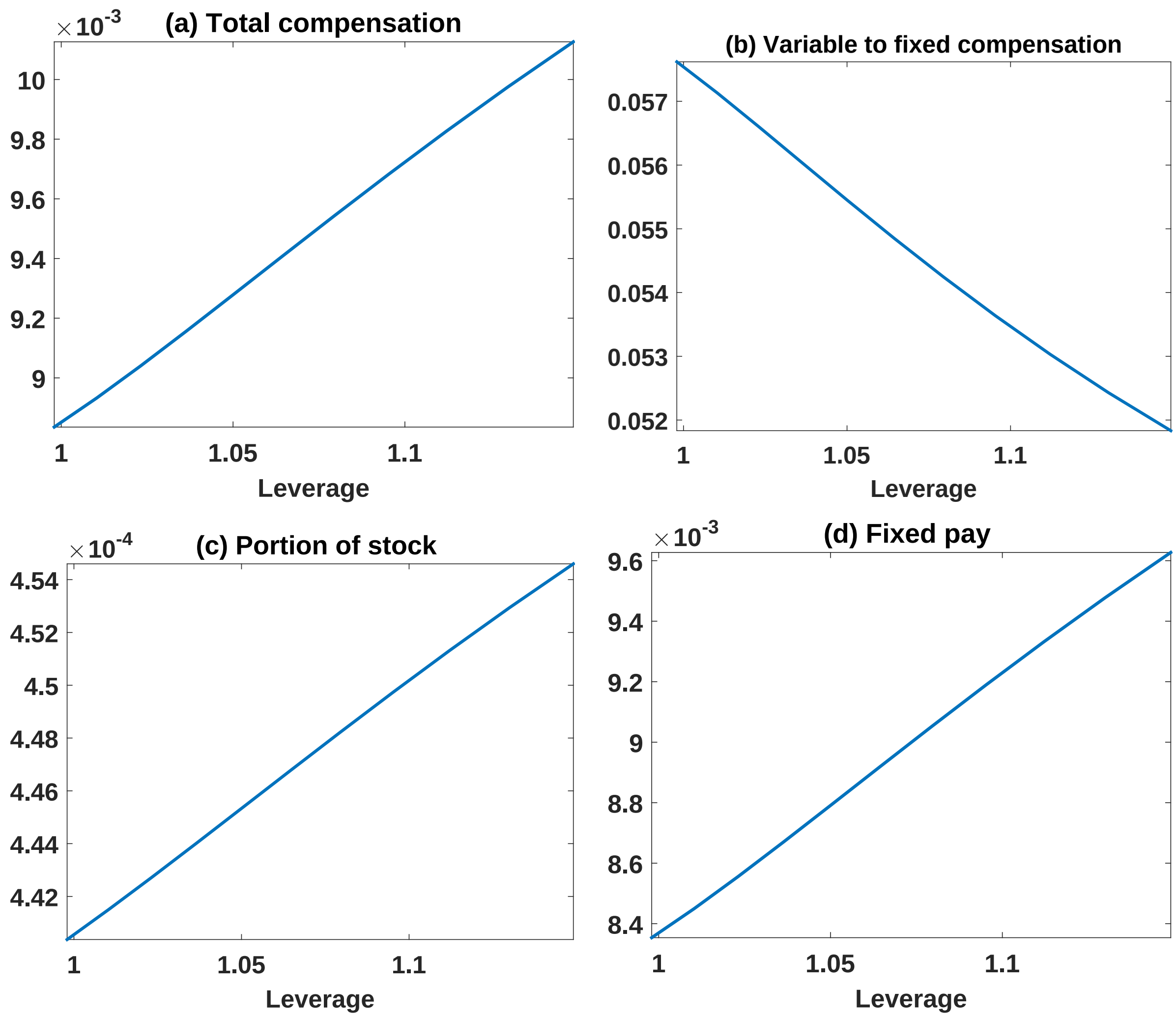

Figure B4. The Cross-section of Compensation Variables and Leverage (Monitoring Cost Edition).
This figure plots the compensation variables versus the firm's leverage. All variables change because the degree of monitoring cost (γ) changes.

Appendix C: Appendix for Chapter 3

Appendix C1: Data Sources and Variable Definitions

Zillow

$\Delta log(Rent/Price_{i,t})$ is the growth of the rent to price ratio in MSA i and year t.

$\Delta log(Price_{i,t})$ is the growth of the price in MSA i and year t.

$\Delta log(Rent_{i,t})$ is the growth of the rent.

StormEvent

$Disasters\,Damage_{i,t-1}$ is the logarithm of aggregate property damage caused by the natural disasters in given time and location. We only include the natural disasters only having significant physical damage to the real-estate and excludes the disasters such as high temperature, dense fog and etc. The disasters we include cover 98% of all the disasters from StormEvent dataset valued by the disasters damage.

$High\,Freq\,Large_{i,t-1}$ (β_1) is the indicator to show that whether the frequency of large disasters (damage > 100 thousand USD) is above the median frequency of the sample.

$High\,Freq\,Small_{i,t-1}$ (β_2) is the indicator to show that whether the frequency of small sized disasters (damage is between 1 thousand to 100 thousand USD) is above the median frequency of the sample.

$Flood\,Disasters\,Damage_{i,t-1}$ is logarithm of the property damage from the disasters related to the floods.

$Other\,Disasters\,Damage_{i,t-1}$ is logarithm of the property damage from the disasters not related to the floods.

HMDA

we only retain mortgage applications, originations and denials for the purchase of a owner-occupied home for 1 to 4 families. We also exclude the loan flagged for data quality concerns. Then, we aggregate the loan data at the MSA level.

$\Delta log(Application_{i,t})$ is the growth rate of the number of the loan applications.

$\Delta log(Origination_{i,t})$ is the growth rate of the number of the loan originations.

$\Delta log(Denial_{i,t})$ is the growth rate of the number of the denied loans. Similarly, the $\Delta log(Application\_Conforming_{i,t})$, $\Delta log(Origination\_Conforming_{i,t})$ and $\Delta log(Denials\_Conforming_{i,t})$ are the growth rates of the loan applications, loan originations and loan denials for the conforming loans. The $\Delta log(Application\_Jumbo_{i,t})$, $\Delta log(Origination\_Jumbo_{i,t})$ and $\Delta log(Denial\_Jumbo_{i,t})$ are the growth rates of the jumbo loan applications, loan originations and loan denials.

HMDA-FFIEC Census Report

$\Delta log(Unit_{i,t})$ is the growth rate of the housing units. Number of units is the total number of dwellings in a given MSA that are built to house fewer than 5 families.

$\Delta log(Occ\_Unit_{i,t})$ is the growth rate of the owner-occupied housing units. Number of owner-occupied units is the number of dwellings, including individual condominiums, that are lived in by the owner.

Appendix C2. Extra Tables and Figures

Table C1. Population

Δlog in	Population	
	(1)	(2)
Disasters Damage$_{i,t-1}$	-0.00113	-0.00232***
	(0.110)	(0.004)
MSA Controls	Yes	Yes
Year FE	Yes	Yes
MSA FE	No	Yes
R^2	0.385	0.388
Observations	1079	1079

The dependent variable $\Delta log(Population)$ is MSA population growth rate. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

1) Table A1 (page 26), is the population growth after the natural disaster. The result shows that the disaster has the negative effect on the population growth. The good thing is that the effect is only significant for the MSA fixed effect specification. It means that the people will not go away from the places where the disasters are always high because it is under their expectation. However, the people will leave away from the places where disasters suddenly surge.

Table C2. Flooding Related Disasters

Δlog in	Rent-to-Price		Rents		Prices	
	(1)	(2)	(3)	(4)	(5)	(6)
Top Flooding Disasters$_{i,t-1}$	0.0159***	0.0202***	0.0174***	0.0215***	0.00146	0.00131
	(0.001)	(0.000)	(0.000)	(0.000)	(0.610)	(0.692)
Top Non Flooding Disasters$_{i,t-1}$	-0.00323	-0.000973	-0.00396	-0.00314	-0.000728	-0.00217
	(0.569)	(0.885)	(0.383)	(0.546)	(0.830)	(0.610)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.276	0.268	0.090	0.055	0.475	0.492
Observations	1079	1079	1079	1079	1079	1079

The dependent variable Δlog(Rent-to-Price), $\Delta log(Rents)$ and $\Delta log(Prices)$ are respectively, the growth rates of the rent-to-price ratio, rents and housing prices. The $Top\,Flood\,Disasters_{i,t-1}$ is an indicator to show whether the MSA i in previous year $t-1$ is among the top 50 percentiles MSAs with the floods related disasters evaluated by property damage. The $Top\,Non\,Flood\,Disasters_{i,t-1}$ is an indicator to show whether the MSA i in the previous year $t-1$ is among the top 50 percentiles MSAs with the damage of disasters not related to the floods. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

Table C3. Coastal Areas

Δlog in	Rent-to-Price		Rents		Prices	
	(1)	(2)	(3)	(4)	(5)	(6)
$Disasters\ Damage_{i,t-1}$	0.00308***	0.00345***	0.00257***	0.00245**	-0.000505	-0.00101
	(0.004)	(0.006)	(0.002)	(0.014)	(0.507)	(0.234)
$Coastal_i$	0.0218		0.0190		-0.00280	
	(0.499)		(0.479)		(0.896)	
$Disasters\ Damage_{i,t-1} \times$	-0.0000764	0.00132	-0.000401	0.000454	-0.000325	-0.000867
$Coastal_i$	(0.972)	(0.593)	(0.823)	(0.824)	(0.833)	(0.695)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.280	0.265	0.086	0.039	0.476	0.493
Observations	1079	1079	1079	1079	1079	1079

The dependent variable Δlog(Rent-to-Price), $\Delta log(Rents)$ and $\Delta log(Prices)$ are respectively, the growth rates of the rent-to-price ratio, rents and housing prices. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

Table C4. Attractive Locations

Δlog in	Rent-to-Price		Rents		Prices	
	(1)	(2)	(3)	(4)	(5)	(6)
Disasters Damage$_{i,t-1}$	0.00366***	0.00447***	0.00288***	0.00297***	-0.000785	-0.00150*
	(0.000)	(0.000)	(0.001)	(0.002)	(0.261)	(0.059)
Attractive Location$_i$	0.0920***		0.0665***		-0.0255	
	(0.003)		(0.001)		(0.437)	
Disasters Damage$_{i,t-1}\times$	-0.00738***	-0.00804***	-0.00474***	-0.00453**	0.00264	0.00351
Attractive Location$_i$	(0.000)	(0.008)	(0.000)	(0.012)	(0.241)	(0.290)
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
MSA FE	No	Yes	No	Yes	No	Yes
R^2	0.281	0.268	0.085	0.041	0.478	0.494
Observations	1079	1079	1079	1079	1079	1079

The dependent variables Δlog(Rent-to-Price), $\Delta log(Rents)$ and $\Delta log(Prices)$ are respectively, the growth rates of the rent-to-price ratio, rents and housing prices. $Attractive\,Location_i$ indicates whether the MSA is listed on the top 10 percentile of the MSAs attracting the senior immigrations (people aged 60+). $Disasters\,Damage_{i,t-1}\times$ $Attractive\,Location_i$ is its interaction with the natural disasters damage. MSA controls are those from Table 3.2. The p-values are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% level. Each observation is an MSA. The standard errors are clustered at the MSA level. The Data Appendix discusses these variables.

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