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Three Essays on Property and Liability Insurance Company Investment

LOU PINGYI

NANYANG BUSINESS SCHOOL

2018

Three Essays on Property and Liability Insurance Company Investment

LOU PINGYI

A thesis submitted to the Nanyang Technological University
in partial fulfillment of the requirement for the degree of
Doctor of Philosophy

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Summary

My thesis discusses the investment made by Property and Liability (or Property and Casualty) insurance companies. We also study the spillover effect of the investment made by these insurance companies as well.

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In Chapter Three, we discuss how the organizational forms will affect Property and Casualty (P&C) insurance companies' investment in underwriting business, from the perspective of internal asset allocation. We study how the return of internal capital markets (ICMs) and the risk of ICMs differ across three alternative organizational forms: publicly-held stock insurers, privately-held stock insurers and mutual insurers. Because of the different combination of owner, manager and customer functions, these three organizational forms are subjected to different aspects and extents of agency problems, which leads to a variation in the performance of ICMs. In terms of return, we find that the sensitivity of investment increase in highly profitable business lines to ICM subsidy is significantly positive for private insurers, but is insignificant for mutual and public insurers. In terms of risk, we find that the sensitivity of investment increase in highly profitable and highly risky business lines to ICM subsidy is significantly positive for public insurers. Finally, we shed light on the association between organizational forms and shadow insurance, one specific ICM transaction associated with increasing firm-level risk. We find that the underwriting ROA volatility is more sensitive to shadow ICM subsidy than to regular ICM subsidy for public insurers.

In Chapter Four, we study the spillover effect of P&C insurance companies' investment behavior. We examine whether the financial health of municipal bond investors can affect the municipal borrowing cost, i.e., the municipal bond yield, especially focusing on the liquidity component. Using the U.S. property and casualty insurance companies as the research setting, we find that the deterioration of the financial health of bond investors raises the liquidity spread of municipal bonds, and this relationship was even stronger during the subprime mortgage crisis. Using Hurricane Sandy as an exogenous shock to the financial health of insurers, we find that the municipal bonds held by insurers suffered loss by the hurricane experience larger increase in liquidity yields in the current and following quarter of Hurricane Sandy.

In Chapter Five, I make a conclusion of my thesis.

Chapter One: Introduction and Background

In U.S., Property and Liability (or Property and Casualty) insurance companies and life insurance companies are the two main categories of insurance companies in the insurance industry. [1] According to SNL, the professional insurance industry data vendor, as of year 2016, the total assets of Property and Casualty (P&C) insurance companies are $1.9 trillion, and the total assets of life insurance companies is $6.6 trillion.

In my thesis, I specially focus on the investment of U.S. P&C insurance companies. U.S. P&C insurers report more than $1.5 trillion of cash and invested assets, on a book adjusted carrying value (BACV) basis, for 2016. This represents a $56.1 billion, or close to 3.6%, increase from year-end 2015. The distribution of cash and invested assets among P&C insurance companies, has not changed significantly over the five years ended 2016.

According to SNL, more than 88.9% of P&C insurer invested asset, were concentrated within bonds, common stock, mortgages, cash and short-term investments. The remaining 11% consisted of contract loans, derivatives, real estate, preferred stock, securities lending and other receivables. Consistent with years prior, in year 2016, bonds remained the largest portion of total cash and invested assets for insurers in 2015, with BACV of $973 billion, or 61% of the total. Insurers reported a total of $345 billion (or 21% of the total) in common stock holdings at year-end 2016, in comparison to $322 billion in 2015. Cash and short-term assets have, over the five-year period analyzed, steadily represented close to 6% of total cash and invested assets. BACV for year-end 2016 was relatively flat to the year prior, at $92 billion, but up by $10 billion from five years ago.

My thesis discusses the investment portfolio of P&C insurance companies, focusing on the return and risk. We also study the spillover effect of the investment made by these insurance companies as well. We are curious to see how the investment of insurance companies can affect the whole economy.

In Chapter Two, we discuss how the regulation will affect insurance investment behavior. We explore the impact of capital adequacy requirements on financial institutions' risk-taking behavior from a new perspective. Specifically, we show that one important feature of the risk-based capital

[1] Other types of insurance companies include health, fraternal and title companies.

(RBC) system, a built-in diversification benefit in aggregating risk categories, induces moral hazard. We find that insurers that face lower RBC costs of fixed-income (FI) investment purchase more risky FI securities. Using Hurricane Katrina and Hurricane Sandy as exogenous shocks to RBC cost, we find that the insurers that suffered more in the two disasters took more risk in their FI investments and that their overall risk increased. These results provide an important regulatory implication for minimum capital calculation in capital regulation regimes.

In Chapter Three, we discuss how the organizational forms will affect P%C insurance companies' investment in underwriting business, from the perspective of internal asset allocation. We study how the return of internal capital markets (ICMs) and the risk of ICMs differ across three alternative organizational forms: publicly-held stock insurers, privately-held stock insurers and mutual insurers. Because of the different combination of owner, manager and customer functions, these three organizational forms are subjected to different aspects and extents of agency problems, which leads to a variation in the performance of ICMs. In terms of return, we find that the sensitivity of investment increase in highly profitable business lines to ICM subsidy is significantly positive for private insurers, but is insignificant for mutual and public insurers. In terms of risk, we find that the sensitivity of investment increase in highly profitable and highly risky business lines to ICM subsidy is significantly positive for public insurers. Finally, we shed light on the association between organizational forms and shadow insurance, one specific ICM transaction associated with increasing firm-level risk. We find that the underwriting ROA volatility is more sensitive to shadow ICM subsidy than to regular ICM subsidy for public insurers.

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In Chapter Five, I make a conclusion of my thesis.

Chapter Two: Marginal Cost of Risk-Based Capital and Risk Taking

Abstract

We explore the impact of capital adequacy requirements on financial institutions' risk-taking behavior from a new perspective. Specifically, we show that one important feature of the risk-based capital (RBC) system, a built-in diversification benefit in aggregating risk categories, induces moral hazard. We find that insurers that face lower RBC costs of fixed-income (FI) investment purchase more risky FI securities. Using Hurricane Katrina and Hurricane Sandy as exogenous shocks to RBC cost, we find that the insurers that suffered more in the two disasters took more risk in their FI investments and that their overall risk increased. These results provide an important regulatory implication for minimum capital calculation in capital regulation regimes.

Keywords: Risk-based capital; Risk taking; Capital regulation; Insurance companies

JEL Classification: G18, G22, G32

1. Introduction

Capital regulations aim to discourage financial institutions from excessive risk taking and to prevent their insolvency. However, their effectiveness in discouraging risk-taking behavior is debatable (VanHoose, 2007). Opponents have argued that capital requirements[2] distort company behavior and can result in more risk taking (Koehn and Santomero, 1980; Kim and Santomero, 1988; Calem and Rob, 1999; Becker and Ivashina, 2015) or unintended consequences, such as procyclical lending, which exacerbates economic downturn (Repullo and Suarez, 2013; Behn, Haselmann and Wachtel, 2016). Most studies have focused on the effect of imposed capital holdings. Little attention has been paid to the moral hazard problems induced by capital regulations regardless of capital adequacy.

We show that particular interactions between the risk categories assumed in required capital calculations may encourage risk taking by lowering the marginal cost of taking additional risks. To show the relationship analytically, we study the case of the risk-based capital (RBC) calculation for U.S. insurance companies and show that applying the predetermined interactions using the square root rule of the RBC formula (i.e., the square root of the sum of the squared risk charges) explicitly assigns the marginal cost of each risk category.[3] Deriving the conditions of optimal risk taking, we hypothesize that insurers' investment decisions are unexpectedly distorted by the implied marginal RBC cost of investment. Assuming particular interactions between risk categories when aggregating risks is a common practice in setting the minimum required capital for financial institutions to incorporate diversification benefits.[4] Therefore, our argument and regulatory implications are not limited to the U.S. insurance industry, but are also applicable to broader regions and the banking industry.

[2] Capital regulation and capital requirements are used interchangeably in the paper.

[3] The effect of marginal RBC cost has been pointed out in practical reports by actuaries. Feldblum (1996) discusses the effect on reserve management incentive, mainly focusing on the liability side of the balance sheet. Zeppetalla (2002) provides a marginal analysis of RBC and suggests that insurers optimally allocate risks to produce the minimum regulatory capital. We provide the first empirical evidence that insurers adjust their risk taking in response to the RBC formula.

[4] In the insurance industry, the covariance adjustment is found in Solvency II in the European Union (e.g., Cofield, Kaufman and Zhou, 2012) and the MCCSR system in Canada. Other insurance regulatory regimes using it include, but are not limited to, Japan, Singapore and Australia. In the banking industry, similar adjustments have been adopted in risk categories in both Basel II and Basel III. Covariance adjustment is applied in both their standard and internal model approaches to set minimum capital requirements for market risk (BIS, 2016). Asset value correlation is also taken into account in the minimum asset requirements for credit risk in the internal rating based approach.

Smith (1998) documents the anecdotal evidence in U.S. life insurance industry. In 1995, GE Capital acquired Amex life insurance at an extreme high price, out of the expectation of the industry. According to Smith, GE Capital had a very asset risk-oriented subsidiary at that time, whereas Amex life was quite underwriting risk-oriented. The combination of these two companies led to very limited incremental required capital for GE due to the predetermined covariance between these two risk categories. The improved regulation capital position enabled GE to bid a higher price and take more underwriting risk at a relatively lower regulatory cost compared to its peers.

Property and casualty (P&C) insurance companies face the similar capital regulation. Under the current U.S. RBC system, there are six risk categories for P&C insurance companies and each category is subject to capital charges.[5] The square root rule applied in the RBC calculation incorporates the assumption of independence between risk categories.[6] Due to the nonlinearity of the square root rule, the marginal RBC cost of a risk category depends on other risk categories. Specifically, the lower the share of a certain risk category in the total risk charge is, the lower the charge is for an additional dollar increase in this risk category. If the marginal cost of risky investment is reduced, insurers may take advantage of the opportunity to seek higher profit at lower capital cost. This illustrates a specific channel through which built-in diversification benefits in the RBC system affect insurance companies' risk taking in investment.

In our empirical analyses, we examine how the RBC formula affects P&C insurers' risk taking in fixed-income (FI) security holdings, the largest portion of total invested assets for P&C insurers.[7] Using a sample of U.S. P&C insurance companies from 2003 to 2010, we find that insurers with lower marginal costs of FI investment increases their risk taking in the portfolio of FI security investments. Particularly, we find that they buy more and sell less *non-investment grade* or *downgraded* bonds regardless of an increase in RBC. This implies that insurers seek higher

[5] Section 2.1 provides a detailed description of the risk categories.

[6] Section 2.2 provides the firm-level RBC formula.

[7] At the 2015 year end, 68% of P&C insurers' total invested assets were FI securities, whereas 12% of their assets were common stocks, representing the second-largest investment category. Some FI instruments can be risky. The high volatility in the high-yield bond market, the mortgage-backed securities (MBS) market, the asset-backed securities (ABS) market and the FI derivative product market may pose substantial risk to insurers. This is especially true for the 2007 to 2008 crisis period. Thus, by investigating investment decisions in the most important asset class with a considerable variation of risk, we show the importance of insurers' distorted risk-taking incentives using the RBC formula.

investment returns by purchasing more risky bonds at low RBC costs. Our argument is also supported by equity holdings, the second-largest portion of total invested assets for P&C insurers.

To mitigate the endogeneity concern, we examine the impact of an exogenous shock on the marginal RBC cost of FI security holdings. We investigate how insurers adjusted their investment behavior after being hit by the two costliest natural disasters in U.S. history, Hurricane Katrina and Hurricane Sandy.[8] Both hurricanes caused affected insurers to amass huge loss reserves for their claimants, raising the capital requirement for reserve risk. Holding the same amount of risky FI investment, an increase in the capital charge of reserve risk translates to a decrease in RBC costs for acquiring additional units of risky FI securities. We show that the insurers reporting more coverage relevant to hurricane loss in severely affected states took more risk in their bond investments and purchased more risky bonds after those hurricanes. This result remains significant after controlling for the shock on capital adequacy. We also find that both relatively undercapitalized insurers and well-capitalized insurers increased their risk taking in FI investment in emergency cases (i.e., after Hurricane Katrina), whereas those with middle-level capital were insensitive to marginal RBC costs.

Our analysis of the natural disasters highlights the side effects of predetermined interactions between the risk categories incorporated into the square root rule of the RBC calculation. Moreover, the insurers did not control their overall risk. Increasing risky bond investment increases the volatility of return on assets (ROA) and overall insolvency probability as measured by the z-score. Our results call for caution in designing capital regulations.

We contribute to the literature on the economic consequences of RBC.[9] In investigating the impact of the RBC requirement, the literature has mainly focused on risk weights. However, we emphasize the importance of risk aggregation approaches. For example, Becker and Opp (2013) and Hanley and Nikolova (2015) find that a decrease in the risk weights assigned to mortgaged-backed securities increases insurers' risky investment. Behn *et al.* (2016) show that banks reduce loans subject to internal risk-based models because the corresponding risk weights increase during a financial crisis. Acharya, Engle and Pierret (2014) find that regulatory risk weights in banking stress tests fail to represent economic risk. We focus on the marginal regulatory cost implicitly

[8] Confirmed as of August 2017.
[9] RBC kind capital regulation regimes attempt to link capital charge to firm risk.

assigned by the calculation rule, which assumes certain interactions between risk categories. Cathcart, El-Jahel and Jabbour (2015) find a similar motivation, indicating the importance of the RBC formula in linking the capital ratio and the leverage ratio, especially during a credit crisis.[10]

We also contribute to the literature on regulatory design. Studies have shown evidence that certain designs in capital adequacy requirements do not effectively reduce the incentives of risk taking in financial institutions. For example, the imperfect benchmarks regime (Becker and Ivashina, 2015) and regulatory accounting rules (Ellul, Jotikasthira, Lundblad and Wang, 2015) are related to greater insurer risk taking. We show that the current predetermined interactions between risk categories implemented by the square root rule distorts insurers' incentives.

Finally, this paper contributes to the extensive literature on how minimum capital standards may affect financial institutions' risk-taking behavior (e.g., Kahane, 1977; Kareken and Wallace, 1978; Koehn and Santomero, 1980; Kim and Santomero, 1988; Furlong and Keeley, 1989; Keeley and Furlong, 1990; Gennotte and Pyle, 1991; Calem and Rob, 1999). The literature has mainly focused on how the level of capital adequacy is related to insurers' risky investments and has shown mixed results.[11] Our findings suggest that risk taking is affected not only by capital level, but also by marginal regulatory costs. Using the RBC regime in the U.S. P&C insurance industry as the research setting, we find that insurers actively make decisions on risky investments in response to the marginal RBC costs that they face.

2. Institutional background

2.1. The risk-based capital system and its components

In the U.S. insurance industry, the RBC system was adopted in 1993 for life insurers and 1994 for P&C insurers. It has since been regarded as the main capital adequacy monitoring tool by the National Association of Insurance Commissioners (NAIC), the regulatory authority of the insurance industry. According to the NAIC, "RBC limits the amount of risk a company can take.

[10] However, they do not explicitly explore how the formula may affect banks' risk taking.

[11] For example, Furlong and Keeley (1989) and Keeley and Furlong (1990) show that risk taking decreases with an increase in capital, whereas Gennotte and Pyle (1991), Kim and Santomero (1988) and Koehn and Santomero (1980) show opposite results.

It requires a company with a higher amount of risk to hold a higher amount of capital."[12] Specifically, RBC is a method of measuring the minimum amount of capital appropriate for a reporting insurer to support its overall business operations. In the RBC system, capital adequacy is assessed by the RBC ratio, defined as the ratio of total adjusted capital (TAC) to the firm's overall RBC:

$$RBC\ ratio = \frac{Total\ adjusted\ capital(TAC)}{0.5*Risk-based\ capital(RBC)} \tag{1}$$

where TAC primarily consists of capital (termed "surplus" in the insurance industry) and RBC is the required capital that reflects business and asset risks. RBC is the aggregation of capital charges of different risk categories. An insurer with a low RBC ratio is subject to regulatory action, which incurs significant costs.[13]

There are six risk categories, termed R_0 to R_5, in P&C insurance companies (Appendix 2.1 describes the risk categories). Risk charge R_0 represents risk in insurers' insurance subsidiaries. Risk charge R_1 denotes a capital charge in all unaffiliated FI securities, such as government bonds, municipal and corporate bonds, mortgage loans and MBS, ABS and other structured securities. Risk charge R_2 represents risk from unaffiliated equity investments, which mainly include common stock and preferred stock. Risk charge R_3 denotes credit risk, which includes reinsurance recoverable and other receivables. Risk charge R_4 represents reserve risk mainly composed of a risk charge for loss and loss-adjusted expenses reserve. Risk charge R_5 denotes a capital charge for premium written in different lines of business.

In risk charge R_1, which measures overall risk in insurers' FI security holdings, the risk of each security is assessed by the NAIC's security valuation office (SVO), which assigns each security in an insurer's portfolio an NAIC designation. Appendix 2.2 shows the one-to-one mapping from the credit rating provided by major rating agencies to the SVO designation, with higher designations

[12] http://www.naic.org/cipr_topics/topic_risk_based_capital.htm.
[13] There are four levels of regulatory action depending on an insurer's RBC ratio. The company action level is 150% to 200%, regulatory capital is 100% to 150%, the authorized control level is 70% to 100% and the mandatory control level is below 70%.

implying higher risk.[14] Securities with designations equal to or greater than 3 are regarded as risky assets, which require more capital.

In risk category R_2, all of the unaffiliated common stocks are charged a flat rate of 15% of stock holdings. The treatment for preferred stocks is the same as that for FI securities in R_1.

2.2. Covariance adjustment and firm-level risk-based capital

Firm-level RBC is not a simple summation of all individual charges (i.e., $\sum_{i=0}^{5} R_i$), but is determined by the following formula:

$$RBC = R_0 + \sqrt{{R_1}^2 + {R_2}^2 + {R_3}^2 + {R_4}^2 + {R_5}^2} \quad (2)$$

The square root rule applied from R_1 to R_5 represent the diversification effect between risk categories (termed "covariance adjustment" in the U.S. RBC regime). The square root rule implicitly assumes that these five risk categories are independent, which is considered more reasonable than the perfect correlation assumption for the simple summation of risk charges.[15] Feldblum (1996) and Zeppetella (2002) illustrate that the square root rule is related to the marginal effect of each risk charge on the total capital requirement. If the RBC formula is differentiable, the marginal contribution of each risk category to RBC is found by taking the derivative of RBC with respect to the risk category. For example, the marginal capital requirement for an additional dollar increase in risk category *j* is defined as follows:

$$\frac{\partial RBC}{\partial R_j} = \frac{R_j}{\sqrt{{R_1}^2 + {R_2}^2 + {R_3}^2 + {R_4}^2 + {R_5}^2}} \text{ for } 1 \le j \le 5 \quad (3)$$

Equation (3) shows that an increase in the overall RBC due to an increase in risk category *j* is its share in firm-level RBC excluding R_0. An important implication of equation (3) is that the marginal charge for an additional dollar of any risk category depends on an insurer's risk portfolio, which varies across companies and across time. In contrast, if equation (2) were a simple summation of

[14] This mapping was discontinued in 2009 for the residential MBS (RMBS) and 2010 for the commercial MBS (CMBS).

[15] Butsic (1994) shows that the degree of correlation between risk elements is critical in setting capital levels and a simple square root rule incorporates the correlation.

R_0 to R_5, the marginal charge would be the same for all insurers, independent of other risk categories.

3. Model

To examine how the RBC rule shapes insurers' investment strategies, we develop a stylized model for a single-period investment optimization problem. We assume that an insurer that maintains a given RBC ratio chooses the extent of investment risk, denoted by R_1 and R_2,[16] and that the investment yields the expected value, $V(R_i)$ for i=1,2. We assume that RBC is differentiable with respect to the choice of investment risks and that $V(R_i)$ is a concave value function ($V'>0$, $V''<0$) representing the risk-return spectrum. The insurer holds a capital, K, that incurs a cost, c, per unit capital. Hence, the capital cost is assumed to be cK. Furthermore, the target RBC ratio is defined by $F=K/\text{RBC}$.

The investment problem is defined as follows:

$$\max_{\{R_1,R_2\}} \sum_{i=1}^{2} V(R_i) - cK$$

subject to

$$\frac{K}{RBC} = F.$$

The objective function can be rewritten as follows:

$$\sum_{i=1}^{2} V(R_i) - cF \times RBC$$

The first-order condition with respect to the risk level of risky FI security investment R_1 is shown as follows:

$$\frac{\partial V}{\partial R_1} = cF\left(\frac{\partial RBC}{\partial R_1}\right) \tag{4}$$

[16] From Section 2, R_1 is the risk charge of FI security investment and R_2 is the risk charge of equity investment.

It is clear that the second-order condition is satisfied. In the first-order condition, the left-hand side is the marginal benefit of investment in risky FI securities and the right-hand side is the marginal cost of the investment. The cost of maintaining the RBC ratio, *cF*, captures the intent of capital regulation, such that a higher RBC ratio discourages risky investment. The capital regulation literature has mostly focused on the effect of capital cost, although empirical findings on the relationship have been mixed (e.g., Calem and Rob, 1999). However, equation (4) indicates that the marginal RBC cost of risky investment, $\partial RBC/\partial R_1$, also affects risk-taking decisions. For example, when the marginal RBC cost of R_1 decreases, the optimal level of the risk charge increases due to the concave expected value function, ceteris paribus. Thus, even if holding an adequate capital can reduce the incentive of making risky investments (e.g., for banks, Furlong and Keely, 1987; Furlong and Keeley, 1989; Keeley and Furlong, 1990), it may not be sufficient to make an insurer risk prudent, as the marginal RBC cost of risky investment may dominate or be independent from the effect of capital cost. Therefore, it is important to investigate how the marginal RBC cost of investment is related to risk taking.

Furthermore, substituting the RBC formula into the first-order condition, we find that optimal risk taking on risky FI security investment is determined by the following relationship:

$$\frac{\partial V}{\partial R_1} = cF\left(\frac{R_1}{\sqrt{{R_1}^2+{R_2}^2+{R_3}^2+{R_4}^2+{R_5}^2}}\right) \tag{5}$$

According to the model prediction, we hypothesize that insurance companies facing a lower RBC cost of FI security risk make more risk in the portfolio of FI security investments (R_1), which may be achieved by increasing holdings of non-investment grade and downgraded FI instruments.[17] These two types of securities are of higher expected return and now be charged at lower marginal regulatory costs for these insurers[18]. Equation (5) also implies that when other risks increase (e.g., when the reserve risk charge R_4 increases), the marginal RBC cost of R_1 decreases and hence the optimal level of R_1 increases. Thus, an exogenous shock on reserve risk is expected to increase the extent of risky FI security investment, providing a prediction regarding the impacts of major hurricanes on the investments reported in Section 6.

[17] We also calculate the risk charge of equity investment R_2 and test a similar hypothesis in the robustness tests.
[18] It means that the net benefit of investing in these risky bonds now becomes larger.

4. Data and sample

4.1. Data and variables

4.1.1. Risky fixed-income security investment

To assess the marginal RBC cost effect on risky FI security investment, we first examine the relationship between the marginal RBC cost of R_1 and the change of R_1, the risk charge of the portfolio of FI securities including government bonds, municipal and corporate bonds, mortgage loans and MBS and ABS.

To further investigate insurers' risky bond investment behaviors, we define risky FI securities as non-investment grade or downgraded FI securities (Duchin and Sosyura, 2014; Becker and Ivashina, 2015; Ellul *et al.*, 2015), which are identified by SVO designations from NAIC Schedule D. Non-investment grade FI securities are instruments with designations equal to or greater than 3, which corresponds to bonds with S&P ratings lower than BB+ (Appendix 2.2). We define downgraded FI securities as instruments with SVO designations that have deteriorated compared to the previous year.

4.1.2. Risky FI investment measures

We measure insurers' risk taking in the portfolio of FI securities by using the growth rate of risk charge for FI securities, R_1.

To capture insurers' investment in risky FI securities, we use the data on insurers' transactions and positions of FI securities obtained from NAIC Schedule D, which provides detailed transaction and year-end holdings at the security level (9-digit CUSIP level). Using the transaction data, we calculate the real purchases and sales of FI securities, disregarding the changes in the holdings that come from maturity, repayment, calls and other non-trading activities (e.g., Hanley and Nikolova, 2015). Focusing on risky investments, we prepare four dependent variables for non-investment grade and downgraded FI securities.

NoninvtFI Buy (*DownFI Buy*) measures the purchase of non-investment grade (downgraded) FI securities. It is defined as the book-adjusted carrying value (BACV) of the acquired non-investment grade (downgraded) FI securities on the purchase day[19] scaled by the year-beginning BACV of the insurer's FI holdings.

NoninvtFI Sell (*DownFI Sell*) measures the sale of non-investment grade (downgraded) FI securities. It is calculated as the BACV of the non-investment grade (downgraded) FI securities sold, scaled by the year-beginning BACV of the insurer's FI holdings.

We further construct *NoninvtFI Net Buy* (*DownFI Net Buy*) to measure insurers' net investment in non-investment grade (downgraded) FI securities. *NoninvtFI Net Buy* is calculated as the difference between *NoninvtFI Buy* and *NoninvtFI Sell*. Similarly, *DownFI Net Buy* is calculated as the difference between *DownFI Buy* and *DownFI Sell*.

To measure the proportion of risky FI in the net purchase of all FI securities during the year, we prepare the variable *NoninvtFI Net Share* (*DownFI Net Share*). It is calculated as the net purchase of non-investment grade (downgraded) FI securities, scaled by the net purchase of all FI securities during the same year, instead of by the year-beginning holdings of all FI securities.

4.1.3. Marginal risk-based capital cost of risky fixed-income security holdings

Although the marginal RBC cost of risky FI security investment is simply defined in equation (3), each risk charge is not readily available. Therefore, we manually calculate risk charges R_0, R_1 and R_2 using data obtained from the insurance companies' annual NAIC statements.[20] Calculating R_1 and R_2, we follow Feldblum (1996) and NAIC instructions and we consider the bond size and concentration factors.[21] The denominator of the RBC cost of FI investment is calculated by subtracting R_0 from firm-level RBC (*RBC*). Thus, we derive the RBC cost of risky FI securities (*RBC Cost FI*), expressed as $R_1/(RBC\text{-}R_0)$. In robustness tests, we also use the RBC cost of equity investment (*RBC Cost Stock*), expressed as $R_2/(RBC\text{-}R_0)$, to test whether insurers' equity investments are related to their equity RBC costs.

4.1.4. Control variables

In the following analyses, we control for a number of firm characteristics that can be classified into broad two categories. The first group consists of insurer operation and profitability (Cheng

[19] The BACV at the purchase day is the actual cost paid by the insurer to acquire the bond.
[20] The NAIC's annual statements do not disclose enough information and data to calculate R_3, R_4 and R_5.
[21] See Risk-Based Capital Forecasting and Instructions - Property/Casualty, 2015.

and Weiss, 2013; Ellul, Jotikasthira and Lundblad, 2011; Lin, Lai and Powers, 2014). This group includes RBC ratio (equation (1)), leverage ratio (liability scaled by admitted assets), return on equity (ROE; net income divided by surplus), size of capital (natural logarithm of surplus), business concentration (line of business Herfindahl index), geographic concentration (geographic Herfindahl index), long-tail business (direct premiums written, DPW, in long-tail lines of business divided by total DPW), organizational form (mutual or stock insurer) and group affiliation (whether the insurer is affiliated to one group).

The second group of control variables is expected to explain insurer investment portfolio characteristics (Yu, Lin, Oppenheimer and Chen, 2008; Ellul *et al.*, 2015). This group includes the proportion of non-investment grade FI securities in the total FI security holdings; the proportion of downgraded FI securities in the total FI security holdings; the share of risky assets in the total invested assets (the book value of equity investment, real asset investment, mortgage loan investment and other long-term investment, scaled by the insurer's total invested assets); and portfolio maturity (the average maturity of the insurer's FI portfolio weighted by its book value). Both groups of control variables are measured at the beginning of the year. Appendix 2.3 provides all of the variable descriptions.

4.2. Sample construction

Our sample space starts with all U.S. P&C insurers filing annual reports to the NAIC from 2003 to 2010. We do not include 2011 to 2015 in our main sample due to the RBC regulation reforms in 2009 and 2010, which took effect in 2010 and 2011, respectively (Becker and Opp, 2013; Hanley and Nikolova, 2015).[22]

We exclude insurers with missing or negative asset values and we only include insurers with positive direct premiums and net premiums written to ensure that our sample insurers are active. Insurer-year observations with missing RBC values are excluded. Insurers that report negative R_1 risk charges are excluded. Due to a lack of detailed information on insurers' subsidiaries and affiliates, we exclude insurers with positive investment in insurance subsidiaries and affiliates[23]

[22] In a robustness test, we expand the sample period from 2003 to 2015 for non-MBS FI securities.

[23] Specifically we drop insurers with risk-based capital charge for investments in their subsidiaries, controlled or affiliated (SCA) companies. The main reason we drop these insurers is that we lack information to calculate the risk charge for these subsidiaries or affiliates. The risk charge is in R_0. We identify insurers with risk-based capital charge for investments in subsidiaries, controlled or affiliated (SCA) companies by investigating the information from

to ensure that we can accurately calculate risk charges R_0 to R_2.[24] Only insurer-year observations with positive holdings of non-investment grade FI securities at the beginning of the year are included. Including insurers with no investment in risky FI securities biases the results towards our hypothesis, as these insurers have nothing to sell in the current year and have low RBC costs of risky FI securities. Our final sample includes 4,226 insurer-year observations from 2003 to 2010, with 1,122 unique insurers and accounting for approximately 61% of total annual industry assets.

4.3. Summary statistics

4.3.1. Risk-based capital cost of fixed-income securities and stocks

Table 2.1 shows the development of the RBC costs of FI securities (*RBC Cost FI*) and stocks (*RBC Cost Stock*). The average (median) RBC cost of FI securities is lower than that of stocks. The average risk charge on FI securities is approximately half of that on stocks. From 2003 to 2015, the increase in the RBC cost of FI securities was dwarfed by the increase in the RBC cost of stocks. The mean and median values of the RBC cost of stocks dropped during the financial crisis from 2008 to 2010, but recovered later. In contrast, the RBC cost of FI securities was not significantly affected by the financial crisis.

4.3.2. Firm-level characteristics

Table 2.2 shows the summary statistics for our sample. The average annual growth rate of risk charge in FI investment (R_1) is 11.1%. The average sale and purchase of non-investment grade FI securities (*NoninvtFI Sell* and *NoninvtFI Buy*) account for approximately 0.68% and 0.5% of all of the FI security holdings at year beginning, respectively. The average sale and purchase of downgraded FI securities (*DownFI Sell* and *DownFI Buy*) account for approximately 0.56% and

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Schedule D part6. There are eight categories of SCA companies. Parent, US P&C, US life, US health, Alien insurer, Non-insurers which controls insurers, Investment subsidiary, and other affiliates.

We drop insurers reporting positive investment in common stocks or preferred stock in the following 6 SCA categories: US life, US P&C, US health Alien insurer, Non-insurer which controls insurer, as we lack information to calculate the risk-based charge for these affiliated investment in R_0. We also drop insurers reporting positive investment in SAC Investment subsidiary. Risk-based capital charge for an Investment subsidiary is determined by looking through the subsidiary to its investment holdings. We don't have information to calculate the risk-based charge for this kind of investment. Please refer to Risk-Based Capital Forecasting and Instructions - Property/Casualty (2015) for detailed information.

[24] This requirement excludes 2,389 firm-year observations (approximately 36%). This restriction excludes relatively large insurers from our sample. The summary statistics of the universe of insurers are available from the authors upon request.

0.24% of all of the FI security holdings, respectively. Thus, the average size of the transactions for non-investment grade FI securities is larger than that for downgraded FI securities. The means of the net purchases of both risky FI securities (*NoninvtFI Net Buy* and *DownFI Net Buy*) are negative. This indicates that the average insurer reduced its holdings of speculative and downgraded FI securities during the sample period.

Our main explanatory variable, the marginal RBC cost of acquiring one additional dollar of risky FI securities (*RBC Cost FI*), is 0.08 on average and varies substantially across insurers and across time. For the other firm-level control variables, the average RBC ratio is 1,220%, significantly higher than the Company Action Level RBC of 200%. This indicates that most insurers have adequate capital. For organization structure, 62.1% of our sample insurers belong to a business group and 17% of them are mutual insurers. For the business operation variables, the average ROE is 6.8%. This indicates that the insurers generally made profit during the sample period. The average insurer in our sample holds capital and surplus of USD36.7 ($=e^{10.51}/1,000$) million. Our business and geographic concentration measures (*Lob Herfindahl* and *Geo Herfindahl*) have mean values of 0.53 and 0.56, respectively, showing diversified business portfolios across lines of business and states. The average firm in our sample has 73.2% of long-tail insurance business (*Longtail*), a significant portion of the firms' business portfolios.

For insurer investment portfolio characteristics, the average insurer's holdings of speculative FI securities (*NoninvFI Position*) and downgraded FI securities (*DownFI Position*) are approximately 2.7% and 2.5% of its total FI security holdings, respectively. The average insurer holds 12.6% of risky assets other than risky FI securities (*Other Risky Assets*) in its invested assets.

5. Empirical methodology and results

5.1. Risk-based capital cost of fixed-income securities and insurers' risky investment

In this section, we first examine whether insurers facing lower RBC costs of FI securities increase the risk charge in R_1, and then we focus on the trading of two specific classes of FI investments: non-investment grade FI securities and downgraded FI securities.

We consider the following linear model with firm-fixed effects to reduce concerns about omitted variables:

$$Growth\ of\ R_1\ or\ Noninvt\ trade(Down\ trade)_{it} = \alpha_0 + \alpha_i + \alpha_t + \beta(RBC\ cost\ FI)_{it-1} + \gamma_x X_{it-1} + \varepsilon_{it} \quad (6)$$

where α_0, α_i and α_t represent constant, firm *i* fixed effect and year *t* fixed effect, respectively. The normally distributed error term is denoted by ε_{it}. The dependent variable is either growth rate of R_1 or insurers' risky FI investment proxies. As described in Section 4.1.2, we prepare four alternative variables to describe insurers' trading of non-investment grade FI securities (*Noninvt trade*) and downgraded FI securities (*Down trade*). They are *NoninvtFI Sell*, *NoninvtFI Buy*, *NoninvtFI Net Buy* and *NoninvtFI Net Share* for non-investment grade FI securities and *DownFI Sell*, *DownFI Buy*, *DownFI Net Buy* and *DownFI Net Share* for downgraded FI securities.

Our explanatory variables include insurers' RBC cost of acquiring FI securities, a *k*-vector of insurer-level control variables and a set of firm- and year-fixed effects. The parameter β is our primary interest and captures the influence of RBC cost on risky FI security investment. We also calculate robust standard errors clustered by insurance companies.

The first column of Table 2.3 reports the ordinary least squares regression results for the growth of risk charge R_1. The coefficients of *RBC Cost FI* is negative and significant, implying that insurers facing lower RBC costs of FI securities increase the overall risk level of the FI security portfolio, R_1. If the RBC cost of FI securities drops from the third quartile to the first quartile of the distribution of *RBC Cost FI* (i.e., by -0.051), the risk charge in R_1 marginally increase by 18.9%.[25] This substantial increase in the risk charge of the FI security portfolio supports our hypothesis that insurers with lower RBC cost of FI securities will increase the R_1 investment.

Columns 2 to 3 of Table 2.3 report the results for insurers' investments in risky FI securities, which are measured by the net purchase of non-investment grade and downgraded FI securities. The coefficients of *RBC Cost FI* are negative and significant in columns 2 and 3, indicating that insurers with lower (higher) RBC costs purchase more (fewer) non-investment grade and downgraded FI securities. We estimate the impact of the marginal RBC cost. If the RBC cost of FI securities drops from the third quartile to the first quartile of the distribution of our sample *RBC Cost FI* (i.e., by -0.051), the average firm's scaled purchase of non-investment grade FI securities increases by 142%

[25] 0.189=-3.7002*(-0.051)

and its scaled purchase of downgraded FI securities increases by 57.6%.[26] Thus, the results are also economically significant.[27]

For other firm-level characteristics, the RBC ratio is significant and positively related to the net purchase of risky FI securities, which is consistent with the literature (Ellul, Jotikasthira and Lundblad, 2011; Ellul *et al.*, 2015). We also find that a higher ROE is related to a higher net purchase of risky FI securities. For the investment portfolio characteristics, we observe that the proportion of other risky assets (*Other Risky Assets*) is positively related to the net purchase of risky FI securities, which is consistent with the finding of Ellul et al. (2015). They argue that the proportion of risky asset measures the risk appetite of an insurer. We also find that initial risky FI positions (*NoninvtFI Position* and *DownFI Position*) are negatively related to the net purchase of risky FI securities.

To examine insurers' choice of risky FI securities in the total current-year investment, in columns 4 and 5 we use *NoninvtFI Net Share* and *DownFI Net Share* as dependent variables. They are the net purchase of risky FI securities, scaled by the current-year net purchase of FI securities instead of by year-beginning FI holdings. We study the share of risky FI investment in the total FI net purchase to investigate whether the above results reflect the situation in which insurers increase their purchase of both risky and non-risky FI securities while the mix of risky and non-risky investment stays constant or even decreases.

The results in columns 4 and 5 consistently show that the marginal RBC cost of FI investment is negatively associated with the share of risky FI investment. The results indicate that insurers facing lower RBC costs of risky FI securities increase their net purchase of risky FI securities more than that of non-risky FI securities. These results are also economically significant. If the RBC cost of FI securities declines from the third quartile to the first quartile of the distribution of our sample *RBC Cost FI* (i.e., by -0.051), the share of non-investment grade FI securities in the total net purchase of FI securities increases by 370.7% and the share of downgraded FI securities increases

[26] 1.42=-0.051*(-0.0504)/|-0.0018|, where -0.0018 is the average of *NoninvestFI Net Buy*. 0.576=-0.051*(-0.0362)/|-0.0032|, where -0.0032 is the average of *DownFI Net Buy* (Table 2.2).
[27] Regardless of the small proportion of these risky investments, these risky investments are economically significant due to the large risk factors applied to these risky investments. See Appendix 2.2.

by 48.7%. The results suggest that insurers with low RBC costs of FI securities have higher shares of net purchase of risky investment. Therefore, the risk of the entire FI portfolio increases.

To understand more about insurers' investment behavior, we disaggregate the net purchase of risky FI securities into FI-selling (*NoninvtFI Sell* or *DownFI sell*) and FI-purchasing (*NoninvtFI Buy* or *DownFI Buy*). Insurers with higher RBC costs of FI investment receive more capital relief for selling risky FI securities than insurers with lower costs. Thus, the coefficient of *RBC Cost FI* is expected to be positive in the FI-selling regressions. Furthermore, insurers with higher RBC costs of FI investment face higher capital charges for acquiring risky FI securities than insurers with lower costs. Thus, the coefficient of *RBC Cost FI* is expected to be negative in the FI-purchasing regressions.

Table 2.4 reports the regression results for the non-investment grade FI securities (columns 1 to 2) and downgraded FI securities (columns 3 to 4), disaggregating the net purchase of risky FI securities. We observe that the coefficients of the marginal RBC cost of FI securities are significant with positive signs in columns 1 and 3 and with negative signs in columns 2 and 4. These results show that insurers with lower RBC costs of acquiring risky FI securities purchase more and sell fewer non-investment grade or downgraded FI securities. If the RBC cost of FI securities declines from the third quartile to the first quartile of the distribution of our sample *RBC Cost FI* (i.e., by -0.051), the average firm decreases its selling of non-investment grade FI securities by 10.2% and of downgraded FI securities by 13.8%. Furthermore, this decrease in the RBC cost of FI securities translates to a 37.5% increase in the purchase of non-investment grade FI securities and a 44.8% increase in the purchase of downgraded FI securities, which are economically significant.

Collectively, these results support our argument that insurers' investment behavior responds to the marginal RBC cost. Insurers take more risk in their financial investments to seek more profit due to the reduced cost of risk taking.

5.2. Domestically controlled versus foreign-controlled insurers

The RBC system is applied to all insurers domiciled in the U.S. However, an insurer's risk taking is affected by its parent firm's regulatory regime, which may be different from that of the U.S. RBC system (e.g., Solvency II in the European Union). Therefore, whether an insurer is controlled by a U.S. insurer or a foreign insurer matters.

To illustrate how capital requirement formulae are different, we compare the Solvency II formula for the basic solvency capital requirement (BSCR) to the U.S. RBC formula. The required capital or BSCR under Solvency II is calculated as follows:

$$BSCR = \text{Intangible asset} + \sqrt{\sum_{i \neq j} \rho_{ij} * C_i * C_j + \sum_{i} {C_i}^2}$$

where C_i denotes Solvency II's risky component. In Solvency II, a set of correlation parameters, ρ_{ij}, is pre-determined in the model, whereas the correlation between risk components is assumed to be 0 in the U.S. RBC formula. The marginal contribution of risk component *j* in Solvency II can be obtained by taking the first derivative of the BSCR with respect to C_j:

$$\frac{\partial BSCR}{\partial C_j} = \frac{2C_j + \sum_{i \neq j} \rho_{ij} * C_i}{2 * \sqrt{\sum_{i \neq j} \rho_{ij} * C_i * C_j + \sum_{i} {C_i}^2}}$$

Thus, the marginal contribution of a risk category is consistent with that for the RBC system in that the marginal cost of risk is not only affected by the risk charge of risk category *j*, but also by other risk categories. However, the marginal BSCR cost is quite different from the U.S. RBC cost of FI securities in equation (3) due to the correlation terms.

We assume that U.S. insurers controlled by foreign entities or persons operate more closely to their parent companies in foreign jurisdictions (e.g., the European Union)[28] and hypothesize foreign-controlled insurers are less sensitive to marginal RBC costs in their risky FI security investment decisions. To test this hypothesis, we define insurers with more than 50% of foreign ownership as foreign-controlled and we split insurers into domestically and foreign-controlled insurers.

Table 2.5 reports the regression results for foreign-controlled insurers and for domestically controlled insurers, respectively. The coefficients of *RBC Cost FI* are significant at 1% level in the domestically controlled subsample. When comparing the coefficient of *RBC Cost FI* across these two subsamples using Chow test, we find that the magnitude of the coefficient is significant larger for domestically controlled insurers, indicating they are more responsive to the RBC cost for their

[28] It can be caused by similar internal control between subsidiaries or branches and their parent firms. Also, Solvency II's requirement for the parent company to consolidate the subsidiaries' risk into their own risk profile deters subsidiaries' regulatory arbitrage in the U.S. RBC system.

investment decision. This contrast between domestically and foreign-controlled insurers provides evidence that the current RBC calculation rule significantly affects insurers' risky FI security investments.

6. Hurricane Katrina and Hurricane Sandy as exogenous shocks

Despite the robust results for the relationship between marginal RBC cost and risky investment, one may raise concerns about endogeneity. For example, bond investment in a subsequent year is related to current bond holdings, whereas current bond holdings affect the RBC cost of FI securities. However, we note that the RBC cost of acquiring FI securities (i.e., the cost of R_1) is not necessarily endogenous, as the operating performance of underwriting business (on the liability side of balance sheets) has an exogenous impact on the RBC cost of FI products (on the asset side). Even if insurers can predict or manage the underwriting result, such as by manipulating reserve [29](e.g., through manipulating reserve error, see Grace and Leverty, 2012; Kamiya and Milidonis, 2016), risk charges R_4 and R_5 are still not necessarily endogenous insurer decisions. According to the NAIC instructions for determining R_4 and R_5, insurers must compare their underwriting results to industry results, which cannot be fully controlled by individual insurers.

To further mitigate the endogeneity concern, we use the two costliest natural disasters in U.S. history, Hurricane Katrina (August 23 to 30, 2005) and Hurricane Sandy (October 30 to 31, 2012), as exogenous shocks. Hurricane Katrina caused USD153.8 billion in damage and killed 1,833 people. Hurricane Sandy was the second-costliest hurricane, causing USD67.6 billion in damage and killing 159 people.[30]

The two hurricanes provide relatively exogenous settings. First, although hurricanes are fairly predictable, the amount of damage they will cause is not. Second, these two hurricanes struck in different areas. Hurricane Katrina hit the Gulf Coast states, whereas Hurricane Sandy hit the mid-Atlantic and the northeastern part of the U.S. The New York Stock Exchange even closed for two

[29] Claims reserve funds are set aside for the future payment of incurred claims that have not been settled and thus represent a balance sheet liability.
[30] See NOAA National Centers for Environmental Information (NCEI). U.S. Billion-Dollar Weather and Climate Disasters (2016). https://www.ncdc.noaa.gov/billions/.

consecutive days. Historically, the mid-Atlantic and the northeastern part of the U.S. have been less likely than the Gulf Coast states to suffer from hurricane disasters.[31]

6.1. Identification strategy

The significant damage produced by these two hurricanes caused the affected insurers to amass loss reserves and loss adjustment expense (LAE) reserves to prepare for unpaid losses and their associated expenses.[32] The R_4 risk charge, mainly the product of firm-specific risk weight and the sum of unpaid loss reserves and LAE reserves, increased as a result of the increase in unpaid loss and LAE reserves.

Figure 2.1 shows the average loss and LAE reserve development of the hurricane-impacted and non-impacted insurers (the left-hand side for Hurricane Katrina and the right-hand side for Hurricane Sandy). The reported reserve is measured by insurers' unpaid loss and LAE reserves occurring in the current year, scaled by the year-beginning RBC. We define hurricane-impacted insurers as insurers with positive DPW in homeowner lines in the hurricane-impacted states during the hurricane year and as non-impacted insurers otherwise. The scaled reserve level spiked upward during the affected years (2005 and 2012) for the hurricane-impacted insurers, whereas the non-impacted firms experienced reserve declines. Both the impacted and non-impacted groups show similar trends of reserve development before and after each hurricane shock.

The impact of the exogenous increase in R_4 on the marginal RBC cost of risky investment can be observed in equation (5): insurers' risky bond investment optimally increases as the RBC cost of FI securities decreases. Affected insurers face the opportunity to seek higher investment return at reduced RBC costs of acquiring risky bonds.

As the R_4 risk charge is not directly observable, we use several metrics to identify the insurers that suffered in each hurricane disaster. In the insurance literature, homeowner lines are regarded as the most prone to hurricane disasters (Cheng and Weiss, 2012). First, we measure one insurer's hurricane exposure by using the proportion of DPW of the homeowner multiple peril line in the

[31] Hurricane Katrina and Hurricane Sandy are commonly used as exogenous shocks in the literature (Barrot and Sauvagnat, 2016; Bernile, Bhagwat and Rau, 2016).

[32] For example, the Mississippi Farm Bureau Mutual Insurance Co., accounting for approximately 20% of the homeowner market share in Mississippi, tripled its loss reserve in 2005 after Hurricane Katrina.

affected states[33] in its total DPW (*DPW Exposure*). For example, the *DPW Exposure* for Hurricane Katrina is measured as follows:

$$DPW\ Exposure_i = \frac{\sum_s\ DPW \text{ in homeowner line}_{is,2005}}{DPW_{i,2005}}, s \in \text{Katrina impacted States}^{34}$$

where *i* indicates insurer and *s* indicates state.[35]

DPW Exposure is a flow variable that captures the operation in a certain period. We also use the share of direct loss unpaid and direct defense cost and expenses unpaid reserve in the impacted states (*Loss resv Exposure*) to measure hurricane exposure. It is a stock variable that reflects one insurer's historical and current hurricane exposure. Similarly, we construct exposure variables for Hurricane Sandy.

We use the difference-in-differences setting to investigate how change in RBC cost affects insurers' investment behavior by estimating the following model:

$$\begin{aligned} &NoninvtFI\ Net\ Buy_{\mathrm{it}}\ (DownFI\ Net\ Buy_{it}) \\ &\qquad = \alpha_0 + \alpha_i + \alpha_t + \beta_1 Post + \beta_2 Exposure + \ \beta_3 Post * Exposure \\ &\qquad + \gamma_x X_{it-1} + \varepsilon_{it} \end{aligned} \tag{7}$$

The treatment variable (*Exposure*) is a continuous variable ranging from 0 to 1. It measures insurers' exposure to Hurricane Katrina in 2005 and to Hurricane Sandy in 2012. As described above, we have two alternative proxies to measure exposure to each hurricane: *DPW Exposure* and *Loss resv Exposure.* The higher the hurricane exposure is, the lower the RBC cost is to acquire risky FI securities.[36] The post-treatment indicator (*Post*) equals 1 in 2006 for the regressions for Hurricane Katrina, 1 in 2013 for the regressions for Hurricane Sandy and 0 otherwise.

[33] Appendix 2.4 lists the states affected by Hurricane Katrina and Hurricane Sandy. We obtain information on the states struck by each hurricane from Table 1 of Barrot and Sauvagnat (2016). They obtain related data from the Spatial Hazard and Loss Database for the United States, maintained by the University of South Carolina.
[34] *DPW* in the equation can be replaced by *Loss resv*.
[35] Similar to DPW, we use direct premiums earned (*DPE Exposure*), direct loss and direct defense cost and expenses (*Loss incur Exposure*) incurred as alternatives. We obtain similar results with these exposure measures.
[36] We also use the dummy variable for the treatment group. The results are similar.

The variable of interest is the post-exposure interaction term (*Post*Exposure*). The parameter β_3 captures the change in the net purchase of non-investment grade FI securities by the hurricane-impacted insurers relative to the change in net purchase by the non-impacted insurers. The estimated coefficient is expected to be positive, indicating that hurricane-affected insurers purchase more risky FI securities, as the increase in R_4 caused by a hurricane reduces the RBC cost of risky FI securities. We control for firm characteristics and for firm and year fixed effects. We report robust standard errors clustered by insurance companies. We use a 3-year window, beginning 1 year before the hurricane and ending 1 year after the hurricane.

6.2. Main results

Table 2.6 shows the results for Hurricane Katrina. In columns 1 and 2, we use *DPW Exposure* to measure hurricane exposure and *Loss resv Exposure* in columns 3 and 4 as an alternative exposure measure. We find that the coefficients of the post-exposure terms are positive and significant in columns 1 to 4, indicating that insurers that are more exposed to hurricanes increase their investments in risky bond investment more. In columns 1 and 2, we observe that compared to the non-impacted insurers, the median-affected insurer (with 9.5% of its DPW in homeowner lines in hurricane-affected states) has 39.6% higher net investments in non-investment grade FI securities and 22.7%[37] higher net purchases of downgraded FI securities.[38]

One concern is that this risk-taking behavior of affected insurers may be caused by loss of capital due to claim payments instead of the marginal RBC cost of risky bond investment. To disentangle the marginal RBC cost incentive from incentives to recover loss of capital, we augment equation (7) with the change of surplus scaled by assets (*ΔSurplus*) and the underwriting income scaled by surplus (*Underwrite Gain*) to further control for the effect of loss of capital. These two variables are also lagged by 1 year in the regression models.

In columns 5 to 8, we add two variables measuring negative capital shock. The coefficients of the post-exposure terms have similar magnitudes and significance levels to those in columns 1 to 4.

[37] 39.6%=|9.5%*1*0.0126/(-0.00302)|, where -0.00302 is the mean of *NoninvestFI Net Buy* in the Katrina sample. 22.7%=|9.5%*1*0.0086/(-0.003586)|, where -0.003586 is the mean of *DownFI Net Buy* in the Katrina sample.

[38] When the firms are hit with large shocks like Katrina, insurers may be forced to sell invested assets to have the liquidity to pay of claims. They may sell the most liquid bonds first (investment grade). However, the selling of most liquid bonds doesn't significantly affect the proxies we used to measure the net purchase of risky bonds.

These results further confirm the presence of RBC cost incentives even after controlling for the shock on capital.

Table 2.7 shows the results for Hurricane Sandy. Due to the RBC reform for the CMBS and RMBS occurring after 2010,[39] we construct our dependent variables on non-MBS FI securities. The estimated coefficients of the post-exposure terms are significant for all non-investment grade FI security regressions, but they are insignificant for downgraded FI security regressions. The magnitudes of the coefficients are consistent with the results in Table 2.6. Compared to non-impacted insurers, the median-affected insurer with 9% of its DPW in homeowner lines in hurricane-affected states has 40% more net purchases of non-investment grade FI securities. In addition, similar to the results for Hurricane Katrina, the coefficients of the interaction term remain positive and significant at the 5% level after controlling for the capital shock variables in Hurricane Sandy.

Overall, these results are consistent with our expectations for the insurers hit more severely by Hurricane Katrina. Their RBC costs of acquiring risky FI securities decrease exogenously, and they take more risks in seeking profit due to the reduced regulatory cost of risk taking.

6.3. Insurer overall risk

In this section, we study whether insurers' overall risks increase after hurricanes. In Section 6.2 we show that hurricane-impacted insurers increase their investment risk. If insurers attempt to keep their overall risk level constant after a hurricane, they may reduce other risks when they increase their investment risk. Following the literature, we measure the aggregate insurer-level risk with two variables (Duchin and Sosyura, 2014; Ljungqvist, Zhang and Zuo, 2017). The first variable is ROA volatility (*ROA Vol*), the standard deviation of annual comprehensive return on admitted assets over the 3-year period from year *t*-2 to year *t*. The second variable is *z-score*, defined by a comprehensive ROA plus capital asset ratio divided by *ROA Vol.* The z-score is a measure of distance to insolvency, which aggregates the effects of leverage and asset composition. It approximates the inverse of default probability, with a higher z-score reflecting a lower chance of

[39] Section 7.1 provides details.

default. We use comprehensive income to construct these two variables, as we want to include the unrealized capital gains from insurers' investment.

We expand our sample by relaxing the restriction that insurers should hold positive non-investment grade FI security positions, as our dependent variables are not the transactions of risky FI securities.

Tables 2.8 and 2.9 show the results for Hurricane Katrina and Hurricane Sandy, respectively. Overall risk is measured by *ROA Vol* in columns 1 to 2 and by *z-score* in columns 3 to 4. Hurricane exposure is measured by *DPW* in columns 1 and 3 and is measured by *Loss resv* in columns 2 and 4. Table 2.8 shows that the coefficients of the post-exposure terms are positive and significant for the ROA volatility measure. These results suggest that insurers with higher exposure to Hurricane Katrina have higher ROA volatility than non-impacted insurers after the hurricane. Insurers do not take a risk-reducing strategy to offset the risk increased in their FI portfolio after a huge loss. In column 3 where we measure exposure to Katrina using loss reserve, we find a significant difference in the post-hurricane z-scores of impacted and non-impacted insurers at the 10% level. We also include loss of capital measures in columns 5 to 8 and obtain similar results.

Table 2.9 shows results for Hurricane Sandy. The estimated coefficients for the interaction term (positive for *ROA Vol* and negative for *z-score*) indicate the firm-level risk would significantly increase for the insurers that suffered Hurricane Sandy. The interaction terms for the z-score models indicate that the insurers' likelihood of default (the inverse of *z-score*) increased in the year following Hurricane Sandy. In column 4, the insurer with median exposure to Sandy (approximately 0.11) had a decrease of 2.7% in z-score, whereas the insurers with no exposure to Sandy had an increase of 7.1% in z-score.[40] After adding loss of capital measures in columns 5 to 8, we obtain similar results.

Collectively, the results reported in Tables 2.6 and 2.7 suggest that insurers hit by hurricanes increase risk in their FI portfolios. If insurers are prudent in their operations, they may maintain or lower their overall risk level after a hurricane by offsetting necessarily increased investment risk with a reduction in underwriting risk. Contrary to such an expectation, Tables 2.8 and 2.9 show

[40] 2.7% = |(0.054-0.2728*0.11)|/0.874, where 0.874 is the average z-score for insurers with positive exposure. 7.1% = (0.054)/0.762, where 0.762 is the average z-score for insurers with positive exposure.

that the overall risk of hurricane-impacted insurers increase more than that of non-impacted insurers after a hurricane.

Thus, the results for the natural disaster cases highlight the side effect of the current calculation formula in the U.S. RBC system. Insurers severely impacted by hurricanes even increase their investment risk and overall risk after suffering from the huge underwriting risk. The results emphasize that the existing RBC system does not provide the right incentive for insurers to manage risks, as the RBC formula embeds the diversification benefit of risk in both assets and liability.

7. Capital adequacy level and insurers' risk taking

To contribute to the capital requirement literature on the effect of capital adequacy on risk-taking incentive, we study how capital adequacy and RBC cost interact to affect insurers' risky investment, in normal time and in emergency time.

The theoretical literature has made mixed predictions on how RBC adequacy is related to insurers' risk investment (e.g. Kahane, 1977; Kareken and Wallace, 1978; Koehn and Santomero, 1980; Kim and Santomero, 1988; Furlong and Keeley, 1989; Keeley and Furlong, 1990; Crouhy and Galai, 1991; Gennotte and Pyle, 1991). Several factors shape this relationship. The first is risk-shifting benefit. Financial institutions attempt to make more risky investments when they hold little capital, as the shareholders can shift the risk to policyholders or debt holders who have fixed claims in the firms. The second is the high yield from risky investment. The third is the regulatory cost incurred when capital adequacy is below the regulatory threshold.

Calem and Rob (1999) reconcile the conflicting views in their theoretical work. They derive a U-shaped relationship between capital holding and risk taking. They argue that banks take more risk when they hold little capital due to the risk-shifting benefit. When capital increases, banks are faced with the possibility that they will experience loss of capital from adverse investment outcomes without insolvency, thus preventing them from fully benefitting from the risk-shifting mechanism. When capital levels increase even more, banks start to take more risk because the risk of insolvency is small and the yield from risky investment is higher than from safe assets.

Based on the theoretical literature, we empirically test the relationship between capital adequacy and insurers' risky investment.[41] We measure insurers' capital level using the RBC ratio. A higher RBC ratio is indicative of more adequate capital. We measure insurers' risk taking by using the sensitivity of risky investment to the RBC cost of FI securities. We first partition our main regression sample into terciles based on insurers' year-beginning RBC ratio[42] and then run regression equation (6) for each subsample. To facilitate comparison, we use the same set of control variables in both cases, not adding loss of capital variables.[43]

Panel A of Table 2.10 shows the results for the entire sample. The coefficients of marginal cost of FI investment (*RBC Cost FI*) are only significant in columns 3 and 6, suggesting that insurers with high RBC ratios take more advantage of reduced RBC cost in their risk taking. These results lend support to Koehn and Santomero (1980) argument that risk taking is positively related to capital level due to the benefit of risk shifting. These results are also consistent with an extensive literature in which empirical findings have demonstrated more risk taking among insurers with higher capital adequacy (e.g., Cummins and Sommer, 1996; Baranoff and Sager, 2002; Cheng and Weiss, 2013).

To study the effect of capital adequacy in the emergency case, we partition the Hurricane Katrina sample into terciles based on the insurers' year-beginning RBC ratio. We then run regression equation (7) for each subsample. Panel B of Table 2.10 presents the results, which differ from those in the normal case (Panel A) in that the coefficients of the post-exposure terms in columns 1 and 4 are also significant with positive signs. They show that both the insurers with low and high RBC ratios took more risk in their risky FI investment after Hurricane Katrina, whereas the insurers with mid-level RBC ratios were insensitive.

The presence of the U-shaped relationship only in the emergency case instead of in the normal case can be explained using Calem and Rob's (1999) framework. After a huge disaster, such as Hurricane Katrina, impacted insurers face a much higher possibility of insolvency. This increases the benefit of risk shifting by making more risky investments and the need to recover capital from the high yield of risky FI securities. A lower marginal RBC cost helps risk taking. Overall, the

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[41] Our paper focuses on how the marginal regulatory costs rather than the capital level affect insurers' risk taking. Therefore, we do not argue a causal link between capital adequacy level and risk taking here. However, these tests will provide interesting patterns to know.

[42] In Appendix 2.6, Panel A shows the distribution of the RBC ratio in each tercile of the entire sample and Panel B shows the distribution of the RBC ratio in each tercile of the Hurricane Katrina sample.

[43] If we include the loss of capital measures, *ΔSurplus* and *Underwrite Gain*, the results are similar.

results suggest that not only insurers with higher capital, but also those with lower capital adequacy invest more in risky FI securities to take advantage of reduced RBC costs after a shock (in this case, Hurricane Katrina), which is against regulators' intentions.

8. Additional evidence

8.1. Additional evidence from 2003 to 2015

As mentioned in Section 3.1, there was an RBC regulation reform in calculating the risk capital charge for RMBS and CMBS products in 2009 and 2010, respectively. The NAIC changed the capital assessment approaches in two ways. First, it removed credit rating as the measure of expected loss and substituted it with valuation estimates provided by PIMCO and Blackrock. Second, the new approach calculates the required capital benchmarking on insurers' carrying value of a security instead of the amortized par (Becker and Opp, 2013).

To make it easier, we discuss the main consequence of the regulation reform. Although an RMBS (or CMBS) product is rated under BB+ (i.e., speculative category), if an insurer acquires this security close to the estimated valuation provided by PIMCO (Blackrock), it could be categorized as an investment-grade bond. As a consequence, many risky RMBS or CMBS products regarded as speculate grade are now treated as investment-grade securities, subject to lower capital charge factors. Becker and Opp (2013) estimate that since 2012, the aggregate capital requirement has decreased from USD19.36 billion to USD3.73 billion.

The reform in capital regulation may affect insurers' incentives to invest in non-investment and downgraded MBS products. In the previous sections, our samples are all from before 2010 to avoid this issue, excluding the sample for the test on Hurricane Sandy. In this section, we utilize the most recent data (up to 2015), but focus on non-MBS FI securities to mitigate the regulation reform effect. With the sample period from 2003 to 2015, we re-run base regressions corresponding to Tables 2.3 to 2.4 and report the estimated coefficients in Table 2.11.

The coefficients of *RBC Cost FI* are positive and significant for the net purchase of risky bonds (columns 1 and 4), which are consistent with the results in Table 2.3. The estimated coefficients are significant with positive signs for risky bond selling (columns 2 and 5) and with negative signs for risky bond purchasing (columns 3 and 6). These results are consistent with the results in Table

2.4. Insurers with lower RBC costs of acquiring risky FI securities purchase more and sell fewer non-investment grade and downgraded FI securities, although we restrict the FI investment in non-MBS instruments, which are not subject to the regulation change.

8.2. Risk-based capital cost of equity risk and its effect on equity investment

All of the above investigations focus on risky FI security trading, which is related to the risk charge of FI securities. To confirm that risk-taking incentives due to the RBC formula are not limited to bond investments, we further examine the relationship between the marginal RBC cost of stock holdings and its investment. Using the RBC cost of stock (*RBC Cost Stock*), expressed as $R_2/\sqrt{R_1^2+R_2^2+R_3^2+R_4^2+R_5^2}$, we conduct an empirical test similar to regression equation (6). We first investigate how the RBC cost of stock affects growth rate of R_2, and then we focus on insurers' behavior on stock trading.

Investing in equity is usually regarded as riskier than investing in bonds or other asset classes, as bonds carry their issuer's promise to return the face value of the security to the holder at maturity. Stocks have no such promise from their issuer. Stock returns are also much more volatile than bond returns. Thus, higher equity investment reflects insurers' risk taking.

To capture risk taking from equity investment, we measure the proportion of equity investment in insurers' total invested assets. We measure equity investment using the variable *Stock Buy*, the actual cost that an insurer pays to acquire a stock during a year, scaled by its total invested assets at the beginning of the year. We further define *Stock Sell,* the BACV[44] of stocks that an insurer sells in a year, scaled by its total invested assets at the beginning of the year. The net effect is measured by *Stock Net Buy*.

The results are reported in Table 2.12. The dependent variable in Column1 is the growth rate of R_2. R_2 is the risk charge on the portfolio of stock investments. The coefficient for the marginal cost of stock is significantly negative. The estimated coefficient implies that if the RBC cost of stock investment drops from the third quartile to the first quartile of the distribution of *RBC Cost FI* (i.e., by -0.33), the risk charge in R_2 will increase by 103.6% (=-3.11*(-0.33)) of the average of R_2.

[44] The BACV of the stock is its market fair value in insurance accounting.

In columns 2 to 4, we report the results for the trading of stocks. The coefficient for the RBC cost for stock is negative and significant for the net purchase measure in column 2, indicating that insurers facing lower RBC costs of equity make more net purchases of common or preferred stocks. When we disaggregate the net purchase into selling and buying in columns 3 and 4, the estimated coefficient for the RBC cost for stock is positive in the stock-selling regression and negative in the stock-purchasing regression. In column 3, a drop of the RBC cost of stock investment from the third quartile to the first quartile of the distribution translates to an increase of 15.4% in the sale of stocks. In column 4, this drop in the RBC cost of stock translates to an increase of 47.6% in the purchase of stock.[45] The results of stock investment are consistent with the results of bond investment. Insurers take more risks in their financial investments to seek higher profits when their regulatory costs of risk taking are lower.

9. Conclusion

We explore the impact of capital adequacy regimes on the risk-taking behavior of insurers. We specifically investigate how covariance adjustment applied by the square root rule in the U.S. RBC calculation affects insurers' investment behavior. The nonlinearity of the RBC formula causes differences in the marginal RBC cost of acquiring risky assets across different insurance companies and across time. Focusing on the marginal RBC cost of risky FI security investment, we find that insurers facing lower RBC costs purchase more and sell fewer risky bonds than insurers with higher RBC costs. Thus, the empirical analyses indicate that insurers actively make their investment decisions in response to marginal regulatory costs.

Using Hurricane Katrina and Hurricane Sandy as the exogenous shocks of increasing reserve risk charge, we find that the insurers that suffered severely in the two disasters increased their investment risks and overall firm-level risks. These special cases highlight the side effect of the current simple rule that embeds the diversification benefit of risk in both the assets and liability of insurers' balance sheets. They imply that regulators should make more effort to supervise the risk-taking behavior of insurance companies, especially after extreme disasters, such as Hurricane Katrina and Hurricane Sandy.

[45] 15.4%=0.33*0.0301/0.06454; 47.6%=0.33*0.1339/0.09286. 0.06454 is the average of the variable *Stock Sell* and 0.09286 is the average of the variable *Stock buy*.

We call for a debate on how to adjust for covariance across different risk elements in the design of the RBC regulation regime. We discuss the square-root type adjustment in the U.S. RBC regime. This type of adjustment or its variation is also adopted in the MCCSR system in Canada and in Solvency II in the European Union. However, we note that there are also many alternative approaches for covariance adjustment in other capital regulation regimes. For example, Basel III does not adopt an adjustment for correlation between market risk, credit risk and operation risk,[46] but some of the diversification benefit is considered within the risk element.[47] In addition, the advanced methods in Basel III and Solvency II also recommend using an internal model to gauge financial institutions' overall risk. These internal models based on scenario simulation may also need to be reviewed with respect to the potential incentives driven by the marginal cost of regulatory capital. Overall, the impact of diversification benefit adjustment on financial institutions' risk-taking behavior is underscored. We provide some evidence to the field.

[46] Although the Basel regulations do not adopt an adjustment for the correlation between market risk and credit risk, the BIS investigates the interaction (BIS, 2009).
[47] Covariance adjustment is applied in their standard approach to set the minimum capital requirement for market risk charge (BIS, 2016).

Appendix 2.1. Components of RBC

Various capital charges in the risk-based capital formula are first combined into six categories, termed R_0 to R_5, as follows: (Quoting from Feldblum, 1996)

Risk Category	Description
R_0	• Investments in insurance affiliates • Non-controlled assets • Guarantees for affiliates • Contingent liabilities

R_1	• Fixed income securities
	    ○ Cash
	    ○ Bonds
	    ○ Bond size adjustment factor
	    ○ Mortgage loans
	• Short term investments
	• Collateral loans
	• Asset concentration adjustment for fixed income securities

R_2	• Equity investments
	    ○ Common stocks
	    ○ Preferred stocks
	    ○ Real estate
	• Other invested assets
	• Aggregate write-ins for invested assets
	• Asset concentration adjustment for equity investments

R_3	• Credit risk
	    ○ Reinsurance recoverables
	    ○ Other receivables

R_4	• Reserving risk
	    ○ Basic reserving risk charge
	    ○ Offset for loss-sensitive business
	    ○ Adjustment for claims-made business
	    ○ Loss concentration factor
	    ○ Growth charge for reserving risk

R_5	• Written premium risk
	    ○ Basic premium risk charge
	    ○ Offset for loss-sensitive business
	    ○ Adjustment for claims-made business
	    ○ Premium concentration factor
	    ○ Growth charge for reserving risk

Appendix 2.2. Mapping of SVO designation to S&P Ratings

SVO Designation	Credit rating (S&P)	Risk factors (Risk weight)
1	A- and above	0.003
2	BBB+, BBB, BBB-	0.010
3	BB+, BB, BB-	0.020
4	B+, B, B-	0.045
5	CCC+, CCC, CCC-	0.100
6	CC, C, D	0.300

Source: Purpose and Procedures Manual of the NAIC Investment Analysis Office (2015)

Appendix 2.3. Variable descriptions

Dependent variables	
Growth of R_1	(R_1 in year *t* – R_1 in year *t*-1)/ R_1 in year *t*. R_1 is the risk charge in FI investment.
NoninvtFI Sell	The book-adjusted carrying value (BACV) of the non-investment grade fixed-income (FI) securities that insurer *i* sold during year *t*, scaled by the year-beginning BACV of its FI investment.
NoninvtFI Buy	The BACV of non-investment grade FI securities on the purchase date acquired during year *t*, scaled by the year-beginning BACV of insurer *i*'s FI investment.
NoninvtFI Net Buy	Net purchase of non-investment grade FI securities. Equal to *NoninvtFI buy* minus *NoninvtFI sell*.
NoninvtFI Net Share	The proportion of net purchases of non-investment grade FI securities in the net purchases of all FI securities during year *t*.
DownFI Sell	The BACV of the downgraded FI securities that insurer *i* sold during year *t*, scaled by the year-beginning BACV of its FI investment.
DownFI Buy	The BACV of the downgraded FI securities on the purchase date acquired during year *t*, scaled by the year-beginning BACV of insurer *i*'s FI investment.
DownFI Net Buy	Net purchase of downgraded FI securities. Equal to *DownFI buy* minus *DownFI Sell*.
DownFI Net Share	The proportion of net purchases of downgraded FI securities in net purchases of all FI securities during year *t*.
ROA Vol	The standard deviation of the annual comprehensive return on admitted assets over the 3-year period from year *t*-2 to year *t*. Comprehensive return is the sum of net income and unrealized capital gains.
z-sore	Comprehensive ROA plus capital to assets ratio, divided by the standard deviation of comprehensive ROA, which is then divided by 100.
Insurer-level characteristics	
RBC Cost FI	The risk-based capital (RBC) cost of acquiring risky FI securities, measured at the beginning of year *t*. Equal to $R_1/\sqrt{{R_1}^2+{R_2}^2+{R_3}^2+{R_4}^2+{R_5}^2}$ or $R_1/(RBC\text{-}R_0)$. R_0 to R_5 are the components of RBC. RBC is at the firm-level.
RBC Ratio	The RBC ratio at the beginning of year *t*. The ratio of total capital to RBC.
ROE	Return on equity at the beginning of year *t*. Equal to the ratio of net income to total surplus.
Ln Surplus	Natural logarithm of insurer *i*'s surplus in $1000 at the beginning of year *t*.
Leverage	Liability divided by assets at the beginning of year *t*.
Mutual	Dummy variable, equal to 1 if insurer *i* is a mutual firm and 0 otherwise.
Group	Dummy variable, equal to 1 if insurer *i* belongs to a group and 0 otherwise.
Lob Herfindahl	Line of business Herfindahl index at the beginning of year *t*.
Geo Herfindahl	Geographical Herfindahl index at the beginning of year *t*.
Longtail	The proportion of direct premiums written (DPW) in long-tail lines of business in total DPW at the beginning of year *t*.
Noninvt FI Position	The share of non-investment grade FI securities in one insurer's total FI investment at the beginning of year *t*.
Down FI Position	The share of downgraded FI securities in one insurer's total FI investment at the beginning of year *t*.

Other Risky Assets	The proportion of invested assets in any of the following asset classes, measured at the beginning of year *t*: common and preferred stocks, nonperforming mortgages and real estate.
Portfolio Maturity	The average maturity of the insurer's FI portfolio weighted by the BACV at the beginning of year *t*.
Hurricane exposure variables	
DPW	The ratio of insurer *i*'s DPW in homeowner multiple peril lines in hurricane-impacted states to its total DPW in the hurricane year.
DPE	The ratio of insurer *i*'s direct premiums earned (DPE) in homeowner multiple peril lines in hurricane-impacted states to its total DPE in the hurricane year.
Loss incur	The ratio of insurer *i*'s loss incurred in homeowner multiple peril lines in hurricane-impacted states to its total loss incurred in the hurricane year.
Loss resv	The ratio of insurer *i*'s loss and loss-adjusted expense (LAE) reserves in homeowner multiple peril lines in hurricane-impacted states to its total loss and LAE reserves in the hurricane year.
ΔSurplus	The change in surplus scaled by year-end assets. This variable is measured at year beginning.
Underwrite Gain	Net underwriting gains scaled by year-end surplus. This variable is measured at year beginning.
Robustness tests	
RBC Cost Stock	The risk-based capital (RBC) cost of acquiring stocks, measured at the beginning of year *t*. Equal to $R_2/\sqrt{R_1{}^2 + R_2{}^2 + R_3{}^2 + R_4{}^2 + R_5{}^2}$.
Growth of R_2	(R_2 in year *t* – R_2 in year *t*-1)/ R_2 in year *t*. R_2 is the risk charge in stock investment.
Stock sell	The fair value of stock insurer *i* sells in year *t*, scaled by the total invested assets by insurer *i* at the beginning of year *t*.
Stock buy	The fair value of stock insurer *i* buys in year *t*, scaled by the total invested assets held by insurer *i* at the beginning of year *t*.
Stock Net Buy	The net purchase of stock. Equal to *Stock buy* minus *Stock sell*.
Stock position	The proportion of common and preferred stocks in invested assets (the sum of stock and bond investments) at the beginning of year *t*.

Appendix 2.4. Affected states by hurricanes

Event	Begin date	End date	Affected States
Hurricane Katrina	8/25/2005	8/30/2005	AL, AR, FL, GA, IN, KY, LA, MI, MS, OH, TN
Hurricane Sandy	10/30/2012	10/31/2012	CT, DE, MA, MD, NC, NH, NJ, NY, OH, PA, RI, VA, WV

Data source: Barrot and Sauvagnat (2016)

Appendix 2.5. RBC ratio distribution

Panel A. Whole sample

RBC ratio	N	Mean	SD	Min	P25	P50	P75	Max
Low	1409	4.13	1.23	1.23	3.29	4.32	5.13	5.95
Middle	1409	7.91	1.27	5.96	6.80	7.77	8.93	10.44
High	1408	24.51	22.72	10.44	12.46	15.64	24.30	117.86

Panel B. Katrina sample

RBC ratio	N	Mean	SD	Min	P25	P50	P75	Max
Low	434	3.90	1.10	0.32	3.23	4.06	4.82	5.44
Middle	434	7.13	1.07	5.45	6.14	7.10	8.01	9.16
High	434	22.53	28.63	9.17	10.79	13.75	21.35	246.78

Reference

Acharya, V., Engle, R., Pierret, D., 2014. Testing macroprudential stress tests: The risk of regulatory risk weights. Journal of Monetary Economics 65, 36-53

Bank for Internal Settlements, 2009. Findings on the interaction of market and credit risk. Working Paper 16

Bank for Internal Settlements, 2016. Standards–minimum capital requirements for market risk.

Baranoff, E.G., Sager, T.W., 2002. The relations among asset risk, product risk, and capital in the life insurance industry. Journal of Banking and Finance 26, 1181-1197

Barrot, J.-N., Sauvagnat, J., 2016. Input specificity and the propagation of idiosyncratic shocks in production networks. Quarterly Journal of Economics 131, 1543-1592

Becker, B., Ivashina, V., 2015. Reaching for yield in the bond market. Journal of Finance 70, 1863-1901

Becker, B., Opp, M., 2013. Regulatory reform and risk-taking: Replacing ratings. National Bureau of Economic Research

Behn, M., Haselmann, R., Wachtel, P., 2016. Procyclical capital regulation and lending. Journal of Finance 71, 919-956

Bernile, G., Bhagwat, V., Rau, P.R., 2016. What doesn't kill you will only make you more risk-loving: Early-life disasters and ceo behavior. The Journal of Finance

Butsic, R.P., 1994. Solvency measurement for property-liability risk-based capital applications. Journal of Risk and Insurance, 656-690

Calem, P., Rob, R., 1999. The impact of capital-based regulation on bank risk-taking. Journal of Financial Intermediation 8, 317-352

Cathcart, L., El-Jahel, L., Jabbour, R., 2015. Can regulators allow banks to set their own capital ratios? Journal of Banking and Finance 53, 112-123

Cheng, J., Weiss, M.A., 2012. The role of rbc, hurricane exposure, bond portfolio duration, and macroeconomic and industry-wide factors in property-liability insolvency prediction. Journal of Risk and Insurance 79, 723-750

Cheng, J., Weiss, M.A., 2013. Risk-based capital and firm risk taking in property-liability insurance. Geneva Papers on Risk and Insurance-Issues and Practice 38, 274-307

Cofield, J., Kaufman, A., Zhou, C., 2012. Solvency ii standard formula and naic risk-based capital (rbc). In: CAS E-Forum, pp. 1-38

Crouhy, M., Galai, D., 1991. A contingent claim analysis of a regulated depository institution. Journal of Banking and Finance 15, 73-90

Cummins, J.D., Sommer, D.W., 1996. Capital and risk in property-liability insurance markets. Journal of Banking and Finance 20, 1069-1092

Duchin, R., Sosyura, D., 2014. Safer ratios, riskier portfolios: Banks' response to government aid. Journal of Financial Economics 113, 1-28

Ellul, A., Jotikasthira, C., Lundblad, C.T., 2011. Regulatory pressure and fire sales in the corporate bond market. Journal of Financial Economics 101, 596-620

Ellul, A., Jotikasthira, C., Lundblad, C.T., Wang, Y., 2015. Is historical cost accounting a panacea? Market stress, incentive distortions, and gains trading. The Journal of Finance 70, 2489-2538

Feldblum, S., 1996. Naic property/casualty insurance company risk-based capital requirements. In: Proceedings of the Casualty Actuarial Society, pp. 297-435

Furlong, F.T., Keeley, M.C., 1989. Capital regulation and bank risk-taking: A note. Journal of Banking and Finance 13, 883-891

Furlong, F.T., Keely, M.C., 1987. Bank capital regulation and asset risk. Economic Review. Federal Reserve Bank of San Francisco

Gennotte, G., Pyle, D., 1991. Capital controls and bank risk. Journal of Banking and Finance 15, 805-824

Grace, M.F., Leverty, J.T., 2012. Property–liability insurer reserve error: Motive, manipulation, or mistake. Journal of Risk and Insurance 79, 351-380

Hanley, K.W., Nikolova, S., 2015. Rethinking the use of credit ratings in capital regulation. Available at SSRN 2357145

Kahane, Y., 1977. Capital adequacy and the regulation of financial intermediaries. Journal of Banking and Finance 1, 207-218

Kamiya, S., Milidonis, A., 2016. Actuarial independence and managerial discretion. Journal of Risk and Insurance Forthcoming

Kareken, J.H., Wallace, N., 1978. Deposit insurance and bank regulation: A partial-equilibrium exposition. Journal of Business 51, 413-438

Keeley, M.C., Furlong, F.T., 1990. A reexamination of mean-variance analysis of bank capital regulation. Journal of Banking and Finance 14, 69-84

Kim, D., Santomero, A.M., 1988. Risk in banking and capital regulation. Journal of Finance 43, 1219-1233

Koehn, M., Santomero, A.M., 1980. Regulation of bank capital and portfolio risk. Journal of Finance 35, 1235-1244

Lin, W.-C., Lai, Y.-H., Powers, M.R., 2014. The relationship between regulatory pressure and insurer risk taking. Journal of Risk and Insurance 81, 271-301

Ljungqvist, A., Zhang, L., Zuo, L., 2017. Sharing risk with the government: How taxes affect corporate risk taking. Journal of Accounting Research 55, 669-707

Repullo, R., Suarez, J., 2013. The procyclical effects of bank capital regulation. Review of Financial Studies 26, 452-490

Smith, B., 1998. Managing risk-based capital (rbc). Society of Actuaries

VanHoose, D., 2007. Theories of bank behavior under capital regulation. Journal of Banking and Finance 31, 3680-3697

Yu, T., Lin, B., Oppenheimer, H.R., Chen, X., 2008. Intangible assets and firm asset risk taking: An analysis of property and liability insurance firms. Risk Management and Insurance Review 11, 157-178

Zeppetella, T., 2002. Marginal analysis of risk-based capital. The Financial Reporter, 18-20

Figure 2.1. Loss Reserve and Hurricanes

This figure shows how insurers' reserves develop before and after the hurricane. The left figure is for Hurricane Katrina (2005) and the right figure is for Hurricane Sandy (2012). *Reserve* is measured by insurers' unpaid loss and loss adjusted expenditure reserve occurring in the current year, scaled by the year-beginning risk-based capital. Hurricane-impacted (Non-impacted) insurers are those with positive (non-positive) direct premiums written in homeowner lines in hurricane-impacted states during the hurricane year. We show the results for the average insurer in each subsample.

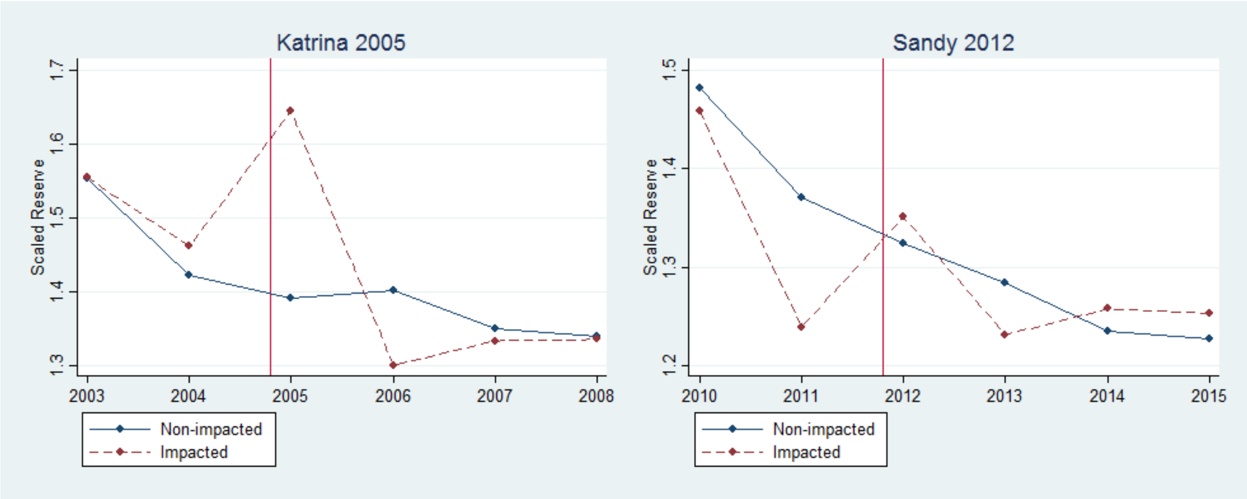

Table 2.1. RBC Components

This table presents descriptive statistics on the marginal RBC cost of FI securities and stocks by year, from 2003 to 2015.

		RBC Cost FI		*RBC Cost Stock*	
Year	N	Mean	Median	Mean	Median
2003	501	0.083	0.055	0.174	0.075
2004	388	0.074	0.054	0.193	0.078
2005	579	0.072	0.050	0.189	0.094
2006	473	0.072	0.050	0.196	0.110
2007	399	0.073	0.050	0.207	0.117
2008	656	0.081	0.057	0.143	0.070
2009	671	0.090	0.058	0.163	0.072
2010	559	0.090	0.060	0.183	0.079
2011	475	0.093	0.063	0.195	0.106
2012	472	0.087	0.059	0.202	0.108
2013	501	0.082	0.055	0.222	0.132
2014	504	0.080	0.055	0.225	0.126
2015	548	0.085	0.057	0.213	0.121
Total	6726	0.082	0.055	0.191	0.095

Table 2.2. Summary statistics

This table presents pooled descriptive statistics on dependent and independent variables in our regressions. Appendix 2.3 provides all variable descriptions.

	Count	Mean	S.D.	Min	P50	Max
Dependent variables						
Growth of R1	4226	0.1110	0.4364	-0.7472	0.0400	2.4364
NoninvtFI Sell	4226	0.0068	0.0127	0	0.0006	0.076
NoninvtFI Buy	4226	0.005	0.0168	0	0	0.1151
NoninvtFI Net Buy	4226	-0.0018	0.0186	-0.076	0	0.1151
NoninvtFI Net Share	4191	-0.0031	0.1347	-0.5883	0	0.819
DownFI Sell	4226	0.0056	0.0103	0	0	0.0561
DownFI Buy	4226	0.0024	0.008	0	0	0.0554
DownFI Net Buy	4226	-0.0032	0.0123	-0.0561	0	0.0554
DownFI Net Share	4191	-0.0141	0.0893	-0.4882	0	0.3885
Insurer-level Characteristics						
RBC Cost FI	4226	0.0822	0.1012	0.0064	0.0539	0.6609
RBC Ratio	4226	12.1818	15.8513	1.2308	7.7716	117.8636
Group	4226	0.6209	0.4852	0	1	1
Mutual	4226	0.1706	0.3762	0	0	1
ROE	4226	0.0683	0.131	-0.5319	0.0767	0.4127
Ln Surplus (in thousands)	4226	10.5108	1.453	7.4073	10.4859	13.8468
Leverage	4226	0.5851	0.1716	0.0715	0.6235	0.8667
Lob Herfindahl	4226	0.5346	0.2869	0.1292	0.4661	1
Geo Herfindahl	4226	0.5647	0.3767	0.0425	0.5292	1
Longtail	4226	0.7324	0.2841	0	0.7911	1
NoninvtFI Position	4226	0.0277	0.0407	0.0002	0.0147	0.2673
DownFI Position	4226	0.0251	0.0301	0	0.0157	0.1645
Other Risky Assets	4226	0.1258	0.1486	0	0.073	0.6733
Hurricane Katrina						
DPW Exposure	1302	0.0408	0.1408	-0.0569	0	1.005
DPE Exposure	1302	0.0408	0.1399	0	0	1
Loss incur Exposure	1302	0.0355	0.1334	-0.0006	0	1
Loss resv Exposure	1302	0.0507	0.1644	-0.1018	0	1.907
ROA Vol	4760	0.0417	0.2783	0.0000	0.0202	13.0731
z-score	4760	0.5568	0.9667	0.0042	0.2379	6.8278
Hurricane Sandy						
DPW Exposure	1030	0.0448	0.146	-0.0011	0	1
DPE Exposure	1030	0.0446	0.1448	0	0	1
Loss incur Exposure	1030	0.0341	0.1268	-0.0005	0	1
Loss resv Exposure	1030	0.0503	0.1636	-0.0024	0	0.9971
ROA Vol	5253	0.0306	0.0468	0.0000	0.01809	1.94711
z-score	5253	0.7835	1.5884	0.0036	0.25670	10.50030
Robustness tests						
Growth of R2	10341	0.3401	1.7216	-1.0000	0.0648	13.9614
Stock Net Buy	10341	0.0283	0.1182	-0.7041	0.0050	0.9982
Stock sell	10341	0.0645	0.1140	0	0.0202	0.7041
stock buy	10341	0.0929	0.1587	0	0.0360	0.9982
RBC Cost Stock	10341	0.2546	0.2491	0.0000	0.1777	0.9680
Stock Position	10341	0.1953	0.2181	0.0001	0.1255	1.0000

Table 2.3. RBC cost and net purchases of risky fixed-income securities

This table reports the coefficients estimated from the panel regression on the relationship between the RBC cost of fixed-income (FI) securities and net purchases of risky FI securities. The sample consists of 4,226 insurer-year observations over 2003 to 2010. Only insurers with no insurance subsidiaries and positive non-investment grade FI positions at the beginning of year *t* are included. The dependent variable in column 1, *Growth of* R_1, is the growth rate of R_1 in year *t*. R_1 is the risk charge in insurers' FI investment. The dependent variable in column 2, *NoninvtFI Net Buy*, is the net purchase of non-investment grade FI securities scalded by the year-beginning Book adjusted carrying value (BACV) of its FI holdings. The dependent variable in column 3, *DownFI Net Buy*, is the net purchase of downgraded FI securities during year *t* scalded by the year-beginning BACV of its FI holdings. In column 4, the dependent variable is *Noninvt FI Net Share*, the proportion of net purchases of non-investment grade FI securities in net purchases of all FI securities during year *t*. In column 5, the dependent variable is *DownFI Net Buy Share*, the proportion of net purchases of downgraded FI securities in net purchases of all FI securities during year *t*. *RBC Cost FI* is the marginal RBC cost of FI securities. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)
Dependent Variables	*Growth of R1*	*NoninvtFI Net Buy*	*DownFI Net Buy*	*NoninvtFI Net Share*	*DownFI Net Share*
RBC Cost FI	-3.7002***	-0.0504***	-0.0362***	-0.2253***	-0.1346***
	(0.3687)	(0.0192)	(0.0094)	(0.0866)	(0.0467)
RBC Ratio	0.0207***	0.0003***	0.0002***	0.0017***	0.0009**
	(0.0029)	(0.0001)	(0.0001)	(0.0007)	(0.0004)
Group	-0.0390	0.0032	0.0007	0.0024	-0.0252**
	(0.0558)	(0.0026)	(0.0022)	(0.0225)	(0.0128)
Mutual	-0.1067	-0.0013	-0.0013	-0.0282	-0.0075
	(0.0664)	(0.0044)	(0.0037)	(0.0201)	(0.0140)
ROE	0.0809	0.0067**	0.0035*	-0.0058	-0.0106
	(0.0861)	(0.0032)	(0.0021)	(0.0245)	(0.0194)
Ln Surplus	-0.1672***	0.0013	-0.0008	0.0032	-0.0129**
	(0.0483)	(0.0023)	(0.0012)	(0.0109)	(0.0064)
Leverage	0.0090	0.0176**	0.0037	0.0546	-0.0082
	(0.2263)	(0.0079)	(0.0055)	(0.0469)	(0.0307)
Lob Herfindahl	0.1291	0.0010	-0.0013	-0.0498	-0.0114
	(0.1294)	(0.0067)	(0.0037)	(0.0369)	(0.0247)
Geo Herfindahl	0.1238	0.0013	-0.0022	0.0055	-0.0049
	(0.1248)	(0.0047)	(0.0031)	(0.0360)	(0.0196)
Longtail	0.1884	0.0041	0.0000	-0.0585*	-0.0311
	(0.1184)	(0.0064)	(0.0037)	(0.0351)	(0.0219)
Portfolio maturity	-0.0027**	-0.0001*	0.0001	-0.0015**	-0.0000
	(0.0012)	(0.0001)	(0.0000)	(0.0006)	(0.0003)
DownBond Position	3.6774***		-0.1144***		-0.3025***
	(0.4325)		(0.0161)		(0.0852)
NoninvtBond Position	0.4691	-0.1157***		-0.0886	
	(0.5748)	(0.0311)		(0.1542)	
Other Risky Asset	0.2764	0.0398***	0.0126**	0.0350	0.0218
	(0.1953)	(0.0110)	(0.0061)	(0.0515)	(0.0308)
Constant	1.5820***	-0.0294	0.0061	0.0117	0.1784**
	(0.6055)	(0.0256)	(0.0143)	(0.1320)	(0.0811)
Observations	4,226	4,226	4,226	4,191	4,191
R-squared	0.2205	0.0693	0.0846	0.0152	0.0201
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer

Table 2.4. RBC cost and risky fixed-income securities net purchase disaggregation

This table reports the coefficient estimated from the panel regression on the relationship between RBC cost of fixed-income (FI) securities and the investment of risky FI securities. We disaggregate the net purchase of risky FI securities (*NoninvtFI Net Buy* or *DownFI Net Buy*) into FI-selling (*NoninvtFI Sell* or *DownFI sell*) and FI-purchasing (*NoninvtFI Buy* or *DownFI Buy*). The sample consists of 4,226 insurer-year observations over 2003 to 2010. Only insurers with no insurance subsidiaries and positive non-investment grade FI positions at the beginning of year *t* are included. Columns 1 and 2 are for non-investment grade FI securities; and columns 3 and 4 are for downgraded FI securities. The dependent variable in column 1, *NoninvtFI Sell*, is the book-adjusted carrying value (BACV) of the non-investment grade fixed-income (FI) securities that insurer *i* sold during year *t*, scaled by the year-beginning BACV of its FI investment. The dependent variable in column 2, *NoninvtFI Buy,* is the BACV of non-investment grade FI securities on the purchase date acquired during year *t*, scaled by the year-beginning BACV of insurer *i*'s FI investment. Columns 3 and 4 are for downgraded FI securities. *RBC Cost FI* is the marginal RBC cost of FI securities. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)
Dependent Variables	*NoninvtFI Sell*	*NoninvtFI Buy*	*DownFI Sell*	*DownFI Buy*
RBC Cost FI	0.0136*	-0.0368**	0.0151***	-0.0211***
	(0.0080)	(0.0157)	(0.0047)	(0.0069)
RBC Ratio	-0.0000	0.0003***	-0.0001*	0.0001***
	(0.0001)	(0.0001)	(0.0000)	(0.0000)
Group	-0.0007	0.0025	-0.0008	-0.0001
	(0.0014)	(0.0030)	(0.0014)	(0.0017)
Mutual	-0.0032	-0.0045**	-0.0002	-0.0016
	(0.0044)	(0.0021)	(0.0040)	(0.0014)
ROE	-0.0031	0.0036	-0.0038**	-0.0002
	(0.0019)	(0.0029)	(0.0018)	(0.0014)
Ln Surplus	-0.0005	0.0008	-0.0002	-0.0009
	(0.0011)	(0.0019)	(0.0010)	(0.0007)
Leverage	0.0009	0.0185***	-0.0023	0.0014
	(0.0048)	(0.0070)	(0.0042)	(0.0039)
Lob Herfindahl	0.0002	0.0012	0.0018	0.0005
	(0.0034)	(0.0054)	(0.0029)	(0.0024)
Geo Herfindahl	0.0019	0.0032	0.0021	-0.0001
	(0.0028)	(0.0042)	(0.0028)	(0.0019)
Longtail	0.0005	0.0046	0.0023	0.0024
	(0.0030)	(0.0056)	(0.0031)	(0.0023)
Portfolio Maturity	-0.0001	-0.0002**	0.0000	0.0001**
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
DownFI Position			0.1266***	0.0122
			(0.0114)	(0.0100)
NoninvtFI Position	0.1497***	0.0340		
	(0.0195)	(0.0273)		
Other Risky Assets	-0.0026	0.0372***	0.0001	0.0127***
	(0.0050)	(0.0101)	(0.0042)	(0.0044)
Constant	0.0089	-0.0205	0.0035	0.0096
	(0.0131)	(0.0226)	(0.0116)	(0.0088)
Observations	4,226	4,226	4,226	4,226
R-squared	0.1318	0.0571	0.1652	0.0513
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer

Table 2.5. Foreign controlled versus domestically controlled insurers

This table reports the coefficients estimated from the panel regression investigating whether the relation between RBC cost of FI securities and the investment of risky FI securities is different between foreign controlled and domestically controlled insurers. Insurers with more than 50% of foreign ownership are considered as foreign controlled. Only insurers with no insurance subsidiaries and positive non-investment grade FI positions at the beginning of year *t* are included. *RBC Cost FI* is the marginal RBC cost of FI securities. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)
	Foreign controlled		**Domestically controlled**	
Dependent Variables	*NoninvtFI Net Buy*	*DownFI Net Buy*	*NoninvtFI Net Buy*	*DownFI Net Buy*
RBC Cost FI	-0.0024	-0.0291*	-0.0625***	-0.0365***
	(0.0185)	(0.0167)	(0.0225)	(0.0105)
RBC Ratio	-0.0000	0.0001	0.0005***	0.0002***
	(0.0001)	(0.0001)	(0.0002)	(0.0001)
Group	0.0010	-0.0011	0.0040	0.0012
	(0.0042)	(0.0034)	(0.0035)	(0.0026)
Mutual	0.0184*	0.0151**	-0.0045	-0.0045
	(0.0094)	(0.0062)	(0.0039)	(0.0031)
ROE	0.0115	0.0075	0.0051	0.0026
	(0.0090)	(0.0059)	(0.0033)	(0.0022)
Ln Surplus	-0.0021	0.0009	0.0014	-0.0015
	(0.0060)	(0.0023)	(0.0024)	(0.0014)
Leverage	0.0023	0.0028	0.0216**	0.0027
	(0.0151)	(0.0102)	(0.0089)	(0.0063)
Lob Herfindahl	0.0101	0.0026	-0.0022	-0.0028
	(0.0081)	(0.0078)	(0.0082)	(0.0039)
Geo Herfindahl	0.0101	0.0079	-0.0005	-0.0043
	(0.0100)	(0.0072)	(0.0050)	(0.0033)
Longtail	-0.0057	-0.0076	0.0069	0.0031
	(0.0069)	(0.0058)	(0.0090)	(0.0043)
Portfolio Maturity	-0.0002	0.0002***	-0.0002	0.0000
	(0.0002)	(0.0001)	(0.0001)	(0.0001)
DownFI Position		-0.2321***		-0.1012***
		(0.0401)		(0.0169)
NoninvtFI Position	-0.4172***		-0.0786**	
	(0.0870)		(0.0327)	
Other Risky Assets	0.0228	0.0009	0.0416***	0.0132**
	(0.0316)	(0.0241)	(0.0116)	(0.0060)
Constant	0.0244	-0.0093	-0.0349	0.0142
	(0.0667)	(0.0256)	(0.0265)	(0.0166)
Observations	710	710	3,516	3,516
R-squared	0.2562	0.2480	0.0641	0.0739
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer
Two sample Chow test (Foreign VS domestically controlled) P-value				
RBC Cost FI	0.0372**	0.7063		

Table 2.6. RBC cost in Hurricane Katrina

This table reports the coefficients estimated from the DID test investigating the relationship between RBC cost of fixed-income (FI) securities and net purchases of risky FI securities from 2004 to 2006. Columns with odd numbers are for non-investment grade FI securities, and columns with even numbers are for downgraded FI securities. The treatment variable in columns 1-2 and 5-6, *DPW Exposure*, is the ratio of insurer *i*'s direct premiums written (DPW) in homeowner multiple peril lines in hurricane-impacted states to its total DPW in the Hurricane Katina year (2005). The treatment variable in columns 3-4 and 7-8, *Loss resv Exposure*, is the ratio of insurer *i*'s loss and loss-adjusted expense (LAE) reserves in homeowner multiple peril lines in hurricane-impacted states to its total loss and LAE reserves in 2005. *Post* is a dummy variable which equals to one for the year after the hurricane and zero otherwise. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*NoninvtFI Net Buy*	*DownFI Net Buy*	*NoninvtFI Net Buy*	*DownFI Net Buy*	*NoninvtFI Net Buy*	*DownFI Net Buy*	*NoninvtFI Net Buy*	*DownFI Net Buy*
Exposure proxy	*DPW*		*Loss resv*		*DPW*		*Loss resv*	
Post	-0.0049**	-0.0036***	-0.0050**	-0.0036***	-0.0038*	-0.0019	-0.0038*	-0.0019
	(0.0022)	(0.0012)	(0.0022)	(0.0012)	(0.0022)	(0.0012)	(0.0022)	(0.0012)
*Post*Exposure*	0.0126***	0.0086***	0.0112***	0.0068**	0.0112***	0.0068**	0.0103***	0.0056*
	(0.0034)	(0.0028)	(0.0033)	(0.0029)	(0.0035)	(0.0029)	(0.0034)	(0.0029)
RBC Ratio	0.0001	0.0001*	0.0001	0.0001*	0.0001	0.0001**	0.0001	0.0001**
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0000)
Group	-0.0003	0.0037	-0.0004	0.0037	-0.0009	0.0031	-0.0010	0.0031
	(0.0024)	(0.0030)	(0.0024)	(0.0030)	(0.0024)	(0.0033)	(0.0024)	(0.0033)
ROE	0.0020	-0.0009	0.0024	-0.0007	-0.0092	-0.0139**	-0.0093	-0.0139**
	(0.0035)	(0.0021)	(0.0034)	(0.0022)	(0.0113)	(0.0065)	(0.0113)	(0.0065)
Ln Surplus	0.0061	0.0044	0.0060	0.0044	0.0022	-0.0005	0.0021	-0.0006
	(0.0072)	(0.0041)	(0.0072)	(0.0041)	(0.0073)	(0.0041)	(0.0073)	(0.0041)
Leverage	-0.0029	0.0078	-0.0031	0.0079	0.0019	0.0133	0.0017	0.0134
	(0.0264)	(0.0145)	(0.0264)	(0.0146)	(0.0275)	(0.0149)	(0.0275)	(0.0150)
Lob Herfindahl	0.0285*	0.0046	0.0281*	0.0043	0.0260*	0.0001	0.0257*	-0.0001
	(0.0154)	(0.0090)	(0.0154)	(0.0090)	(0.0153)	(0.0092)	(0.0153)	(0.0092)
Geo Herfindahl	-0.0228*	-0.0081	-0.0235*	-0.0085	-0.0224*	-0.0071	-0.0230*	-0.0075
	(0.0135)	(0.0069)	(0.0134)	(0.0069)	(0.0135)	(0.0070)	(0.0135)	(0.0069)
Longtail	0.0173	0.0258***	0.0177	0.0261***	0.0180	0.0265***	0.0184	0.0267***
	(0.0117)	(0.0066)	(0.0117)	(0.0066)	(0.0119)	(0.0066)	(0.0119)	(0.0066)
Portfolio maturity	-0.0005	-0.0003	-0.0005	-0.0003	-0.0005	-0.0003	-0.0005	-0.0003
	(0.0005)	(0.0003)	(0.0005)	(0.0003)	(0.0005)	(0.0003)	(0.0005)	(0.0003)

NoninvtFI Position	-0.1694**		-0.1698**		-0.1658**		-0.1661**	
	(0.0674)		(0.0673)		(0.0678)		(0.0677)	
DownFI Position		-0.1177***		-0.1179***		-0.1184***		-0.1186***
		(0.0435)		(0.0435)		(0.0435)		(0.0434)
Other Risky Assets	0.0744**	0.0234	0.0745**	0.0235	0.0715*	0.0215	0.0714*	0.0215
	(0.0366)	(0.0229)	(0.0366)	(0.0229)	(0.0383)	(0.0239)	(0.0383)	(0.0239)
Loss of capital measure								
ΔSurplus					0.0163	0.0212***	0.0164	0.0214***
					(0.0127)	(0.0081)	(0.0126)	(0.0081)
Underwrite Gain					0.0077	0.0087**	0.0080	0.0090**
					(0.0074)	(0.0043)	(0.0074)	(0.0044)
Constant	-0.0790	-0.0700	-0.0779	-0.0698	-0.0412	-0.0210	-0.0396	-0.0202
	(0.0889)	(0.0503)	(0.0889)	(0.0505)	(0.0890)	(0.0497)	(0.0891)	(0.0498)
Observations	1,302	1,302	1,302	1,302	1,276	1,276	1,276	1,276
R-squared	0.0940	0.0916	0.0941	0.0910	0.0963	0.1030	0.0966	0.1027
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer

Table 2.7. RBC cost in Hurricane Sandy, Non-MBS fixed-income securities

This table reports the coefficients estimated from the DID test investigating the relationship between RBC cost of fixed-income (FI) securities and net purchases of risky FI securities from 2011 to 2013. Columns with odd numbers are for non-investment grade FI securities, and columns with even numbers are for downgraded FI securities. The treatment variable in columns 1-2 and 5-6, *DPW Exposure*, is the ratio of insurer *i*'s direct premiums written (DPW) in homeowner multiple peril lines in hurricane-impacted states to its total DPW in the Hurricane Sandy year (2012). The treatment variable in columns 3-4 and 7-8, *Loss resv Exposure*, is the ratio of insurer *i*'s loss and loss-adjusted expense (LAE) reserves in homeowner multiple peril lines in hurricane-impacted states to its total loss and LAE reserves in 2012. *Post* is a dummy variable which equals to one for the year after the hurricane and zero otherwise. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*NoninvtFI Net Buy*	*DownFI Net Buy*	*NoninvtFI Net Buy*	*DownFI Net Buy*	*NoninvtFI Net Buy*	*DownFI Net Buy*	*NoninvtFI Net Buy*	*DownFI Net Buy*
Exposure proxy	*DPW*		*Loss resv*		*DPW*		*Loss resv*	
Post	-0.0042**	0.0002	-0.0042**	0.0002	-0.0047**	0.0003	-0.0048**	0.0002
	(0.0019)	(0.0008)	(0.0019)	(0.0008)	(0.0019)	(0.0009)	(0.0019)	(0.0009)
*Post*Exposure*	0.0155**	0.0037	0.0142**	0.0040	0.0169***	0.0034	0.0153***	0.0038
	(0.0060)	(0.0036)	(0.0056)	(0.0033)	(0.0059)	(0.0035)	(0.0056)	(0.0033)
RBC Ratio	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0000)
Group	0.0406**	0.0114	0.0407**	0.0113	0.0406**	0.0113	0.0408**	0.0113
	(0.0179)	(0.0074)	(0.0178)	(0.0074)	(0.0179)	(0.0073)	(0.0179)	(0.0073)
Mutual	-0.0041	-0.0065	-0.0041	-0.0065	-0.0040	-0.0066	-0.0040	-0.0066
	(0.0032)	(0.0057)	(0.0032)	(0.0057)	(0.0031)	(0.0056)	(0.0031)	(0.0056)
ROE	-0.0026	-0.0038	-0.0026	-0.0039	-0.0001	-0.0028	0.0002	-0.0027
	(0.0136)	(0.0050)	(0.0136)	(0.0050)	(0.0448)	(0.0203)	(0.0448)	(0.0202)
Ln Surplus	0.0006	-0.0008	0.0006	-0.0008	0.0027	-0.0033	0.0026	-0.0032
	(0.0107)	(0.0053)	(0.0106)	(0.0053)	(0.0109)	(0.0052)	(0.0109)	(0.0052)
Leverage	0.0103	-0.0098	0.0105	-0.0097	0.0068	-0.0086	0.0071	-0.0085
	(0.0273)	(0.0167)	(0.0273)	(0.0167)	(0.0294)	(0.0172)	(0.0294)	(0.0172)
Lob Herfindahl	0.0341	-0.0069	0.0339	-0.0070	0.0353	-0.0087	0.0351	-0.0088
	(0.0337)	(0.0122)	(0.0337)	(0.0122)	(0.0341)	(0.0119)	(0.0341)	(0.0119)
Geo Herfindahl	0.0013	0.0066	0.0012	0.0066	-0.0003	0.0074	-0.0004	0.0075
	(0.0152)	(0.0168)	(0.0152)	(0.0168)	(0.0155)	(0.0167)	(0.0155)	(0.0167)
Longtail	-0.0126	-0.0195	-0.0125	-0.0195	-0.0145	-0.0192	-0.0144	-0.0192
	(0.0251)	(0.0167)	(0.0251)	(0.0167)	(0.0266)	(0.0169)	(0.0266)	(0.0169)
Portfolio maturity	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0000)

NoninvtFI Position	-0.0481		-0.0481		-0.0485		-0.0485	
	(0.0325)		(0.0325)		(0.0323)		(0.0323)	
DownFI Position		-0.1086**		-0.1087**		-0.1092**		-0.1093**
		(0.0493)		(0.0493)		(0.0498)		(0.0498)
Other Risky Assets	0.0098	-0.0110	0.0100	-0.0109	0.0030	-0.0048	0.0032	-0.0048
	(0.0282)	(0.0162)	(0.0282)	(0.0162)	(0.0286)	(0.0137)	(0.0286)	(0.0137)
Loss of capital measure								
ΔSurplus					-0.0133	0.0098	-0.0131	0.0098
					(0.0151)	(0.0066)	(0.0151)	(0.0066)
Underwrite Gain					-0.0019	-0.0016	-0.0021	-0.0017
					(0.0362)	(0.0194)	(0.0362)	(0.0194)
Constant	-0.0415	0.0277	-0.0411	0.0276	-0.0591	0.0530	-0.0586	0.0527
	(0.1353)	(0.0665)	(0.1352)	(0.0665)	(0.1381)	(0.0654)	(0.1380)	(0.0653)
Observations	1,030	1,030	1,030	1,030	999	999	999	999
R-squared	0.0645	0.0769	0.0646	0.0772	0.0691	0.0831	0.0692	0.0835
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer

Table 2.8. Overall risks after Hurricane Katrina

This table reports the coefficients estimated from the DID test investigating insurer overall risks during 2004 to 2006. The sample is larger than Table 2.6 because we remove the restriction that insurers should hold positive non-investment grade FI securities position. The treatment variable in columns with odd numbers, *DPW Exposure*, is the ratio of insurer *i*'s direct premiums written (DPW) in homeowner multiple peril lines in hurricane-impacted states to its total DPW in the Hurricane Katrina year (2005). The treatment variable in columns with even numbers, *Loss resv Exposure*, is the ratio of insurer *i*'s loss and loss-adjusted expense (LAE) reserves in homeowner multiple peril lines in hurricane-impacted states to its total loss and LAE reserves in 2005. *Post* is a dummy variable which equals to one for the year after the hurricane and zero otherwise. The dependent variable in columns 1-2 and 5-6 is *ROA Vol*, the standard deviation of the ratio of comprehensive income to admit assets (ROA) over the 3-year period from year *t*-2 to year *t*. The dependent variable in columns 3-4 and 7-8 is z-score, computed as the sum of ROA and the capital to assets ratio, divided by the standard deviation of ROA, which is then divided by 100. A lower z-score indicates a higher risk of default. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*ROA Vol*		*z-score*		*ROA Vol*		*z-score*	
Exposure proxy	*DPW*	*Loss Resv*	*DPW*	*Loss Resv*	*DPW*	*Loss Resv*	*DPW*	*Loss Resv*
Post	-0.0127	-0.0131	0.1713***	0.1719***	-0.0295**	-0.0298**	0.1717***	0.1723***
	(0.0096)	(0.0098)	(0.0307)	(0.0306)	(0.0118)	(0.0120)	(0.0315)	(0.0314)
*Exposure*Post*	0.0261*	0.0292*	-0.1229*	-0.1038	0.0333**	0.0312**	-0.1231*	-0.1038
	(0.0152)	(0.0163)	(0.0661)	(0.0797)	(0.0162)	(0.0145)	(0.0662)	(0.0797)
RBC Ratio	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group	-0.0015	-0.0016	-0.1017	-0.1011	0.0001	-0.0000	-0.1020	-0.1014
	(0.0084)	(0.0084)	(0.1211)	(0.1211)	(0.0092)	(0.0092)	(0.1212)	(0.1212)
Mutual	-0.0111**	-0.0113**	0.1595***	0.1595***	-0.0054**	-0.0055**	0.1592***	0.1592***
	(0.0052)	(0.0052)	(0.0221)	(0.0221)	(0.0023)	(0.0023)	(0.0221)	(0.0220)
Leverage	0.0078	0.0073	-0.1928	-0.1921	0.0289	0.0286	-0.1936	-0.1930
	(0.0334)	(0.0332)	(0.1347)	(0.1348)	(0.0513)	(0.0512)	(0.1347)	(0.1348)
ROE	-0.0011	-0.0011	-0.0000	-0.0000	0.0012**	0.0012**	-0.0000	-0.0000
	(0.0010)	(0.0010)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0009)	(0.0009)
Ln Surplus	-0.0315*	-0.0313*	-0.0102	-0.0110	0.0638*	0.0640*	-0.0124	-0.0132
	(0.0171)	(0.0172)	(0.0441)	(0.0441)	(0.0361)	(0.0362)	(0.0520)	(0.0520)
Longtail	0.0025	0.0025	-0.0053	-0.0054	0.0019	0.0019	-0.0053	-0.0054
	(0.0039)	(0.0039)	(0.0088)	(0.0088)	(0.0025)	(0.0025)	(0.0088)	(0.0088)

Lob Herfindahl	-0.0812	-0.0813	0.0920	0.0922	-0.0320	-0.0321	0.0900	0.0902
	(0.0528)	(0.0528)	(0.1687)	(0.1687)	(0.0440)	(0.0440)	(0.1691)	(0.1691)
Geo Herfindahl	0.0295	0.0289	0.0507	0.0530	0.0276	0.0270	0.0510	0.0532
	(0.0339)	(0.0336)	(0.1769)	(0.1770)	(0.0369)	(0.0367)	(0.1770)	(0.1771)
NoninvtFI Position	-0.0127	-0.0082	-0.1451	-0.1586	-0.0129	-0.0086	-0.1456	-0.1590
	(0.0273)	(0.0266)	(0.2404)	(0.2417)	(0.0401)	(0.0394)	(0.2405)	(0.2418)
Other Risky Assets	-0.0249	-0.0251	0.1422	0.1436	-0.0306	-0.0309	0.1422	0.1436
	(0.0446)	(0.0446)	(0.1609)	(0.1608)	(0.0448)	(0.0448)	(0.1609)	(0.1609)
Portfolio Maturity	-0.0000	-0.0000	-0.0013	-0.0014	-0.0007	-0.0006	-0.0013	-0.0013
	(0.0003)	(0.0003)	(0.0055)	(0.0055)	(0.0008)	(0.0008)	(0.0055)	(0.0055)
Loss of capital measures								
ΔSurplus					-0.2018***	-0.2018***	0.0094	0.0093
					(0.0731)	(0.0731)	(0.0141)	(0.0142)
Underwrite Gain					-0.0096***	-0.0096***	-0.0004	-0.0004
					(0.0015)	(0.0015)	(0.0025)	(0.0025)
Constant	0.3821**	0.3809**	0.6164	0.6218	-0.5653	-0.5669	0.6381	0.6437
	(0.1725)	(0.1728)	(0.4712)	(0.4712)	(0.3747)	(0.3752)	(0.5410)	(0.5410)
Observations	4,760	4,760	4,760	4,760	4,760	4,760	4,760	4,760
R-squared	0.0054	0.0054	0.0177	0.0177	0.1619	0.1619	0.0177	0.0177
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer

Table 2.9. Overall risk after Hurricane Sandy

This table reports the coefficients estimated from the DID test investigating insurer overall risks during 2004 to 2006. The sample is larger than Table 2.6 because we remove the restriction that insurers should hold positive non-investment grade FI securities position. The treatment variable in columns with odd numbers, *DPW Exposure*, is the ratio of insurer *i*'s direct premiums written (DPW) in homeowner multiple peril lines in hurricane-impacted states to its total DPW in the Hurricane Katrina year (2005). The treatment variable in columns with even numbers, *Loss resv Exposure*, is the ratio of insurer *i*'s loss and loss-adjusted expense (LAE) reserves in homeowner multiple peril lines in hurricane-impacted states to its total loss and LAE reserves in 2005. *Post* is a dummy variable which equals to one for the year after the hurricane and zero otherwise. The dependent variable in columns 1-2 and 5-6 is *ROA Vol*, the standard deviation of the ratio of comprehensive income to admit assets (ROA) over the 3-year period from year *t*-2 to year *t*. The dependent variable in columns 3-4 and 7-8 is z-score, computed as the sum of ROA and the capital to assets ratio, divided by the standard deviation of ROA, which is then divided by 100. A lower z-score indicates a higher risk of default. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*ROA Vol*		*z-score*		*ROA Vol*		*z-score*	
Exposure proxy	*DPW*	*Loss Resv*	*DPW*	*Loss Resv*	*DPW*	*Loss Resv*	*DPW*	*Loss Resv*
Post	0.0023**	0.0023**	0.0496	0.0540	0.0023**	0.0023**	0.0492	0.0537
	(0.0011)	(0.0011)	(0.0397)	(0.0395)	(0.0011)	(0.0011)	(0.0395)	(0.0393)
*Exposure*Post*	0.0115***	0.0106***	-0.1960	-0.2728**	0.0115***	0.0106***	-0.1954	-0.2723**
	(0.0036)	(0.0031)	(0.1369)	(0.1340)	(0.0036)	(0.0031)	(0.1369)	(0.1340)
RBC Ratio	-0.0000	-0.0000	0.0000	0.0000	-0.0000	-0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0000)	(0.0000)	(0.0001)	(0.0001)
Group	0.0095*	0.0095*	-0.0585	-0.0561	0.0099*	0.0098*	-0.0598	-0.0574
	(0.0056)	(0.0056)	(0.0629)	(0.0630)	(0.0056)	(0.0056)	(0.0629)	(0.0630)
Mutual	-0.0072	-0.0072	0.0924	0.0908	-0.0072	-0.0071	0.0924	0.0907
	(0.0044)	(0.0044)	(0.1349)	(0.1350)	(0.0045)	(0.0044)	(0.1350)	(0.1350)
Leverage	-0.0175**	-0.0174**	0.2316	0.2278	-0.0161**	-0.0160**	0.2286	0.2248
	(0.0081)	(0.0081)	(0.2438)	(0.2433)	(0.0071)	(0.0071)	(0.2477)	(0.2473)
ROE	0.0024***	0.0024***	-0.0116	-0.0114	0.0090*	0.0090*	-0.0404	-0.0397
	(0.0008)	(0.0008)	(0.0078)	(0.0078)	(0.0051)	(0.0051)	(0.0298)	(0.0299)
Ln Surplus	-0.0159***	-0.0159***	0.1166	0.1157	-0.0135***	-0.0135***	0.1170	0.1156
	(0.0048)	(0.0048)	(0.0760)	(0.0760)	(0.0044)	(0.0044)	(0.0907)	(0.0906)
Longtail	0.0011***	0.0011***	0.0102	0.0098	0.0009	0.0009	0.0102	0.0098
	(0.0003)	(0.0003)	(0.0177)	(0.0177)	(0.0006)	(0.0006)	(0.0183)	(0.0183)

Lob Herfindahl	-0.0042	-0.0042	0.0944	0.0985	-0.0041	-0.0042	0.0942	0.0983
	(0.0055)	(0.0055)	(0.3601)	(0.3602)	(0.0056)	(0.0056)	(0.3603)	(0.3604)
Geo Herfindahl	-0.0003	-0.0002	0.0312	0.0294	-0.0004	-0.0004	0.0312	0.0295
	(0.0069)	(0.0069)	(0.2437)	(0.2437)	(0.0069)	(0.0069)	(0.2436)	(0.2436)
NoninvtFI Position	-0.0254*	-0.0253*	0.4754*	0.4762*	-0.0258*	-0.0258*	0.4760*	0.4767*
	(0.0139)	(0.0139)	(0.2864)	(0.2861)	(0.0141)	(0.0141)	(0.2864)	(0.2862)
Other Risky Assets	0.0015	0.0015	-0.0157	-0.0160	0.0015	0.0015	-0.0160	-0.0162
	(0.0038)	(0.0038)	(0.1475)	(0.1475)	(0.0038)	(0.0038)	(0.1475)	(0.1475)
Portfolio Maturity	-0.0000	-0.0000	0.0009	0.0009	-0.0000	-0.0000	0.0009	0.0009
	(0.0000)	(0.0000)	(0.0008)	(0.0008)	(0.0000)	(0.0000)	(0.0008)	(0.0008)
Loss of capital measures								
ΔSurplus					-0.0050	-0.0050	-0.0032	-0.0022
					(0.0081)	(0.0081)	(0.0842)	(0.0842)
Underwrite Gain					-0.0045	-0.0045	0.0190	0.0187
					(0.0031)	(0.0031)	(0.0198)	(0.0199)
Constant	0.1926***	0.1926***	-0.5997	-0.5912	0.1685***	0.1684***	-0.5984	-0.5861
	(0.0514)	(0.0514)	(0.8821)	(0.8814)	(0.0444)	(0.0445)	(1.0373)	(1.0363)
Observations	5,253	5,253	5,253	5,253	5,253	5,253	5,253	5,253
R-squared	0.0120	0.0120	0.0033	0.0036	0.0135	0.0135	0.0033	0.0037
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer

Table 2.10. Subsample partition based on RBC ratio

This table shows how the capital adequacy (measured by RBC ratio) affects the sensitivity of the risky FI investment to the RBC cost of FI securities, in normal case and in emergency time. In panel A we partition the whole sample into terciles based on observations' year-beginning RBC ratio. In Panel B we partition the Katrina sample into terciles based on observations' year-beginning RBC ratio. A higher RBC ratio is indicative of more adequate capital. The dependent variable in columns 1-3, *NoninvtFI Net Buy*, is the net purchase of non-investment grade FI securities scalded by the year-beginning Book adjusted carrying value (BACV) of its FI holdings. The dependent variable in columns 4-6, *DownFI Net Buy*, is the net purchase of downgraded FI securities during year *t* scalded by the year-beginning BACV of its FI holdings. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

Panel A. Whole sample

	(1)	(2)	(3)	(4)	(5)	(6)
RBC ratio terciles	Low	Middle	High	Low	Middle	High
VARIABLES		*NoninvtFI Net Buy*			*DownFI Net Buy*	
RBC Cost FI	-0.0432	-0.0521	-0.0381**	-0.0373	-0.0251	-0.0230**
	(0.0667)	(0.0492)	(0.0178)	(0.0423)	(0.0182)	(0.0102)
Group	0.0088	-0.0035	0.0005	0.0029	0.0035	-0.0022
	(0.0063)	(0.0071)	(0.0033)	(0.0036)	(0.0058)	(0.0041)
Mutual	0.0187	0.0009	-0.0036	0.0169	-0.0038	-0.0040
	(0.0123)	(0.0081)	(0.0037)	(0.0116)	(0.0072)	(0.0025)
ROE	0.0111**	0.0114	0.0141*	0.0042	0.0096*	0.0146**
	(0.0051)	(0.0079)	(0.0082)	(0.0034)	(0.0054)	(0.0062)
Ln Surplus	0.0054	0.0028	0.0041	0.0000	-0.0018	0.0015
	(0.0046)	(0.0050)	(0.0030)	(0.0024)	(0.0028)	(0.0023)
Leverage	0.0343*	0.0486**	-0.0098	0.0067	0.0220*	-0.0065
	(0.0207)	(0.0217)	(0.0128)	(0.0138)	(0.0133)	(0.0081)
Lob Herfindahl	-0.0147	-0.0113	0.0086	-0.0134*	0.0022	0.0020
	(0.0170)	(0.0117)	(0.0083)	(0.0074)	(0.0087)	(0.0060)
Geo Herfindahl	0.0054	0.0057	0.0054	0.0011	0.0022	-0.0033
	(0.0127)	(0.0094)	(0.0078)	(0.0074)	(0.0060)	(0.0051)
Longtail	0.0034	0.0253*	-0.0026	0.0013	0.0102	-0.0046
	(0.0171)	(0.0150)	(0.0057)	(0.0125)	(0.0121)	(0.0048)
Portfolio maturity	0.0001	-0.0002	-0.0001	0.0003**	0.0000	0.0001
	(0.0003)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
DownFI Position				-0.1131***	-0.0999***	-0.1206***
				(0.0311)	(0.0266)	(0.0296)
NoninvtFI Position	-0.1482**	-0.1224**	-0.1461***			
	(0.0604)	(0.0554)	(0.0433)			
Other Risky Assets	0.0676***	0.0541**	0.0027	0.0286***	0.0333**	-0.0052
	(0.0188)	(0.0246)	(0.0162)	(0.0104)	(0.0156)	(0.0116)
Constant	-0.0854	-0.0716	-0.0349	-0.0081	-0.0091	-0.0027
	(0.0547)	(0.0586)	(0.0359)	(0.0307)	(0.0309)	(0.0283)
Observations	1,409	1,409	1,408	1,409	1,409	1,408
R-squared	0.0952	0.1145	0.0877	0.0922	0.1042	0.1034
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer

Panel B. Katrina sample

The exposure to Hurricane Katrina is measured by *DPW Exposure*, the ratio of insurer *i*'s direct premiums written (DPW) in homeowner multiple peril lines in hurricane-impacted states to its total DPW in the Hurricane Katrina year (2005). The sample is from 2004-2006.

	(1)	(2)	(3)	(4)	(5)	(6)
RBC ratio tertile	Low	Middle	High	Low	Middle	High
Dependent Variable	*NoninvtFI Net Buy*			*DownFI Net Buy*		
Exposure proxy	*DPW*			*DPW*		
Post	-0.0021	-0.0070	-0.0066	-0.0020	-0.0050*	-0.0034
	(0.0040)	(0.0045)	(0.0047)	(0.0025)	(0.0029)	(0.0022)
*Post*Exposure*	0.0195*	0.0026	0.0145**	0.0178**	-0.0023	0.0127**
	(0.0103)	(0.0106)	(0.0065)	(0.0069)	(0.0058)	(0.0050)
RBC Ratio	-0.0063**	0.0015	0.0001	-0.0012	0.0011	0.0000
	(0.0030)	(0.0018)	(0.0001)	(0.0020)	(0.0013)	(0.0001)
Group	-0.0043		-0.0047	0.0051		-0.0044***
	(0.0030)		(0.0060)	(0.0038)		(0.0016)
ROE	0.0032	0.0128	0.0073	-0.0004	0.0102	0.0056
	(0.0070)	(0.0176)	(0.0210)	(0.0048)	(0.0100)	(0.0123)
Ln Surplus	0.0014	0.0177	0.0105	-0.0016	0.0110	-0.0016
	(0.0102)	(0.0160)	(0.0195)	(0.0068)	(0.0106)	(0.0088)
Leverage	-0.0836*	0.0886	0.0453	-0.0309	0.1074***	0.0184
	(0.0449)	(0.0746)	(0.0670)	(0.0287)	(0.0404)	(0.0305)
Lob Herfindahl	0.0443*	0.0880	-0.0243	0.0249	0.0699	-0.0320
	(0.0268)	(0.0623)	(0.0398)	(0.0164)	(0.0470)	(0.0250)
Geo Herfindahl	-0.0239	-0.0278	-0.0662*	-0.0189	-0.0332*	-0.0278
	(0.0191)	(0.0242)	(0.0396)	(0.0121)	(0.0185)	(0.0261)
Longtail	-0.0279	0.0789	-0.0087	0.0027	0.0433	0.0175
	(0.0321)	(0.0690)	(0.0206)	(0.0207)	(0.0504)	(0.0130)
Portfolio maturity	0.0005	0.0006	-0.0014*	0.0004	0.0003	-0.0004
	(0.0006)	(0.0008)	(0.0008)	(0.0006)	(0.0006)	(0.0003)
NoninvtFI Position	-0.0747	-0.2650**	-0.2509**			
	(0.1139)	(0.1167)	(0.1085)			
DownFI Position				-0.0618	-0.1457**	-0.2108***
				(0.0851)	(0.0725)	(0.0622)
Other Risky Assets	0.1046*	0.2888**	0.0282	0.0544*	0.1517**	-0.0526
	(0.0551)	(0.1262)	(0.0627)	(0.0279)	(0.0664)	(0.0478)
Constant	0.0605	-0.3752**	-0.0500	0.0216	-0.2580**	0.0458
	(0.1272)	(0.1825)	(0.2284)	(0.0776)	(0.1148)	(0.1035)
Observations	434	434	434	434	434	434
R-squared	0.1422	0.2844	0.1435	0.1045	0.2145	0.2313
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer

Table 2.11. Extended sample period for Non-MBS fixed-income securities

This table reports the coefficients estimated from the panel regression on the relationship between the RBC cost of fixed-income (FI) securities and purchases of risky FI securities. The sample consists of 6,305 insurer-year observations from 2003 to 2015. Only insurers with no insurance subsidiaries and positive risky FI securities positions at the beginning of the year are included. The dependent variables are constructed using Non-MBS FI securities. Columns 1-3 are for non-investment grade FI securities. The dependent variable in column 1, *NoninvtFI Net Buy,* is the net purchase of non-investment grade FI securities scalded by the year-beginning Book adjusted carrying value (BACV) of its FI holdings. In columns 3 and 4 the net purchase is disaggregated into buy and sell parts. Columns 4-6 are for downgraded FI securities. *RBC Cost FI* is the marginal RBC cost of FI securities. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variables	*NoninvtFI Net Buy*	*NoninvtFI Sell*	*NoninvtFI Buy*	*DownFI Net Buy*	*DownFI Sell*	*DownFI Buy*
RBC Cost FI	-0.0354**	0.0120*	-0.0234	-0.0215***	0.0108***	-0.0107*
	(0.0166)	(0.0062)	(0.0148)	(0.0076)	(0.0037)	(0.0058)
RBC Ratio	0.0003***	-0.0001*	0.0002**	0.0001***	-0.0001*	0.0001**
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0000)	(0.0000)
Group	0.0071**	-0.0018	0.0053**	0.0035*	-0.0011	0.0024
	(0.0029)	(0.0012)	(0.0026)	(0.0019)	(0.0009)	(0.0015)
Mutual	-0.0090***	0.0023	-0.0066**	-0.0039*	0.0022	-0.0017*
	(0.0025)	(0.0036)	(0.0029)	(0.0023)	(0.0022)	(0.0010)
ROE	0.0067*	-0.0030*	0.0037	0.0045**	-0.0040***	0.0006
	(0.0034)	(0.0016)	(0.0032)	(0.0018)	(0.0013)	(0.0015)
Ln Surplus	-0.0017	-0.0001	-0.0017	-0.0014	0.0006	-0.0008
	(0.0016)	(0.0008)	(0.0014)	(0.0008)	(0.0006)	(0.0006)
Leverage	0.0139*	-0.0027	0.0112	0.0022	-0.0004	0.0019
	(0.0073)	(0.0036)	(0.0073)	(0.0038)	(0.0027)	(0.0031)
Lob Herfindahl	-0.0008	-0.0010	-0.0019	-0.0016	-0.0004	-0.0020
	(0.0058)	(0.0025)	(0.0050)	(0.0027)	(0.0018)	(0.0019)
Geo Herfindahl	-0.0001	0.0011	0.0011	-0.0029	0.0036*	0.0007
	(0.0040)	(0.0022)	(0.0036)	(0.0025)	(0.0019)	(0.0015)
Longtail	0.0097*	-0.0024	0.0073	0.0024	0.0007	0.0031
	(0.0058)	(0.0023)	(0.0050)	(0.0029)	(0.0020)	(0.0019)
Portfolio Maturity	0.0000	-0.0000	0.0000	0.0000	-0.0000	0.0000
	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0000)
DownFI Position				-0.0897***	0.1238***	0.0341***
				(0.0135)	(0.0088)	(0.0101)
NoninvtFI Position	-0.0834***	0.1542***	0.0708***			
	(0.0261)	(0.0169)	(0.0250)			
Other Risky Assets	0.0230***	0.0014	0.0244***	0.0081*	0.0003	0.0084**
	(0.0084)	(0.0038)	(0.0081)	(0.0043)	(0.0025)	(0.0041)
Constant	-0.0021	0.0096	0.0075	0.0106	-0.0034	0.0073
	(0.0191)	(0.0090)	(0.0176)	(0.0097)	(0.0070)	(0.0076)
Observations	6,305	6,305	6,305	6,305	6,305	6,305
R-squared	0.0469	0.1647	0.0470	0.0548	0.1646	0.0343
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer

Table 2.12. RBC cost and stock investment

This table reports the coefficients estimated from the panel regression on the relationship between the RBC cost of stocks and net purchases of stocks. The sample consists of 10,341 insurer-year observations from 2003 to 2015. Only insurers with no insurance subsidiaries and positive stock investment positions at the beginning of the year are included. The dependent variable in column 1, *Growth of* R_2, is the growth rate of R_2 in year t. R_2 is the risk charge in insurers' stock investment. The dependent variable in column 2, *Stock Net buy*, is the net purchase of stocks during year *t* scalded by the insurer's all invested assets at the beginning of year *t*. In columns 3 and 4 we split *Stock Net buy* into buy and sell parts. *RBC Cost Stock* is the marginal RBC cost of stocks. *Stock position* is the proportion of common and preferred stocks in invested assets at the beginning of year *t*. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)
Dependent Variables	*Growth of R2*	*Stock Net Buy*	*Stock Sell*	*Stock Buy*
RBC Cost Stk	-3.1131***	-0.1639***	0.0301**	-0.1339***
	(0.2849)	(0.0229)	(0.0146)	(0.0248)
RBC Ratio	0.0157***	0.0017***	-0.0001	0.0016***
	(0.0055)	(0.0004)	(0.0002)	(0.0005)
Group	-0.0514	-0.0084	0.0127	0.0043
	(0.1362)	(0.0110)	(0.0084)	(0.0123)
Mutual	-0.2382*	-0.0013	0.0005	-0.0008
	(0.1401)	(0.0157)	(0.0197)	(0.0294)
Leverage	-1.1159***	-0.0834***	0.0409*	-0.0425
	(0.4320)	(0.0287)	(0.0237)	(0.0379)
ROE	0.3575**	0.0366**	-0.0333***	0.0033
	(0.1733)	(0.0160)	(0.0116)	(0.0174)
Ln Surplus	-0.0215	-0.0137	-0.0123**	-0.0260**
	(0.0793)	(0.0088)	(0.0056)	(0.0105)
Lob Herfindahl	-0.0071	0.0148	-0.0006	0.0141
	(0.2684)	(0.0180)	(0.0152)	(0.0221)
Geo Herfindahl	-0.1043	-0.0169	0.0035	-0.0134
	(0.2609)	(0.0174)	(0.0127)	(0.0195)
Longtail	-0.2034	0.0227	0.0187	0.0414
	(0.3027)	(0.0159)	(0.0218)	(0.0302)
Other Risky Assets	-0.0146	-0.0024***	0.0009	-0.0015*
	(0.0112)	(0.0008)	(0.0006)	(0.0008)
Stock position	-0.5151*	-0.0141	0.2330***	0.2190***
	(0.2818)	(0.0306)	(0.0268)	(0.0377)
Constant	2.4156**	0.2471**	0.0966	0.3438***
	(0.9954)	(0.0973)	(0.0613)	(0.1183)
Observations	10,341	10,341	10,341	10,341
R-squared	0.0658	0.0511	0.0929	0.0382
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer

Chapter Three: Internal Capital Markets and Organizational Forms

Abstract

We study how the return of internal capital markets (ICMs) and the risk of ICMs differ across three alternative organizational forms: publicly-held stock insurers, privately-held stock insurers and mutual insurers. Because of the different combination of owner, manager and customer functions, these three organizational forms are subjected to different aspects and extents of agency problems, which leads to a variation in the performance of ICMs. In terms of return, we find that the sensitivity of investment increase in highly profitable business lines to ICM subsidy is significantly positive for private insurers, but is insignificant for mutual and public insurers. In terms of risk, we find that the sensitivity of investment increase in highly profitable and highly risky business lines to ICM subsidy is significantly positive for public insurers. Finally, we shed light on the association between organizational forms and shadow insurance, one specific ICM transaction associated with increasing firm-level risk. We find that the underwriting ROA volatility is more sensitive to shadow ICM subsidy than to regular ICM subsidy for public insurers.

JEL classification: G22; G32

Keywords: internal capital markets, organizational forms, insurance, mutual, private, shadow insurance

1. Introduction

Recent empirical works show that internal capital markets (ICMs) are active and highly prevalent within conglomerates. However, conflicting empirical results have been documented on whether they genuinely improve the efficiency of capital allocation within a conglomerate. These conflicting results can be readily explained by competing hypotheses derived from theoretical models[48]. From the bright-side view, for example, Stein (1997) argues that capital is allocated to business units with better investment opportunities and such opportunities are determined via winner-picking methods carried out by the conglomerate's top manager. This conjectures that ICM do improve the efficiency of capital allocation within a conglomerate. From the dark-side view, for example, Scharfstein and Stein (2000) show that the conflicts of interest between that of the division manager and top manager, and that of the top manager and shareholders, bring about inefficient capital allocation through the ICM of a conglomerate.

Taken together, the conflicting views suggest that the efficiency of the ICMs are dependent on the organizational form within the conglomerate. More specifically, it has been widely documented in prior literature that a variation in organizational form is associated with a variation in the agency costs the firm is subjected to (Jensen and Meckling, 1976; Shleifer and Vishny, 1997). In our context, we note that the increase in agency costs arising from a variation in organizational form within a conglomerate can be reflected by the deterioration in the efficiency of the firm's ICM.

We aim to study how different organizational forms affect the operation of internal capital markets. More explicitly, we seek to determine how alternative organizational forms, which are subjected to different aspects and extents of agency problems, will lead to a variation in the efficiency[49] and risk of the firm's ICM. We investigate the return and risk of investments related to ICM operation in 3 different kinds of organizational forms: (1) Public stock firm, (2) Private stock firm, and (3) Mutual firm. We propose and show that the key differences in return and risk of investment related to ICM between the 3 different types of organizational forms arise from agency problems, i.e., the

[48] See the survey paper by Maksimovic and Phillips (2007).

[49] We refer to firm's return when we use the term "efficiency". The ICM literature of industrial firms measures the investment opportunities using Tobin's Q, whereas the ICM literature of financial institutions measures the investment opportunities using ROA or other performance proxies (Campello, 2002; Cremers et al., 2011; Powell et al., 2008). We note that Tobin's Q incorporates the risk of ICMs because the market value is discounted by the risk of the firm. However, when measuring ICM efficiency using performance proxies, the literature does not consider the embedded risk.

conflicts of interest among different parties within the firm (e.g. Meyer et al., 1992; Rajan et al., 2000; Scharfstein and Stein, 2000).

We use the US insurance property and casualty (P&C) industry as our research setting for two reasons. First, there exists a broad range of organizational forms that is suitable for our analysis: There are the stock companies which employs the standard corporate organizational form. Similar to other industrial corporations, some of these insurers are publicly-held while the others are privately-held. There are also the mutual and reciprocal companies that are owned by its customers. Second, more than 70% of P&C insurance companies belong to financial conglomerates. This specific setting allows for a potentially active ICM where capital can be readily cross-subsidized across group companies.

In the insurance industry, there are three important functions within each organizational form. The first is the manager function, where managers make the decisions to maximize firm value. The second is the owner function, where owners provide capital and are the residual income claimant. The third is the customer function, where policyholders pay insurance premiums in return for a promise that they will get a stipulated reimbursement from the insurance companies if the specified loss occurs, as a result policyholders are sometimes considered debtholders as well.

The three organizational forms we study in this paper differ in how the three functions are combined. Following Mayers and Smith (2013), we illustrate the relationship in Figure 3.1. Mutual companies merge the customer and owner functions as the policyholders are also the owners the company (Mayers and Smith, 2013). Stock companies are incorporated with the complete separation of the manager, owner and customer functions. However, compared to publicly-held insurers, privately-held insurers often have owner-managers or at the very least possess concentrated illiquid ownership (Cheng et al., 2017; Gao et al., 2013; Ke et al., 1999)[50] and this helps to better align the manager and owner functions.

The different combinations of the three functions suggest that the three proposed organizational forms are subjected to different aspects of the agency problems. On the one hand, because of the separation of owner and manager functions, public stock firms and mutual firms are exposed to the owner-manager conflicts. This means that managers make decisions to maximize their own

[50] Cheng et al. (2017) hand collect the ownership data for US P&C insurance companies over the period 1993-2006. In their sample, 73.2 % of privately-held insurers are family firms, of which 74.1% have family-member CEO.

utility and this, at times, might be conflicting against the owners' interests (Jensen and Meckling, 1976). On the other hand, because owners and customers are separate parties, stock insurance companies are subjected to the risk-shifting problem (Jensen and Meckling, 1976). Similar to the incentive conflict between shareholders and debtholders in industrial corporations, owners of the insurance companies have the incentive to engage in risk-taking activities to increase the value of their residual claims at the expense of the policyholders' fixed claim (Mayers and Smith, 2013).

There are also some other factors that affect the severity of agency problems in the different organizational forms. First, we focus on the owner-manager conflict that exists in both public stock and mutual firms. For public stock firms, the conflict can be mitigated by external governance, this can take the form of monitoring by institutional investors or by the takeover threats that exist in the U.S. market. However, such an external monitoring mechanism does not exist for mutual insurers because they are unable to issue public stock (Mayers et al., 1997). Second, we focus on the reduction in risk-taking decisions by both private stock and mutual firms. For private stock firms, the concentrated ownership and risk aversion of owner-manager help to mitigate the risk-shifting problem and serve to discourage excessive risk-taking (Mayers and Smith, 1990). For mutual firms, the organizational form serves to discourage excessive risk-taking not only because the owner-customer (i.e., shareholder-debtholder) relationship helps to mitigate risk-shifting concerns but also because policyholders are more risk averse as they tend not to have diversified wealth.

Using a sample of P&C insurance companies in the U.S. over the period of 2001-2015, we first study how the efficiency of ICMs differ in these three different organizational forms. In accordance with prior literature, we first measure the efficiency of ICMs by the sensitivity of investments in highly profitable segments to ICM subsidy. We find that compared to publicly-held insurers and mutual insurers, privately-held insurers experience a significantly higher investment increase in profitable lines with the same amount of internal capital subsidy. We next employ the ICM efficiency index, we again find that privately-held insurers have the most efficient capital allocation via ICM transactions.

Second, we study the risk implications of organizational forms on ICM operations. We conduct an independent double sort of the business lines based on the return and volatility of underwriting results, we find that compared to publicly-held insurers, mutual insurers and privately-held insurers experience a significant investment decrease in the highly profitable and highly risky business lines with the ICM subsidy. In addition, we also find that privately-held insurers experience a significantly higher investment increase in highly profitable but lowly risky segments compared to that publicly-held insurers. In support of prior results, we also find that the ICM subsidy is associated with a significantly higher firm-level underwriting ROA (UROA) volatility for public stock insurers as compared to mutual and private stock insurers.

Finally, we investigate how the different organizational forms are related to *shadow insurance*. In 2012 New York State Department of Financial Services (NYDFS) initiated an investigation into shadow insurance and are concerned that it could put policyholders and taxpayers at greater risk (Lawsky, 2013). Koijen and Yogo (2016) document shadow insurance grew significantly in the past 10 years and could reduce risk-based capital and increase expected loss for the industry. Through shadow insurance, "Insurance companies shift blocks of insurance policy claims to their affiliated special entities in order to take advantage of looser reserve and regulatory requirements" (Lawsky, 2013). We divide our ICM subsidy into two portions, the shadow ICM subsidy and the regular ICM subsidy. We define shadow ICM subsidy as the capital provided through shadow transactions[51] whereas the residual capital provided constitutes as the regular ICM subsidy. We find that the underwriting ROA volatility are significantly more sensitive to shadow ICM subsidy than regular ICM subsidy in public stock insurers, while both sensitivities are not significant in private stock insurers.

Our study contributes to the literature in three different ways. First, we provide a holistic analysis on how the agency problems, arising from differences in organizational forms, affect the operation of ICMs. Existing empirical literature that studies agency problems in ICMs largely focuses on the owner-manager conflict. The literature has investigated this conflict of interest from the perspective of manager equity ownership or the international differences in law and legal enforcement (Gugler et al., 2013; Ozbas and Scharfstein, 2010). In our paper, we provide a comprehensive setting that investigates multiple organizational forms which are subjected to different aspects and extents of the agency problems. By considering the different combinations of owner, manager and customer functions, we are able to provide a broader picture of how the

[51] Shadow transactions are reinsurance ceded to affiliated insurers that are subjected to a looser set of reserve and regulatory requirement. See section 6 for details.

conflicts of interest between different parties affect the performance of the ICMs. We also base our analysis from both the return and risk perspectives for a well-rounded argument. More specifically, one of our key results shows that in private stock firms, where there is a greater alignment between owners' and managers' incentives, the ICM functions more desirably where ICM subsidies are directed towards investing in highly profitable and lowly risky segments compared to that of public stock insurers.

Second, we contribute to the literature on the ICM operation in privately-held firms and non-stock firms. A majority of existing empirical literature conducts research on public firms due to data availability. In recent years, there is also a growing literature on investigating ICM operation on privately-held firms using proprietary dataset (e.g. Cremers et al., 2011; Glaser et al., 2013; Natividad, 2013). However, minimal research has been conducted on the comparison of ICM operation between publicly-held and privately-held firms, our paper serves to fill this gap. Furthermore, very little is known about how the ICMs work in non-stock firms, such as mutual firms or cooperatives, where customer are owners of the firm. Powell et al. (2008) fills this gap by showing that ICMs are active for both stock and mutual insurers. Our study provides new evidence to this literature by comparing ICM operations between stock and mutual insurers.

Third, we contribute to the literature on how organizational forms affect economic activities. A survey paper by Mayers and Smith (2013) presents that organizational forms have an effect on firm's executive compensation (Eckles and Halek, 2010; Mayers and Smith, 1992), board composition (Mayers et al., 1997), risk management (Ho et al., 2013; Lammtennant and Starks, 1993; Mayers and Smith, 1990) etc. Our paper serves to show that organizational forms affect internal capital allocation activity.

2. Hypotheses development

2.1 Efficiency in ICM operation

There are mixed views on whether internal capital markets indeed function efficiently. On the one hand, Williamson (1975) and Stein (1997) suggest that the ICMs can allocate resources more efficiently than external financing market because the top managers of a diversified firm is better informed about the investment opportunities of its sectors than outsiders. By contrast, Rajan et al.

(2000) argue that rent seeking by divisional managers induces corporate headquarters to allocate excessive capital to divisions with poor investment opportunities where rent-seeking incentives are the strongest. Scharfstein and Stein (2000) introduce the conflicts of interest between the top managers and outside shareholders to illustrate why capital, rather than cash, is allocated to rent-seeking managers.

Scharfstein and Stein (2000) predict that the inefficient capital allocation is partly due to the agency problems present in the top management of organizations, and this is supported by evidence from many empirical papers. For example, Ozbas and Scharfstein (2010) show that higher manager ownership is related to a more efficient allocation of capital. Gugler et al. (2013) find that the parent firms from a country with strong institutions have the best functioning ICMs. Kolasinski (2009) shows that firms using subsidiary debt mitigate the socialism capital allocation because it help to mitigate the free-cash flow problem.

Based on prior theoretical and empirical works on the determinants of the efficiency of ICMs, we argue that the extent to which the different organizations suffer from manager-owner type agency problems will have an impact on the efficient functioning of ICMs. We propose that compared to publicly-held stock and mutual insurance companies, privately-held stock insurance companies will possess greater alignment between the manager and owner functions as these firms usually have owner-managers or large illiquid shareholders. This implies that privately-held insurance companies will have a more efficient ICMs.

However, there are also some corporate governance mechanisms that help to mitigate the manager-owner conflicts. Both publicly-held and mutual insurers are subjected to the inside monitoring from the board of directors. In addition, as publicly-held insurers are listed, they are also subjected to the external monitoring from the capital markets, taking the form of monitoring by block institutional investors or by the takeover threats that exist in the U.S. market. Furthermore, public insurers can provide stock-based compensation to managers to better align their incentives but mutual insurers are unable to do so as they do not issue stock. This leads us to the question of how efficient the internal and external monitoring are in the functioning of the firms' ICM.

Consequentially, it is an empirical question of how the efficiency of internal capital markets differs in these three organizational forms. We state our research hypotheses in the null-form below:

H1: The efficiency of internal capital markets is the same for privately-held insurance companies and publicly-held insurance companies.

H2: The efficiency of internal capital markets is the same for mutual insurance companies and publicly-held insurance companies

In our empirical tests, we use both the sensitivity of investments in highly profitable segments to ICM subsidy, as well as the ICM Efficiency Index to measure the efficiency of internal capital markets.

2.2 Risk induced by internal capital markets

Empirical literature finds evidence that internal capital markets are related to both risk-reducing and risk-taking behaviors. An example of evidence on risk-reducing behaviors is He et al. (2013) who find that internal capital markets facilitate risk-sharing among business groups in China. They find that group affiliation significantly reduces ROA volatility and probability of default. Another example is Gopalan et al. (2007) who show that business groups in India use intra-group loans to transfer cash across affiliated firms and they suggest that this may be done so as to avoid default by a group firm. In contrast, evidence on risk-taking behaviors related to ICMs is concentrated in financial groups. Koijen and Yogo (2016) recently documented that U.S. life insurers had increasingly used a particular type of internal capital market transactions, named shadow insurance (i.e., reinsurance ceding to less regulate and unrated off-balance-sheet reinsurers) to disproportionally reduce required capital. This kind of off-balance sheet capital management, which retains the risk in the financial group while reduces the regulatory capital, is also observable in bank industries and regarded as the catalyzer of recent financial crisis (termed *shadow banking*, Acharya et al. (2013)).

The risk-shifting problem that leads to excessive risk-taking by the firm arises from the conflict of interest between shareholders and policyholders (or debtholders) (Jensen and Meckling, 1976). For mutual insurers, where the policyholders are the owners of the firm, the owner-policyholder type agency problem is absent. However, for stock insurers, the stockholders have the incentive to take on higher risks because policyholders share the losses but not the gains. A typical way to take on higher risk is to sell more insurance contracts in lines of business that are highly volatile, which subsequently leads to a higher volatility in underwriting ROA.

In addition, risk aversion is another determinant of risk-taking behavior. For example, Faccio et al. (2011) argues that "if their wealth is largely concentrated in the firms they own, risk-adverse owners will seek to avoid risk even more so than they would had they held a diversified portfolio." Consistent with the argument, they find evidence that owners with less diversified portfolios are associated with reduced risk-taking. Prior literature documents that privately-held insurers often have owner-managers and possess concentrated ownership (Cheng et al., 2017; Gao et al., 2013; Ke et al., 1999). Using reinsurance purchase as a proxy to measure risk-management, Mayers and Smith (1990) find that single family and closely-held insurers buy more reinsurance than publicly-held insurers. A similar risk-averse argument can also be applied to mutual firms, where the owners-customers who do not have a diversified portfolio will also be associated with reduced risk-taking activities.

Taken together, we formulate the following research hypotheses:

H3: Compared to publicly-held insurance companies, the investment related to ICM activity is less risky for mutual insurance companies.

H4: Compared to publicly-held insurance companies, the investment related to ICM activity is less risky for privately-held insurance companies.

In our empirical tests, we use both the sensitivity of investments in highly risky segments to ICM subsidy, as well as the firm-level underwriting ROA volatility to measure the risk induced by the internal capital markets.

2.3. Organizational forms and shadow insurance

As discussed in section 2.2, Koijen and Yogo (2016) document that some U.S. life insurers are engaging in one particular type of internal capital market activity, shadow insurance. Different from common ICM reinsurance transaction in which insurance liabilities are moved to regular affiliated companies, in shadow ICM reinsurance transaction, insurance liabilities are moved to affiliated reinsurers located in states or off-shore domiciles with looser capital regulation and favorable tax laws. Koijen and Yogo (2016) 's model shows that the shadow reinsurance transactions relax the capital requirements and reduce the risk-based capital because it allows life insurers to issue more policies for a given amount of equity.

The saved regulatory capital from shadow reinsurance transactions can support insurers to underwrite business in high risky business. Existing Literature shows that there are positive relationship between capital and risk-taking, both theoretically and empirically (e.g., Baranoff and Sager, 2002; Cheng and Weiss, 2013; Cummins and Sommer, 1996). Therefore, with more capital saved from shadow ICM, the insurance company can engage in highly risky lines of business and thus the firm-level risk rises. We formulate the following research hypotheses:

H5: The sensitivity of firm-level risk to shadow ICM transaction is higher than that of regular ICM transaction.

In section 2.2 we have already discussed that publicly-held stock insurance companies are more likely to take higher risk compared to privately-held stock insurance companies and mutual insurance companies. Therefore, we propose the following hypothesis:

H6: The sensitivity of firm-level risk to shadow ICM transaction is higher for public stock insurers than that for private stock insurers.

3. Research design

3.1. Construction of key variables

3.1.1. Measure of insurance companies' investment

We follow Powell et al. (2008) by measuring the insurance companies' investment using the gross premiums written, which is the main business for insurers. Gross premiums written is defined as direct premiums written (DPW) plus reinsurance assumed. Reinsurance assumed is the premium income from supplying reinsurance services. It can be earned from either affiliated insurers, or unaffiliated insurers, or both.

Invt Amount= Gross premiums written = Direct premiums written + Reinsurance assumed from affiliated insurers + Reinsurance assumed from unaffiliated insurers

3.1.2 Measure of insurance companies' investment in highly profitable / lowly profitable lines of business.

We disaggregate the *Invt Amount* variable into investments made in highly profitable and lowly profitable business lines, given by *Invt_HP Amount* and *Invt_LP Amount* respectively, and then define *Invt_HP* (*Invt_LP*) as the proportion of investment made in highly (lowly) profitable business lines. [52] The partition is based on the median lines-of-business (LOB) profitability within each insurer-year observation. If the business line's profitability is equal to or higher than the median, it will be classified as a highly profitable line of business, otherwise it will be classified as a lowly profitable line of business.

Insurance companies usually write insurance contracts in a variety of lines of business, such as homeowner lines, marine lines, etc. The underwriting results of each lines of business reported in the insurers' annual statement are on the page of Underwriting and Investment Exhibit (UIE) and Insurance Expense Exhibit (IEE), in a standard format. There are around 48 lines of business appearing on UIE and IEE, this number varies a little between years. We exclude 3 lines of business which focus on non-proportional reinsurance, this leads to 45 lines of business used in our analysis.

In our study, we consolidate the 45 lines of business into 14 lines of business according to the SNL classification[53]. SNL is a professional data provider for the insurance industry. We engage in this consolidation because of three reasons. As argued by Elango et al. (2008), "First, some lines of business represent insignificant proportion of the typical P&C insurance's book of business and thus would represent trivial inclusions in any data analysis if included separately. Second, consolidation among certain lines is feasible and reasonable where the underwriting and loss characteristics of those lines are relatively homogenous." The third reason is the data in UIE and IEE is classified into different variation of sub-business lines, thus by consolidating into the 14 lines of business allows for a fair comparison of information between both databases[54].

After the consolidation, we measure a business line's profitability by calculating the ratio of pre-tax profit excluding investment gains for a given line scaled by the net premium earned in that line[55]. Only lines of business reporting both positive net premium earned and net premium written

[52] E.g., *Invt_HP= Invt_HP Amount/ Invt Amount*

[53] Appendix 3.2 shows how these lines of business are consolidated.

[54] For example, in UIE, line 5 Commercial multiple peril is reported, while in IEE, it is disaggregated in to non-liability proportion (line 5.1) and liability proportion (line 5.2).

[55] Pre-tax profit excluding investment gains is in column 33, Part II, IEE and net premium earned is in column 1, Part II, IEE.

are included in our analysis. In each insurance company, we then partition the lines of business into highly profitable (HP) and lowly profitable (LP) lines based on the median value of LOB profitability.

3.1.3. Measure of insurance companies' investment in four return-risk groups

Similar to our construction of the *Invt_HP* and *Invt_LP* variables, we disaggregate the *Invt Amount* variable into investments made into four groups, which describe both the risk and return features of the insurance companies' investment. Within each insurer-year observation, we independently sort the 14 consolidated lines of business into four return-risk groups (HP/HR, HP/LR, LP/HR, LP/LR), defined as the intersection of two profitability groups (Highly profitable Vs Lowly profitable) and two risk groups (Highly risky Vs Lowly risky).

Our partition of HP (Highly profitable) and LP (Lowly profitable) groups is the same as that in section 3.1.2. Our partition of HR (Highly risky) and LR (Lowly risky) groups is based on the median LOB loss ratio volatility within each insurer-year observation. If the business line's loss ratio volatility is equal to or higher than the median, it will be classified as a highly risky line of business, otherwise it will be classified as a lowly risky line of business. The LOB loss ratio volatility, which measures the risk of each business line, is calculated as the standard deviation of loss ratio over the past 5 years. The loss ratio describes the underwriting result, which is calculated as the loss incurred divided by the net premiums earned.[56]

3.1.4. Firm-level efficiency measure

Our firm-level ICM efficiency measure is similar in spirit to Akhigbe and Whyte (2015). The ICM efficiency index is defined as the sum across a firm's lines of business of the product of each line's ICM subsidy and its relative profitability, scaled by the sum of total net premiums earned (NPE) of this insurer. The relative profitability measures one line's deviation from the median LOB profitability within this firm. Firm *i*'s ICM efficiency index is calculated as follows:

[56] loss incurred is in column 7 Part II, IEE

$$ICM\ Eff\ index_i = \frac{1}{NPE_i}\sum_{j=1}^{N_{lob}}[ICMSubsidy_j * [\left(\frac{Profit_j}{NPE_j}\right) - Firm\ median_i\ (\frac{Profit}{NPE})]]$$

A higher ICM efficiency index value indicates an internal capital market that functions more efficiently.

3.1.5. Firm-level risk measure

We use the volatility of net underwriting ROA over the past 5 years to measure the firm-level risk (see Faccio et al., 2011; Gugler et al., 2013). For example, the volatility of the underwriting ROA for year 2010 is calculated as its standard deviation from 2006-2010. An insurers' underwriting ROA is defined as the underwriting income divided by its assets. Underwriting ROA is equal to ROA except that investment income is subtracted from the numerator for underwriting ROA. We use underwriting ROA because it provides a direct measure of the riskiness of an insurer's underwriting investment.

3.1.6. Measure of ICM subsidy.

We follow Powell et al. (2008) and Fier et al. (2013) by measuring the ICM transactions using affiliated reinsurance transactions. A reinsurance contract is an insurance policy purchased by one insurance company (the ceding companies) from another insurance company (the reinsurer). Hence, within the insurance industry, reinsurance purchases are akin to traditional insurance purchases by industrial corporations or individuals.

The primary purpose of reinsurance is risk management where the reinsurer shares in the losses of the reinsurance portfolio. In addition, reinsurance also serves as a substitute for equity capital. When the ceding insurer purchases reinsurance, they transfer risk to the reinsurer, this reduces the net premiums written and thus, reduces the strain on the insurer's capital (Adiel, 1996).[57]

The reinsurance can be purchased from either affiliated insurers or unaffiliated insurers. As the reinsurance can act as a substitute for equity capital, the reinsurance transaction purchased within the group serves the role of providing capital to affiliated companies. Although there are other

[57] The ratio of net premium written to surplus is used by regulators to monitor the solvency of insurance companies. This ratio is included in Financial Analysis Tracking System solvency screen mechanism and Insurance Regulatory Information Systems (Grace et al., 1998). The purchase of reinsurnace directly reduce theis ratio and help insurers to avoid regulatory attension.

kinds of ICM transactions, such as dividend payment, direct capital contributions, Powell et al. (2008) show that affiliated reinsurance represents the largest proportion of ICM transactions within a group.

Henceforth, following Powell et al. (2008), we use the affiliated reinsurance to proxy for ICM transactions. The ICM subsidy is defined as the reinsurance ceded (purchased) minus the reinsurance assumed (sold) from affiliated companies, scaled by the gross premium written. This measures the portion of gross premiums written that are supported by affiliated insurers.

ICMSubsidy= (Reinsurance ceded from affiliates-Reinsurance assumed from affiliates) / Gross premiums written.

A positive value implies that the insurer is a net purchaser of affiliated reinsurance, and receives capital subsidy from other group members; while a negative value implies that the insurer is a net seller of affiliated reinsurance, and provides capital to its group members.

3.2. Regression model design

3.2.1. Efficiency of ICMs

To alleviate the concern of omitted variable in the level regression, we follow Powell et al. (2008) by using the change regression specification to compare the difference in efficiency of ICM functions across publicly-held, privately-held and mutual insurers. Our regression is specified as follows:

$$\Delta Invt\_XP_{it} = \alpha_0 + \beta_1 \Delta ICMSubsidy + \beta_2 \Delta ICMSubsidy * Private + \beta_3 \Delta ICMSubsidy * Mutual + \beta_4 Private + \beta_5 Mutual + \beta_6 \Delta Capitalization\ Controls + \beta_7 \Delta underwriting\ exposure\ contorls + \alpha_t + \varepsilon_{it} \quad (1)$$

We run two regressions here, where *ΔInvt_XP* takes on *ΔInvt_HP* and *ΔInvt_LP* as the dependent variable for the first and second regression respectively. This allows us to observe how insurers with different organizational forms behave in relation to investments in highly profitable and lowly profitable business lines.

All change variables, apart from *ΔSurplus*, are defined as the first difference between the current and last year's observation. *ΔSurplus* is defined as the change (in dollar amount) in the policyholder's surplus from period *t*-2 to *t*-1, scaled by the policyholder's surplus in period *t*-1 (i.e., the lagged surplus growth rate). Powell states that this modification is used to mitigate the mechanical relationship between changes in surplus and investment. As a robustness check, we define *ΔInvt_XP* as the investment change (in dollar amount) in the corresponding profitability group XP (i.e., HP or LP), scaled by gross premiums written of the previous period[58] and obtain similar results which are reported in Appendix 3.3.

The control group in our regressions is the publicly-held stock insurers. Therefore, $\Delta ICMSubsidy * Public$ will be omitted from our regression. The variables of interest for our regressions are *ΔICMSubsidy*Mutual* and *ΔICMSubsidy*Private*. These variables measure how the sensitivity of investments to ICM subsidy in highly (lowly) profitable business lines differs across the three different organizational forms. A higher sensitivity in the *ΔInvt_HP* (*ΔInvt_LP*) regression indicates a more efficient (less efficient) ICM of the corresponding organizational form relative to that of the publicly-held stock insurers.

As argued by Powell et al. (2008), insurance companies' investment is related to both the change in capitalization and the change in underwriting risk exposure. Following their paper, we include two sets of control variables. The first set measures the change in capitalization, included are surplus (*ΔSurplus*) and external reinsurance (*ΔExrein*). We expect these variables to be positively related to the insurance companies' investment because they increase the insurers' capacity to write more insurance contracts without a corresponding increase in the probability of insolvency.

The second set measures the change in underwriting risk exposure, included are geographic concentration, business concentration and the proportion of direct premiums written in long-tailed lines. Business concentration (*LobH*) is defined as the sum of squared ratio of the direct premiums written in lines of business to the total premiums written. A value of 1 indicates that the insurer focuses on a single line of business. Geographic concentration (*GeoH*) is defined as the sum of the squared ratio of the direct premiums written in each state to the total premium written in all states. A value of 1 indicates that the insurer focuses on business in a single state. The share of long-tailed business (*Longtail*) is defined as the ratio of direct premiums written in long-tailed lines to total direct premiums written. Catastrophe exposure (*CatExposure*) is calculated as the proportion of direct premiums written in the catastrophe related lines of business in the Cat Zones, provided by

[58] For example, $\Delta Invt\_HP_t = (Invt\_HP\ Amount_t - Invt\_HP\ Amount_{t-1})/ Invt\ Amount_{t-1}.$

SNL.[59] We expect these variables to be negatively related to the change in investment because a lower underwriting risk allows insurers to write more insurance contracts.

We also use our ICM efficiency index to measure the firm-level underwriting risk. We replace the dependent variable in equation (1) with the first difference of ICM efficiency index (*ΔEff index*). The variables of interest for this regression are *ΔICMSubsidy*Mutual* and *ΔICMSubsidy*Private*. These variables measure how the sensitivity of ICM efficiency index to ICM subsidy differs across the three different organizational forms. A higher sensitivity indicates a more efficient ICM of the corresponding organizational form relative to that of the publicly-held stock insurers.

3.2.2. Risk of ICMs

We use the investment change in the four return-risk groups to further investigate the risk change associated with the ICM transactions.

$$\begin{aligned}\Delta Invt\_XPXR_{it} &= \alpha_0 + \beta_1 \Delta ICMSubsidy + \beta_2 \Delta ICMSubsidy * Private + \beta_3 \Delta ICMSubsidy \\ &* Mutual + \beta_4 Private + \beta_5 Mutual + \beta_6 \Delta Capitalization\ Controls \\ &+ \beta_7 \Delta underwriting\ exposure\ contorls + \alpha_t + \varepsilon_{it}\end{aligned} \quad (2)$$

Essentially, the dependent variable in equation (1) is replaced by the change in investments across four groups of business lines: Highly profitable and highly risky (*ΔInvt_HPHR*), highly profitable and lowly risky (*ΔInvt_HPLR*), lowly profitable and highly risky (*ΔInvt_LPHR*) and lowly profitable and lowly risky (*ΔInvt_LPLR*). See section 3.1.2 for the detailed variable construction process. Similar to the construction of *ΔInvt_XP*, *ΔInvt_XPXR* is defined as the first change of the variable *Invt_XPXR*.

The control group in our regressions is the publicly-held stock insurers, thus $\Delta ICMSubsidy * Public$ is omitted in the regression. The variables of interest for our regressions are *ΔICMSubsidy*Mutual* and *ΔICMSubsidy*Private*. Following H3, we expect mutual insurers to

[59] Refer to Appendix 3.1 for detailed information.

take on lesser risk after their ICM transaction, as compared to publicly-held stock insurers. Therefore, we predict a negative coefficient (positive coefficient) on the interaction term *ΔICMSubsidy*Mutual* in HP/HR or LP/HR regression (HP/LR or LP/LR regression).

Following H4, in a similar fashion, we expect privately-held stock insurers to take on lesser risk after their ICM transaction, as compared to publicly-held stock insurers. Therefore, we predict a negative coefficient (positive coefficient) on the interaction term *ΔICMSubsidy*Private* in HP/HR or LP/HR regression (HP/LR or LP/LR regression).

Furthermore, we study the change in firm-level risk after the ICM subsidy. We replace the dependent variable in equation (2) with the underwriting ROA over the past most recent 5 years. Following both H3 and H4, we predict negative coefficients on both the interaction terms *ΔICMSubsidy*Mutual* and *ΔICMSubsidy *Private*.

4. Data and sample

4.1. Data source and sample selection

Our sample is based on all US P&C insurers filing annual reports to NAIC from year 2000 to 2015. Most of the insurance companies' statutory data used in our analysis are pulled from SNL Financial database, unless explicitly stated otherwise. SNL Financial collects and organizes data from regulatory filings that P&C insurers file with the NAIC.

We identify each insurance company's organizational form from NAIC's Demographics File For P&C Companies. The organizational forms reported include stocks, mutuals, Lloyds, risk retention groups and reciprocals. We define an insurance company as publicly-held based on the status of its ultimate-parent. First, we conduct a trace back to the ultimate parent using SNL (which provides the latest information) and the insurance firm's statutory annual report (focusing on Schedule Y and Notes to Financial Statement Point 10). If these sources do not reveal the ultimate owner, we conduct an additional search via the internet. Second, we conduct a check to ascertain if the ultimate parent firm is publicly-held and if so, the date it went public using the data from CRSP. We repeat this procedure for each insurance group.

We retrieve the underwriting data for each business line from both the page of Underwriting and Investment Exhibit (UIE) and the Insurance Expense Exhibit (IEE) of the annual statutory statement. We use IEE as it supplements the UIE by reporting loss adjustment expenses and all other underwriting expense in each business line (e.g., advertising, commission and brokerage expense, allowance to managers and agents). This information allows us to calculate the LOB profitability accurately. In practice, employing the IEE is a standard methodology used to analyze underwriting results and ratemaking for each LOB (See Willis Towers Watson's ratemaking manual, Werner and Modlin (2016)).

We exclude all insurance companies without any group affiliation because these companies would not have the data required for our ICM analysis.[60] We only include insurance companies with any of these three organizational forms: publicly-held stock insurers, privately-held stock insurers, and privately-held mutual insurers.[61] Furthermore, we exclude insurance companies with missing or negative asset values, and include only insurance companies with both direct premiums written (DPW) and net premiums written (NPW) in excess of 1 million USD. Following Powell et al. (2008), we also drop observations whose dependent or explanatory variables have changed by more than 100% over the previous year.[62]

As we are using the regression model specified in section 3.2, and the variable *ΔSurplus* is lagged by one year, our sample has to start from 2002. To reduce the impact of outliers across all analyses, all continuous variables are winsorized at the 1% level in both tails. After the screening methodology described above, our final sample consists of 10,226 insurer-year observations from year 2002 to 2015, with 1,271 unique insurers, and accounts for approximately 69.6% of total industry assets every year.

For our risk analysis, our sample is restricted to run from year 2005 to 2015. This arises from the need to calculate the 5-year rolling loss ratio volatility in each LOB and 5-year rolling underwriting ROA volatility.

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[60] i.e., we only include insurers with non-zero group code.
[61] There are 251 insurer-year observations of publicly-held mutual, which means that these mutual insurers belong to the groups with the ultimate parents listed in any main stock exchange. We don't include them in our regression analysis because the number of observations is relatively small compared to other categories. They are not typical mutual insurers. Publicly-held firms control mutual insurance companies via management agreement.
[62] Powell et al. (2008) winsorize these observations at 100% because simply dropping the outliers will diminish their sample significantly. We drop these observations because we have a relatively larger sample over a longer period.

4.2 Descriptive statistics

Table 3.1 reports the descriptive statistics for our sample firms across three alternative organization forms. All continuous variables are winsorized at the 1% level in both tails. We report the summary statistics for all variables based on their observed values and change in values, where change in values variables are used in our regression analyses as stated in section 3.2 , while the observed values allow for ease of interpretation and comparison. In our sample, publicly-held stock insurers, privately-held stock insurers and mutual insurers account for approximately 49.8%, 37.6% and 12.6% of all firm-year observations respectively. There are 600 unique publicly-held stock insurers, 545 unique privately-held stock insurers, and 126 unique mutual insurers.

The mean (median) proportion of investments in highly profitable lines of business (*Invt_HP*) is 47.6% (44.0%) for publicly-held stock insurers, 48.7% (45.4%) for privately-held stock insurers, and 40.3% (35.0%) for mutual insurers. These results show that privately-held stock insurers invest most heavily in highly profitable business lines, while mutual insurers invest the least among the three different organizational forms. Both the two sample t-test and Wilcoxon-test reject the null hypothesis that mutual and publicly-held stock insurers have the same proportion of investments in highly profitable business lines. Similar results are found for the comparison of mutual and privately-held stock insurers, while no significant difference is found between publicly-held and privately-held stock insurers.

The mean (median) proportion of investments in lowly profitable lines of business (*Invt_LP*) (i.e., the complement set of *Invt_HP*) is 50.6% (53.9%) for publicly-held stock insurers, 49.4% (51.7%) for privately-held stock insurers, and 57.2% (63.1%) for mutual insurers.

The mean (median) proportion of investments in highly profitable and highly risky lines of business (*Invt_HPHR*) is 22.0% (7.6%) for publicly-held stock insurers, 23.8% (6.7%) for privately-held stock insurers, and 14.1% (6.1%) for mutual insurers. Both the two-sample t-test and Wilcoxon test show that publicly-held stock insurers have a significantly different investment proportion than privately-held stock and mutual insurers.

The mean (median) proportion of investments in highly profitable and lowly risky business lines (*Invt_HPLR*) is 23.0 (10.2%) for publicly-held stock insurers, 22.2% (6.9%) for privately-held stock insurers, and 26.0% (14.1%) for mutual insurers. Both the two sample t-test and Wilcoxon-test suggest that mutual insurers invest most heavily in highly profitable and lowly risky business lines across these three organizational forms.

The mean (median) proportion of investment in lowly profitable and highly risky business lines (*Invt_LPHR*) is 16.6% (6.5%) for publicly-held stock insurers, 18.5% (6.7%) for privately-held stock insurers, and 21.2% (11.5%) for mutual insurers. Similar to prior results, mutual insurers invest most heavily in lowly profitable and highly risky business lines relative to publicly-held and privately-held stock insurers, as supported by both t-test and Wilcoxon-test.

In terms of the mean (median) proportion of investments in lowly profitable and lowly risky lines (*Invt_LPLR*), mutual insurers invest most heavily with 35.1% (34.3%), followed by publicly-held stock insurers with 33.0% (25.0%), while privately-held stock insurers invest the least with 30.3% (15.7%). There are also significant differences across these three organizational forms, as supported by both t-test.

The mean (median) of the firm-level ICM efficiency index (Eff index) is -0.059 (0.0000) for publicly-held stock insurers, -0.060 (0.0000) for privately-held stock insurers, and -0.031 (0.0014) for mutual insurers. The two sample t test suggests that there is no significant difference in efficiency index across the three different organizational forms, while the Wilcoxon-test shows that mutual firms have the higher efficiency index compared to the other two organizational forms.

We measure firm-level risk using standard deviation of underwriting ROA over the prior 5 years (*UROA Volatility*). The average volatility is 3.0% for publicly-held stock insurers, 3.0% for privately-held stock insurers, and 2.8% for mutual insurers. The t-test shows that mutual firms are least volatile compared to the publicly-held and privately-held stock insurers, while there is no significant difference between publicly-held and privately-held stock insurers.

The ICM subsidy *(ICMSubsidy*) is measured by the proportion of business written supported by affiliated insurers. The mean (median) value of ICM subsidy is 13.5% (8.9%) for publicly-held stock insurers, 6.3% (4.1%) for privately-held stock insurers and -4.6% (-3.8%) for mutual insurers. The negative mean and median value for mutual insurers suggest that the average mutual insurer is a net capital supplier within the business group. Both the t-test and Wilcoxon-test show that publicly-held stock insurers receive more internal capital subsidy than privately-held stock insurers, with the mutual insurers receive the least (and is actually a net supplier of capital).

The utilization of external reinsurance (*Exrein*) is measured as the proportion of business written supported by unaffiliated insurers. It is significantly different across all three organizational forms, with privately-held stock insurers using it the most, with a mean value of 9.0% , followed by mutual insurers with a mean value of 8.5 %, and publicly-held stock insurers using it the least with a mean value of 5.2%.

The size of the insurers are measured by the natural logarithm of policyholder's surplus (*Ln Surplus*). The mean value of surplus is 143.5 million (=$e^{11.87}$/1000) for publicly-held stock insurers, 67.5 million (=$e^{11.12}$/1000) for privately-held stock insurers and 191.6 million (=$e^{12.16}$/1000) for mutual insurers.

For the underwriting exposure variables, LOB concentration is measured by LOB Herfindahl index (*LobH*). A value of 1 denotes that the insurer focuses on a single line of business. The mean value of *LobH* is 0.43 for publicly-held stock insurers, 0.50 for privately-held stock insurers and 0.38 for mutual insurers, indicating that mutual insurers are more diversified in their underwriting in terms of business lines.

Geographic concentration of the insurer's business is measured by the geographic Herfindahl index (*GeoH*). A value of 1 denotes that the insurer writes businesses only in one state. The mean value of *GeoH* is 0.32 for publicly-held stock insurers, 0.47 for privately-held stock insurers and 0.47 for mutual insurers, indicating that publicly-held stock insurers are more diversified in their underwriting in terms of geography.

Finally, the mean value of the proportion of direct business written in long-tailed business lines (*Longtail*) is 0.68 for publicly-held stock insurers, 0.72 for privately-held stock insurers and 0.76 for mutual insurers. The t-test suggests that there exists significant difference across the three different organizational forms.

5. Main results

5.1. ICM efficiency

Table 3.2 reports the regression results of investment change in highly and lowly profitable business lines, as per equation (1). We compare the sensitivity of investment change to ICM subsidy across publicly-held stock (*Public*), privately-held stock (*Private*) and mutual (*Mutual*) insurers. The control group in all our regressions is the publicly-held stock insurers.

In column 1, the dependent variable is investment change in highly profitable LOB. The coefficient on *ΔICMSubsidy* is insignificant, this suggests that the ICM subsidy is not related to investment change in highly profitable LOB for public insurers. The coefficient on *ΔICMSubsidy*Mutual* is also insignificant, this suggests that there is no significant difference in the sensitivity of investment to ICM subsidy between mutual and public insurers in highly profitable LOB. However, the coefficient on *ΔICMSubsidy*Private* is positively significant at 5% level. Furthermore, the coefficient on *ΔICMSubsidy*Private* is significantly different from the coefficient on *ΔICMSubsidy*Mutual* (two-tailed Wald test p=0.0887). Taken together, these evidence suggest that the sensitivity of investment to ICM subsidy, in highly profitable LOB, is stronger in private insurers than that of public and mutual insurers. In terms of economic significance, a one standard deviation increase in the growth of ICM subsidy (0.11 for *ΔICMSubsidy*) is associated with an increase in the growth of investment in highly profitable business lines (*ΔInvt_HP*) of 1.1% for the private insurers, and a decrease of 0.72 % and 1.41% for the public and mutual insurers respectively.[63]

In column 2, the dependent variable is investment change in lowly profitable LOB. The coefficient on *ΔICMSubsidy*Private* is significantly negative, suggesting that the investment sensitivity in lowly profitable segment for private stock insurers are lower than that of public stock insurers. We also find the coefficient on *ΔICMSubsidy*Private* is significantly different from the coefficient on *ΔICMSubsidy*Mutual* (two-tailed Wald test p=0.0431). It suggests that the investment sensitivity in lowly profitable LOB are more positive for mutual insurers than that for private insurers. These results are also of great economic significance. A one standard deviation increase in the growth of ICM subsidy (0.11 for *ΔICMSubsidy*) is associated with an increase in the growth of investment in lowly profitable LOB (*ΔInvt_LP*) of 1.40% for mutual insurers, 0.17% for public insurers, and a decrease of 1.56% for private insurers.

For the control variables, we find that the change in utilization of external reinsurance (*ΔExrein*) is insignificant in both regressions. LOB concentration variable (*ΔLobH*) is significantly positive in column 1, but becomes significantly negative in column 2. To compare with prior research, we replace the dependent variable with overall investment change and, we document that the

[63] 1.1%=0.11*(0.1670-0.0658)*100%, where 0.1 is the standard deviation of *ΔICMSubsidy.* 0.1670 is the coefficient of *ΔICMSubsidy*Private;* -0.0658 is the coefficient of *ΔICMSubsidy.* Similarly, -0.72 %=0.11*(-0.0658)*100% and -1.41%=0.11*(-0.0658 -0.0624)*100%.

coefficient on LOB concentration is now insignificant, consistent with Powell et al's findings. Surplus growth (*ΔSurplus*) is insignificant in both column 1 and column 2, however, it becomes significantly positive when we use the overall investment change as the dependent variable. This provides support for Powell et al. (2008)'s argument that insurers' capital is positively related to insurance firms' investment. Geographical concentration (*ΔGeoH*) are insignificant in both column 1 and column 2. The coefficient on the proportion of long-tailed business (*ΔLongtail*) is significantly negative in column 1, becomes significantly positive in column 2, and is insignificant after we replace the dependent variable with overall investment change.

In column 3, we use firm-level ICM efficiency index as our dependent variable to measure the overall efficiency improvement related to ICM subsidy. The coefficient on the interaction term *ICMSubsidy*Private* is significantly positive at 10% level. This suggests that, compared to public or mutual insurers, the increase in efficiency index is more responsive to ICM subsidy for private insurers.

Overall, our results show that private insurers have the most efficiently functioning ICMs in terms of its highest (lowest) sensitivity of investment in highly (lowly) profitable business lines. The results are in line with our argument where public insurers, who suffer from a separation in manager and owner function (which led to the owner-manager agency problem), is associated with a less efficiently functioning ICM than private insurers, who enjoy greater alignment in manager and owner function. The results also support the argument that mutual insurers, who suffer from both owner-manager agency problem (due to a separation in manager and owner function) and possess only limited corporate governance mechanisms (due to their inability to issue stock), is also associated with a less efficiently function ICM than private insurers.

Our results are consistent with prior literature that compares the production and cost efficiency between mutual and stock insurers (Cummins et al., 2004; Cummins et al., 1999; Jeng et al., 2007), who documented that mutual insurers are less efficient than stock insurers in relation to cost control. Our results are also consistent with prior findings that public companies operate less efficiently than private companies because of stronger owner-manager agency problems (Bargeron et al., 2008; Gao et al., 2013).

5.2. Risk with ICMs

The purpose of this section is twofold: first, inspired by prior literature, we attempt to investigate how ICM transaction is related to firm-level risk across different organizational forms; and second, we can help mitigate the concern that the results documented in section 5.1, where private insurers invest their ICM subsidy more heavily in LOB with high profitability, is due to private insurers taking on significantly more risk than public and mutual insurers. Therefore, we further disaggregate the overall investments based on both underwriting profitability and volatility.

Table 3.3 reports the regression results of investment change in four risk-return groups, as per equation (2). In column 1, the dependent variable is investment change in highly profitable and highly risky LOB (*ΔInvt_HPHR*). We observe that the coefficient on *ΔICMSubsidy* is significantly positive, this indicates that public insurers use the ICM subsidy to facilitate investments in highly profitable and highly risky business lines.

The coefficients on both *ΔICMSubsidy*Mutual* and *ΔICMSubsidy*Private* are significantly negative. This suggests that compared to public insurers, private and mutual insurers invest less of the ICM subsidy in highly profitable and highly risky LOB. We further test whether each of the coefficient on "*ΔICMSubsidy*Mutual + ΔICMSubsidy*" and "*ΔICMSubsidy*Private + ΔICMSubsidy*" equals to zero (p=0.0659 and p=0.7512 respectively). The results suggests that ICM Subsidy is negatively related to investments increase in highly profitable and highly risky LOB for mutual insurers.

In column 2, the dependent variable is investment change in highly profitable and lowly risky LOB (*ΔInvt_HPLR*). We observe that the coefficients on both *ΔICMSubsidy* is significantly negative at the 10% level. The coefficient on *ΔICMSubsidy*Mutual* is insignificant, while the coefficient on *ΔICMSubsidy*Private* is significantly positive. These results suggest that the sensitivity of investments, in highly profitable and lowly risky LOB, to ICM subsidy is stronger for private insurers than public insurers.

In column 3, the dependent variable is investment change in lowly profitable and highly risky LOB (*ΔInvt_LPHR*). The coefficients on *ΔICMSubsidy*Mutual* is positive. In column 4, the dependent variable is investment change in lowly profitable and lowly risky LOB (*ΔInvt_LPLR*). We document that the coefficients on all key variables of interests are insignificant.

In column 5, we use the volatility of underwriting ROA as our dependent variable to measure changes in firm-level risk related to ICM subsidy. The coefficient on *ΔICMSubsidy* is significantly positive, this indicates that ICM subsidy is associated with higher firm–level volatility in overall underwriting business for public insurers. The coefficients on both *ΔICMSubsidy*Mutual* and *ΔICMSubsidy*Private* are significantly negative, this suggests that the volatility-ICM subsidy sensitivity is significantly weaker in mutual and private insurers. We further test whether each of the coefficient on "*ΔICMSubsidy*Mutual* + *ΔICMSubsidy*" and "*ΔICMSubsidy*Private* + *ΔICMSubsidy*" equals to zero (two-tailed p=0.0507 and p=0.1209 respectively). This indicates that ICM Subsidy is positively related to increase in firm-level volatility for mutual insurers.

Overall, we document that given an increase in ICM subsidy, public insurers are associated with the highest increase in firm-level underwriting ROA volatility, and highest investments increase in highly profitably and highly risky LOB. These results suggest that ICM subsidy is related to an increase in underwriting risk for public insurers. Our results also indicate that mutual and private firms seem to operate more prudently. These results support Hypothesis 3 where mutual insurers, as opposed to public insurers, take on lesser risk in their ICM transaction because of the merge in customer and owner functions. The results also lend support to Hypothesis 4 where private insurers, as opposed to public insurers, take on lesser risk because of significant risk aversion by owners arising from concentrated ownership.

6. Additional supporting evidence from the parent organizational forms and ICM performance

In previous section we study the organizational forms of individual insurers. In this section we rerun all the regressions based on the organization forms of the insurer's ultimate parent.

To control for the difference in the organizational forms of the sample individual insurers, we restrict our sample to stock insurers. In addition, we only include insurers whose ultimate parent is either mutual or stock firms (i.e., we excluded insurers whose ultimate parent is an association or reciprocal exchange, etc.). We define three organizational forms for the ultimate parents. *Parent Public* consists of insurers whose ultimate parent is a stock firm and the ultimate parent is public listed. *Parent Private* consists of insurers whose ultimate parent is a stock firm and the ultimate parent is privately held. *Parent mutual* consists of insurers whose ultimate parent is a mutual firm.

Results are shown in Table 3.4. They are quite consistent with our previous findings based on the organizational forms of the individual insurers. The coefficients on the interaction term

*ΔICMSubsidy*Parent Private* is significantly positive in column 1, significantly negative in column 2 and significantly positive in column 3, implying insurers with an ultimate parent of privately-held stock firm have the most efficient ICMs in terms of facilitating investment in the highly profitable lines of business.

In columns 4-8 we investigate the risk and return simultaneously. The coefficient of *ΔICMSubsidy* in column 4 is significantly positive, indicating insurers with ultimate parent of publicly-held stock insurers are increasing their investment in highly risky and highly profitable lines of business. In column 8, using the volatility of underwriting ROA as the firm level risk measure, we find *ΔICMSubsidy* is significantly positive and *ΔICMSubsidy*Parent Private* is significantly negative, indicating that ICM subsidy is related to increase in the underwriting volatility for insurers with ultimate parents of publicly-held stock firms, whereas it is not the case for insurers whose ultimate parents are privately-held stock firms.

Overall, the results are consistent with our previous findings based on the organizational forms of individual insurers. Mutual and private stock organizational forms tend to have lower risk ICMs and private stocks have higher ICM efficiency as well.

7. Shadow insurance

In this section we investigate how the different organizational forms affect one particular type of internal capital market (ICM) transactions: *shadow insurance.*

Koijen and Yogo (2016) find that insurers are using shadow insurance to manage capital in the life insurance industry. They define shadow insurance transaction as the reinsurance business ceded to (purchased from) affiliated insurers who are subjected to a looser set of reserve and regulatory requirements.[64] Insurers usually create a wholly-owned subsidiary known as a "captive", the insurers then transfer blocks of insurance policy claims to these captives through reinsurance transactions (Lawsky, 2013). After these transactions, the ceding insurer's (purchaser's) underwriting business will be supported by these captives, but the risk of the business is still retained within the group. Therefore, shadow insurance is considered as a highly risky way for insurers to manage capital.

[64] Reserves are funds that insurers set aside to pay policyholder claims. Being subjected to a looser set of reserve and regulatory requirements mean that insurers only need to hold lesser funds (capital) for the same amount of risk. This is highly risky as the insurers, holding lesser capital, might not be able to fulfil all subsequent claims by policyholder.

We divide the ICM subsidy into two parts. The first part is shadow insurance where the underwriting business is ceded to shadow insurers, this means that the ICM subsidy is provided by shadow insurers. Shadow reinsurers are defined as affiliated and unauthorized companies without AM best rating, as per Koijen and Yogo (2016).[65] The other part is regular affiliated reinsurance transaction where the underwriting business is ceded to non-shadow affiliated reinsurers, this means that the ICM subsidy is provided by regular affiliated reinsurers.

ICMSubsidy = Regular ICMSubsidy + Shadow ICMSubsidy

Detailed reinsurance ceding (purchasing) transaction information is retrieved from Schedule F part 3 of the NAIC financial statements. This allows us to identify the name of the reinsurer (seller), whether the reinsurer is affiliated, and whether the reinsurer is authorized. Reinsurers' AM best ratings are retrieved from SNL. We only have the most current ratings, while Koijen and Yogo (2016) use the historical ratings. This may not be a great concern because we focus on whether a reinsurer is rated, rather than how the ratings change over time. Our sample is from 2005 to 2015, but we drop the observations from 2001 to 2004 as we need to estimate the 5-year ROA volatility. We only include insurers who engage in shadow insurance at least once during our sample period. A P&C insurer is defined as using shadow insurance for the year if the shadow ICM subsidy is positive in the same year. Our shadow sample consists of 2,045 insurer-year observations, with 179 unique public insurers, 122 unique private insurers and 20 mutual insurers.

Table 3.5 shows the descriptive statistics for our shadow insurance sample. The participation rate is calculated as the insurer-year observations included in our shadow insurance sample scaled by total insurer-year observations of that organizational form in our sample period from 2005–2015. Public insurers are most likely to be included in our shadow sample with a participation rate of 29.2%, followed by private insurers with a participation rate of 22.7%, while the mutual insurers are least likely to be included with a participation rate of 16.6%.

The mean (median) proportion of *Shadow ICMSubsidy* (i.e., gross premiums written supported by shadow insurers) is 6.94% (0%) for public insurers, 17.90% (0.69%) for private insurers and 2.71%

[65] As stated by Koijen and Yogo (2016), the definition of shadow reinsurers is stricter than "captives" because some captives are actually authorized.

(0.25%) for mutual insurers. The two sample t-test suggests that private insurers have a significantly larger *Shadow ICMSubsidy* than mutual or public insurers.

The mean (median) proportion of *Regular ICMSubsidy* (i.e., gross premiums written supported by non-shadow insurers) is 8.02% (5.30%) for public insurers, -0.14% (-0.90%) for private insurers and 0.46% (1.15%) for mutual insurers. The negative mean and median values for private insurers suggest that the average and the median private insurers in our sample assume more reinsurance than it cedes, thus serve the role as a net capital provider.

In our main test, we exclude mutual insurers because of the relatively low frequency. We are interested in how the shadow and regular ICM subsidy are related to firm-level risk and how this relationship differs between public and private insurers. Consistent with prior regression design, the change regression specification is used and specified as follows:

$$\begin{aligned}\Delta UROA\ Volatility_{it} &= \alpha_0 + \beta_1 \Delta Shadow\ ICMSubsidy * Private + \beta_2 \Delta Regular\ ICMSubsidy \\ &* Private + \beta_3 \Delta Shadow\ ICMSubsidy + \beta_4 \Delta Regular\ ICMSubsidy \\ &+ \beta_5 Private + \beta_6 \Delta Capitalization\ Controls \\ &+ \beta_7 \Delta Underwriting\ exposure\ contorls + \alpha_t + \varepsilon_{it}\end{aligned} \tag{3}$$

The control group in our regression is the publicly-held stock insurers. The variables of interest for our regression are *ΔShadow ICM Subsidy* and the interaction term *ΔShadow ICM Subsidy*Private*. These variables indicate how the firm-level underwriting ROA volatility changes in response to variation in shadow ICM subsidy for public and private insurers.

Results are reported in column 1, table 3.6. We observe that the coefficient on *ΔShadow ICM Subsidy* (i.e., the change in proportion of gross premiums written supported by shadow insurers) is significantly positive. This suggests that the shadow ICM subsidy is associated with an increase in underwriting volatility ROA for public insurers. The coefficient on *ΔShadow ICM Subsidy*Private* is significantly negative, this indicates that the firm-level risk for private insurers are less sensitive to changes in shadow ICM subsidy. We further test whether the coefficient on "*ΔShadow ICMSubsidy*Private+ΔShadow ICMSubsidy*" is equal to zero (two-tailed p=0.6302).

The null hypothesis cannot be rejected, this suggests that the shadow ICM subsidy used by private insurers are not related to an increase in firm-level risk.

We also study how differently the shadow and regular ICM subsidy are associated with firm-level risk for public insurers. We test the null hypothesis where the coefficient for "*ΔShadow ICMSubsidy*" is equals to "*ΔRegular ICMSubsidy*". The null is rejected with two-tailed p-value of 0.0567, this indicates that firm-level risks are more sensitive to changes in shadow ICM subsidy than in regular ICM subsidy for public insurers. These results support the concern by Benjamin Lawsky, the former superintendent of the NYDFS, that shadow insurance transactions may represent "financial alchemy" and "could leave insurance companies on the hook for losses at their more weakly capitalized shell companies."

In column 2, we include mutual insurers in our regression. However, the results related to mutual insurers should be interpreted with caution because of the relatively small number of observations for mutual insurers. We interact both *ΔShadow ICMSubsidy* and *ΔRegular ICMSubsidy* with the two organizational dummies, Private and Mutual. We document that the coefficients estimated for public and private insurers are similar with those in column 1 in terms of magnitude and significance. The coefficient on *ΔShadow ICMSubsidy*Mutual* is insignificant, this suggests that there is no difference in the sensitivity of underwriting ROA volatility to shadow ICM subsidy between mutual and public insurers. This result may be caused by the small sample of mutual insurers. We further test whether the coefficient on "*ΔShadow ICMSubsidy*Mutual+ΔShadow ICMSubsidy*" equals to zero (two-tailed p=0.3308). The null hypothesis cannot be rejected, this indicates that changes in shadow ICM subsidy (*ΔShadow ICMSubsidy*) is not related to an increase in firm-level risk for mutual insurers.

Overall, these results suggest that compared to private insurers, public insurers are more risk-taking in terms of their shadow ICM transactions. Although we do not include the mutual insurers in column 1, the smallest participation rate for mutual insurers engaging in shadow ICMs partly reflects the fact that mutual firms are less likely to take on excessive risks. These results further lend credence to our hypotheses that mutual and private firms are more prudent in their ICM operation than public firms.

8. Conclusion

The range of organizational forms within the insurance industry is much broader than that of other major industries (Mayers and Smith, 2013). Cummins et al. (1999) argue that agency-theoretic hypotheses can explain why different organizational forms coexist in the industry. Because agency problems are also the determinant of performance of ICM activity, the coexistence of a variety of organizational forms within insurance industry provides the research setting to study how different aspects and extents of agency problems will affect the return and risk of internal capital allocations.

Specifically, we investigate how the return and risk of ICMs differ across public stock firms, private stock firms and mutual firms. Our argument follows that different organizational forms, arising from various combinations of the manager, owner and customer functions, are subjected to different agency problems (i.e., the conflicts of interest among managers, owners and customers). Consequentially, these agency problems will impact and result in differing performance of the firm's ICM. We document results that serve to paint a broader picture of the agency problem and its relation to organizational form and ICMs.

Using the U.S. P&C insurance industry as our research setting, we find that privately-held insurers perform better in their capital allocation of ICM subsidy. The sensitivity of investments in highly profitable LOB to ICM subsidy is significantly higher for privately-held insurers than publicly-held and mutual insurers. This result suggests that privately-held insurers are associated with a more efficient ICM. In terms of risk in ICM transactions, we document that given an increase in ICM subsidy, publicly-held insurers are associated with the highest increase in firm-level underwriting ROA volatility, and highest investments increase in highly profitable and highly risky LOB. These results suggest that ICM subsidy is related to an increase in firm-level risk for publicly-held insurers.

This paper also enhanced our understanding of the operation of ICMs in private firms. Despite the fact that private U.S. firms accounted for 68.7% of private-sector employment, and 48.9% of aggregate pretax profits (Asker et al., 2015), most of our knowledge on ICMs come from the public firms. We document economically important differences in the ICM operations between private and public firms.

We shed light on one specific ICM transaction, shadow insurance. Recent regulatory reports highlight and raise concern on the widespread use of shadow insurance in the life insurance industry. We document that shadow insurance is also related to high risk in the P&C insurance industry, especially for publicly-held firms. We find that for publicly-held insurers, the underwriting ROA volatility is more sensitive to changes in shadow ICM subsidy than to changes in regular ICM subsidy. Both sensitivities become insignificant in privately-held insurers. Our results suggests the supervision of shadow insurance should be relatively more focused on public insurance companies.

Reference

Acharya, VV, Schnabl, P, Suarez, G. Securitization without Risk Transfer. Journal of Financial Economics 2013;107;515-536.

Adiel, R. Reinsurance and the Management of Regulatory Ratios and Taxes in the Property-Casualty Insurance Industry. Journal of Accounting and Economics 1996;22;207-240.

Akhigbe, A, Whyte, AM. Seo Announcement Returns and Internal Capital Market Efficiency. Journal of Corporate Finance 2015;31;271-283.

Asker, J, Farre-Mensa, J, Ljungqvist, A. Corporate Investment and Stock Market Listing: A Puzzle? Review of Financial Studies 2015;28;342-390.

Baranoff, EG, Sager, TW. The Relations among Asset Risk, Product Risk, and Capital in the Life Insurance Industry. Journal of Banking and Finance 2002;26;1181-1197.

Bargeron, LL, Schlingemann, FP, Stulz, RM, Zutter, CJ. Why Do Private Acquirers Pay So Little Compared to Public Acquirers? Journal of Financial Economics 2008;89;375-390.

Campello, M. Internal Capital Markets in Financial Conglomerates: Evidence from Small Bank Responses to Monetary Policy. The Journal of Finance 2002;57;2773-2805.

Cheng, J, Cummins, JD, Lin, TT. Organizational Form, Ownership Structure, and Ceo Turnover: Evidence from the Property–Casualty Insurance Industry. Journal of Risk and Insurance 2017;84;95-126.

Cheng, J, Weiss, MA. Risk-Based Capital and Firm Risk Taking in Property-Liability Insurance. Geneva Papers on Risk and Insurance-Issues and Practice 2013;38;274-307.

Cremers, KJM, Huang, R, Sautner, Z. Internal Capital Markets and Corporate Politics in a Banking Group. Review of Financial Studies 2011;24;358-401.

Cummins, JD, Rubio-Misas, M, Zi, HM. The Effect of Organizational Structure on Efficiency: Evidence from the Spanish Insurance Industry. Journal of Banking and Finance 2004;28;3113-3150.

Cummins, JD, Sommer, DW. Capital and Risk in Property-Liability Insurance Markets. Journal of Banking and Finance 1996;20;1069-1092.

Cummins, JD, Weiss, MA, Zi, HM. Organizational Form and Efficiency: The Coexistence of Stock and Mutual Property-Liability Insurers. Management Science 1999;45;1254-1269.

Eckles, DL, Halek, M. Insurer Reserve Error and Executive Compensation. Journal of Risk and Insurance 2010;77;329-346.

Elango, B, Ma, YL, Pope, N. An Investigation into the Diversification-Performance Relationship in the U.S. Property-Liability Insurance Industry. Journal of Risk and Insurance 2008;75;567-591.

Faccio, M, Marchica, MT, Mura, R. Large Shareholder Diversification and Corporate Risk-Taking. Review of Financial Studies 2011;24;3601-3641.

Fier, SG, McCullough, KA, Carson, JM. Internal Capital Markets and the Partial Adjustment of Leverage. Journal of Banking and Finance 2013;37;1029-1039.

Gao, H, Harford, J, Li, K. Determinants of Corporate Cash Policy: Insights from Private Firms. Journal of Financial Economics 2013;109;623-639.

Glaser, M, Lopez-de-Silanes, F, Sautner, Z. Opening the Black Box: Internal Capital Markets and Managerial Power. Journal of Finance 2013;68;1577-1631.

Gopalan, R, Nanda, V, Seru, A. Affiliated Firms and Financial Support: Evidence from Indian Business Groups. Journal of Financial Economics 2007;86;759-795.

Grace, MF, Harrington, SE, Klein, RW. Risk-Based Capital and Solvency Screening in Property-Liability Insurance: Hypotheses and Empirical Tests. Journal of Risk and Insurance 1998;65;213-243.

Gugler, K, Peev, E, Segalla, E. The Internal Workings of Internal Capital Markets: Cross-Country Evidence. Journal of Corporate Finance 2013;20;59-73.

He, J, Mao, XY, Rui, OM, Zha, XL. Business Groups in China. Journal of Corporate Finance 2013;22;166-192.

Ho, C-L, Lai, GC, Lee, J-P. Organizational Structure, Board Composition, and Risk Taking in the U.S. Property Casualty Insurance Industry. Journal of Risk and Insurance 2013;80;169-203.

Jeng, V, Lai, GC, McNamara, MJ. Efficiency and Demutualization: Evidence from the Us Life Insurance Industry in the 1980s and 1990s. Journal of Risk and Insurance 2007;74;683-711.

Jensen, MC, Meckling, WH. Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure. Journal of Financial Economics 1976;3;305-360.

Ke, B, Petroni, K, Safieddine, A. Ownership Concentration and Sensitivity of Executive Pay to Accounting Performance Measures: Evidence from Publicly and Privately-Held Insurance Companies. Journal of Accounting and Economics 1999;28;185-209.

Koijen, RSJ, Yogo, M. Shadow Insurance. Econometrica 2016;84;1265-1287.

Kolasinski, AC. Subsidiary Debt, Capital Structure and Internal Capital Markets. Journal of Financial Economics 2009;94;327-343.

Lammtennant, J, Starks, LT. Stock Versus Mutual Ownership Structures - the Risk Implications. Journal of Business 1993;66;29-46.

Lawsky, MB 2013. Shining a Light on Shadow Insurance: A Little-Known Loophole That Puts Insurance Policyholders and Taxpayers at Greater Risk, Regulatory white paper. New York State Department of Financial Services; 2013.

Maksimovic, V, Phillips, G 2007. Conglomerate Firms and Internal Capital Markets. In: Eckbo, E (Ed), Handbook of Corporate Finance: Empirical Corporate Finance. Elsevier: Amsterdam ; London; 2007.

Mayers, D, Shivdasani, A, Smith, CW. Board Composition and Corporate Control: Evidence from the Insurance Industry. Journal of Business 1997;70;33-62.

Mayers, D, Smith, CW. On the Corporate Demand for Insurance: Evidence from the Reinsurance Market. Journal of Business 1990;63;19-40.

Mayers, D, Smith, CW. Executive-Compensation in the Life-Insurance Industry. Journal of Business 1992;65;51-74.

Mayers, D, Smith, CW 2013. On the Choice of Organizational Form: Theory and Evidence from the Insurance Industry, Handbook of Insurance. Springer; 2013.

Meyer, M, Milgrom, P, Roberts, J. Organizational Prospects, Influence Costs, and Ownership Changes. Journal of Economics and Management Strategy 1992;1;9-35.

Natividad, G. Financial Capacity and Discontinuous Investment: Evidence from Emerging Market Multibusiness Firms. Review of Financial Studies 2013;26;2375-2410.

Ozbas, O, Scharfstein, DS. Evidence on the Dark Side of Internal Capital Markets. Review of Financial Studies 2010;23;581-599.

Powell, LS, Sommer, DW, Eckles, DL. The Role of Internal Capital Markets in Financial Intermediaries: Evidence from Insurer Groups. Journal of Risk and Insurance 2008;75;439-461.

Rajan, R, Servaes, H, Zingales, L. The Cost of Diversity: The Diversification Discount and Inefficient Investment. Journal of Finance 2000;55;35-80.

Scharfstein, DS, Stein, JC. The Dark Side of Internal Capital Markets: Divisional Rent-Seeking and Inefficient Investment. Journal of Finance 2000;55;2537-2564.

Shleifer, A, Vishny, RW. A Survey of Corporate Governance. The Journal of Finance 1997;52;737-783.

Stein, JC. Internal Capital Markets and the Competition for Corporate Resources. Journal of Finance 1997;52;111-133.

Werner, G, Modlin, C 2016. Basic Ratemaking. Willis Towers Watson; 2016.

Williamson, OE. Markets and Hierarchies. New York 1975;26-30.

Appendix 3.1. Variable definitions

Dependent Variables

Invt Amount: Defined as Gross premiums written (GPW) = Direct premiums written (DPW) + Reinsurance assumed from affiliated insurers + Reinsurance assumed from unaffiliated insurers

ΔInvt: Growth rate of *Invt Amount*, i.e., ($Invt\ Amount_t$ - $Invt\ Amount_{t-1}$)/ $Invt\ Amount_{t-1}$

Invt_HP: The proportion of GPW in highly profitable lines of business, i.e., *Invt_HP Amount/ Invt Amount*, where *Invt_HP Amount* is the dollar amount of GPW in highly profitable lines of business.

ΔInvt_HP: First difference of *Invt_HP*

Invt_LP: The proportion of GPW in lowly profitable lines of business.

ΔInvt_LP: First difference of *Invt_LP*

Invt_HPHR: The proportion of GPW in highly profitable & highly risky lines of business.

ΔInvt_HPHR: First difference of *Invt_HPHR*

Invt_HPLR: The proportion of GPW in highly profitable & lowly risky lines of business.

ΔInvt_HPLR: First difference of *Invt_HPLR*

Invt_LPHR: The proportion of GPW in lowly profitable & highly risky lines of business.

ΔInvt_LPHR: First difference of *Invt_LPHR*

Invt_LPLR: The proportion of GPW in lowly profitable & lowly risky lines of business.

ΔInvt_LPLR: First difference of *Invt_LPLR*

Eff Index:

$$ICM\ Eff\ index_i = \frac{1}{NPE_i}\sum_{j=1}^{N_{lob}}[ICMSubsidy_j * [\left(\frac{Profit_j}{NPE_j}\right) - Firm\ median_i\ (\frac{Profit}{NPE})]]$$

ΔEff Index: First difference of *Eff Index*.

UROA Volatility: Standard deviation of the underwriting ROA over year t-4 to year t.

ΔUROA Volatility: First difference of *UROA Volatility*.

Explanatory variables:

Public: Equal to one if the insurance company is a stock firm and its ultimate parent is a public listed firm; zero otherwise.

Private: Equal to one if the insurance company is a stock firm and its ultimate parent is a privately held firm; zero otherwise.

Mutual: Equal to one if the insurance company is a mutual firm; zero otherwise.

Parent Public: Equal to one if the insurer's ultimate parent is a stock firm and the ultimate parent is public listed; zero otherwise.

Parent Private: Equal to one if the insurer's ultimate parent is a stock firm and the ultimate parent is privately held; zero otherwise.

Parent mutual: Equal to one if the insurer's ultimate parent is a mutual firm; zero otherwise.

ICMSubsidy: Net reinsurance ceded to affiliated insurers scaled by GPW. i.e., *(Reinsurance ceded from affiliates-Reinsurance assumed from affiliates) / GPW*

ΔICMSubsidy: First difference of *ICMSubsidy*.

Shadow ICMSubsidy: Net reinsurance ceded to shadow insurers scaled by GPW. Shadow insurers are unauthorized affiliated insurers without AM best ratings.

ΔShadow ICMSubsidy: First difference of *Shadow ICMSubsidy*.

Regular ICMSubsidy: Net reinsurance ceded to non-shadow insurers scaled by GPW, equal to *ICMSubsidy - Shadow ICMSubsidy.*

ΔRegular ICMSubsidy: First difference of *Regular ICMSubsidy*.

ExRein: Net reinsurance ceded to unaffiliated insurers scaled by GPW.

ΔExRein: First difference of *ExRein*.

Ln Surplus ($000): Natural logarithm of an insurer's surplus ($'000).

ΔSurplus: Growth rate of surplus, over the prior year.

Exposure variables:

LobH: The sum of square ratio of direct (non-negative) premiums written in lines of business to total premiums written (1=single line). Note: based on all nonconsolidated NAIC lines of business on the "Underwriting & Investment" page.

ΔLobH: First difference of *LobH*.

GeoH: The sum of square ratio of direct (non-negative) premiums written in each state to total premiums written in all states (1=single state).

ΔGeoH: First difference of *GeoH*

Longtail: The share of direct (non-negative) premiums written in long-tail lines to total direct premiums written. Long-lines business chosen include Farm owners multiple perils, Homeowners multiple perils, Commercial multiple peril (non-liability portion and liability portion), Medical malpractice (occurrence and claims made), Workers' compensation, Products liability (occurrence and claims made), Automobile liability and "other" liability.

ΔLongtail: First difference of *Longtail*.

Cat Exposure: The insurer's exposure to catastrophic loss. The proportion of direct premiums written in Catastrophe Risk LOBs in earthquake and hurricane cat zones, defined by SNL. According to SNL, Catastrophe Risk LOBs consist of Allied Lines (Sub), Commercial Auto Physical Damage, Commercial Multiple Peril (Non-Liability), Earthquake, Farmowners Multiple Peril, Federal Flood, Fire, Homeowners Multiple Peril, Inland Marine, Multiple Peril Crop, Private Passenger, Auto Physical Damage and Private Crop Private Flood. Earthquake and hurricane cat zones consist states of Alaska, California, Nevada, Oregon, Washington, Puerto Rico, Virgin Islands, Florida, Alabama, Louisiana, Mississippi, Texas, Connecticut, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Delaware, District of Columbia, Georgia, Maryland, North Carolina, South Carolina, Virginia.

ΔCat Exposure: First difference of *Cat Exposure*.

Appendix 3.2. Consolidation of lines of business according to SNL.

P&C SNL Lines	NAIC As Reported Lines	NAIC line code
Aircraft (All Perils)	Aircraft (All Perils)	22
Combined Accident & Health Business	All Other Accident & Health	15.7
	Collectively Renewable Accident & Health	15.1
	Credit Accident & Health (Group & Individual)	14
	Federal Employees Health Benefits Program	15.8
	Group Accident & Health	13
	Grted Renewable Accident & Health	15.3
	Medicare Title XVIII Exempt from State Taxes or Fees	15.6
	Non-Cancelable Accident & Health	15.2
	Non-Renewable for Stated Reasons Only	15.4
	Other Accident Only	15.5
Commercial Auto: State	Commercial Auto No-Fault (Personal Injury Protection)	19.3
	Commercial Auto Physical Damage	21.2
	Other Commercial Auto Liability	19.4
Commercial Multiple Peril	Commercial Multiple Peril (Liability)	5.2
	Commercial Multiple Peril (Non-Liability)	5.1
Fidelity & Surety	Fidelity	23
	Surety	24
Financial & Mortgage Guaranty	Financial Guaranty	10
	Mortgage Guaranty	6
Fire and Allied Lines Combined	Allied Lines (Sub)	2.1
	Earthquake	12
	Federal Flood	2.3
	Fire	1
	Multiple Peril Crop	2.2
	Private Crop	2.4
	Private Flood	2.5
Homeowners & Farmowners	Farmowners Multiple Peril	3
	Homeowners Multiple Peril	4
Marine Lines Combined	Inland Marine	9
	Ocean Marine	8
Medical Professional Liability	Medical Professional Liability	11
Other and Product Liability Lines Combined	Excess Workers' Compensation	17.3
	Other Liability (Claims Made)	17.2
	Other Liability (Occurrence)	17.1
	Product Liability	18
Other Commercial	Boiler & Machinery	27
	Burglary & Theft	26
	Credit	28
	State Page Other P&C Lines of Business	34
	Warranty	30
Private Auto: State	Other Private Passenger Auto Liability	19.2
	Private Passenger Auto No-Fault (Personal Injury Protectio	19.1
	Private Passenger Auto Physical Damage	21.1
Workers' Compensation	Workers' Compensation	16

Appendix 3.3. Change the definitions of investment variables.

We change the definition of all the change of investment variables. They are now defined as the investment change (in dollar amount) in the corresponding group, scaled by gross premiums written of the previous period. For example. $\Delta Invt\_HP_t=(Invt\_HP\ Amount_t - Invt\_HP\ Amount_{t-1})/\ Invt\ Amount_t$, instead of

$\Delta Invt\_HP_t=Invt\_HP_t - Invt\_HP_{t-1}=Invt\_HP\ Amount_t\ /Invt\ Amount_t\ -\ Invt\_HP\ Amount_{t-1}/\ Invt\ Amount_{t-1}$.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ΔInvt_HP	ΔInvt_LP	ΔInvt_HPHR	ΔInvt_HPLR	ΔInvt_LPHR	ΔInvt_LPLR
ΔICMSubsidy*Private	0.1659**	-0.1580**	-0.1136*	0.1596**	0.0347	-0.0236
	(0.0728)	(0.0713)	(0.0612)	(0.0725)	(0.0597)	(0.0750)
ΔICMSubsidy*Mutual	-0.0609	0.1029	-0.2212***	0.0646	0.1431	0.0581
	(0.1150)	(0.1137)	(0.0703)	(0.1242)	(0.1112)	(0.1518)
ΔICMSubsidy	-0.0647	0.0143	0.1280***	-0.0825*	-0.0178	-0.0455
	(0.0519)	(0.0511)	(0.0391)	(0.0465)	(0.0390)	(0.0532)
Private	0.0072**	-0.0084**	-0.0074**	0.0043	0.0004	0.0023
	(0.0034)	(0.0034)	(0.0033)	(0.0036)	(0.0032)	(0.0042)
Mutual	0.0042	-0.0052	-0.0003	-0.0097**	0.0019	0.0031
	(0.0035)	(0.0036)	(0.0032)	(0.0045)	(0.0033)	(0.0046)
ΔExRein	0.0262	-0.0738	0.0535	-0.1107	-0.0246	0.1225
	(0.0789)	(0.0803)	(0.0757)	(0.0741)	(0.0676)	(0.0779)
ΔSurplus	0.0262	-0.0171	0.0246	0.0208	-0.0070	-0.0398
	(0.0237)	(0.0237)	(0.0250)	(0.0223)	(0.0241)	(0.0260)
ΔLobH	0.2253***	-0.1377*	0.1007	0.1405	-0.0698	-0.0308
	(0.0830)	(0.0803)	(0.0741)	(0.0927)	(0.0717)	(0.0890)
ΔGeoH	-0.0783	0.0657	-0.0379	-0.1327*	0.1807**	-0.0102
	(0.0694)	(0.0702)	(0.0681)	(0.0763)	(0.0712)	(0.0888)
ΔLongtail	-0.2488***	0.1937**	-0.0329	-0.0965	0.1121	-0.0660
	(0.0863)	(0.0868)	(0.0745)	(0.0896)	(0.0756)	(0.0866)
Observations	10,864	10,864	8,140	8,140	8,140	8,140
R-squared	0.0042	0.0043	0.0088	0.0074	0.0079	0.0051
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer

Figure 3.1. Organizational forms within the insurance industry and their respective combination of manager, owner, and customer functions.

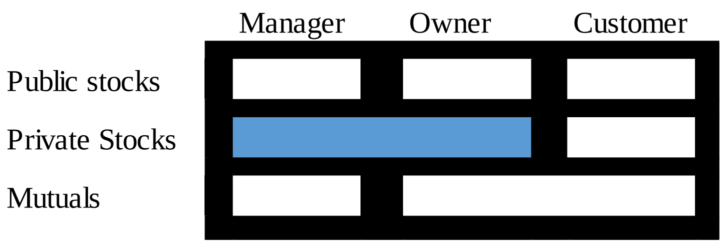

Table 3.1. Descriptive statistics

The sample consists of 10,226 insurer-year observations, with 5,091 public insurer year observations, 3,850 private insurer-year observations and 1,285 mutual insurer-year observations from 2002 to 2015. For our risk analysis, we restrict our sample from year 2005 to 2015, because we need to calculate the 5-year rolling loss ratio volatility in each lines of business and 5-year rolling underwriting ROA volatility. Thus the number of observations of risk related variables is smaller. All continuous variables are winsorized at the 1% and 99% levels. Test statistics of the t-test and Wilcoxon-test of the differences in insurer characteristics between public and private, public and mutual, and private and mutual are given in superscript ***, **, *denoting statistical significance at 1%, 5% and 10% levels, respectively. Appendix 3.1 provides all of the variable descriptions.

	Publicly-Held Stock				Privately-Held Stock				Mutual				Public Vs Private		Public Vs Mutual		Private Vs Mutual	
	N	Mean	Median	StdDev	N	Mean	Median	StdDev	N	Mean	Median	StdDev	T-test	W-test	T-test	W-test	T-test	W-test
# unique insurers	600				545				126									
Change in Variables																		
ΔInvt	5091	0.0004	0.0000	0.0281	3850	-0.0003	0.0000	0.0273	1285	-0.0001	0.0000	0.0166		*				
ΔInvt_HP	5091	-0.0073	0.0000	0.3368	3850	-0.0011	0.0000	0.3484	1285	-0.0020	-0.0005	0.3139						
ΔInvt_LP	5091	0.0083	0.0000	0.3364	3850	0.0008	0.0000	0.3479	1285	0.0015	0.0004	0.3131						
ΔInvt_HPHR	3819	0.0012	0.0000	0.2203	2845	-0.0072	0.0000	0.2367	1011	0.0004	0.0000	0.1766						
ΔInvt_HPLR	3819	0.0005	0.0000	0.2999	2845	0.0054	0.0000	0.3087	1011	-0.0074	0.0000	0.3087				*		**
ΔInvt_LPHR	3819	0.0003	0.0000	0.2321	2845	0.0001	0.0000	0.2455	1011	-0.0004	0.0000	0.2204						
ΔInvt_LPLR	3819	0.0056	0.0000	0.3140	2845	0.0084	0.0000	0.3310	1011	0.0095	0.0000	0.3323						
ΔEff Index	5091	0.0035	0.0000	1.2045	3850	-0.0102	0.0000	0.8723	1285	-0.0073	0.0000	0.4832						*
ΔUROA Volatility	3970	-0.0013	-0.0001	0.0112	2897	-0.0012	-0.0001	0.0114	989	-0.0006	0.0001	0.0099			*	**		*
ΔICMSubsidy	5091	-0.0022	0.0000	0.1144	3850	-0.0012	0.0000	0.1113	1285	-0.0038	-0.0011	0.0684				**		**
ΔExRein	5091	-0.0017	0.0000	0.0473	3850	-0.0027	0.0000	0.0546	1285	-0.0013	0.0000	0.0412						
ΔSurplus	5091	0.0387	0.0236	0.1400	3850	0.0380	0.0282	0.1211	1285	0.0486	0.0459	0.1207		**	**	***	***	***
ΔLobH	5091	0.0012	0.0000	0.0446	3850	0.0009	0.0000	0.0440	1285	0.0014	0.0000	0.0285						
ΔGeoH	5091	-0.0024	0.0000	0.0478	3850	-0.0043	0.0000	0.0492	1285	-0.0035	0.0000	0.0291	*	***		***		
ΔLongtail	5091	0.0017	0.0000	0.0409	3850	0.0011	0.0000	0.0337	1285	0.0023	0.0007	0.0214						***
ΔCatExposure	5091	0.0009	0.0000	0.0347	3850	0.0016	0.0000	0.0313	1285	0.0011	0.0000	0.0197						

Level of Variables																		
Invt_HP	5091	0.4764	0.4400	0.3345	3850	0.4867	0.4546	0.3594	1285	0.4029	0.3495	0.3002			***	***	***	***
Invt_LP	5091	0.5064	0.5390	0.3349	3850	0.4941	0.5170	0.3585	1285	0.5720	0.6313	0.3008	*		***	***	***	***
Invt_HPHR	4254	0.2200	0.0764	0.3077	3163	0.2381	0.0669	0.3450	1105	0.1411	0.0607	0.2167	**	***	***	***	***	**
Invt_HPLR	4254	0.2295	0.1024	0.2810	3163	0.2221	0.0686	0.2896	1105	0.2588	0.1412	0.2851			***	***	***	***
Invt_LPHR	4254	0.1654	0.0646	0.2250	3163	0.1852	0.0667	0.2658	1105	0.2118	0.1147	0.2331	***		***	***	***	***
Invt_LPLR	4254	0.3296	0.2493	0.3281	3163	0.3029	0.1577	0.3361	1105	0.3513	0.3428	0.3069	***		***	***	***	***
Eff Index	5091	-0.0587	0.0000	1.0007	3850	-0.0599	0.0000	0.7261	1285	-0.0310	0.0014	0.3612				***		***
UROA Volatility	4370	0.0294	0.0219	0.0248	3207	0.0299	0.0235	0.0238	1091	0.0275	0.0232	0.0181		**	**		***	
ICMSubsidy	5091	0.1346	0.0892	0.4535	3850	0.0632	0.0410	0.3894	1285	-0.0459	-0.0376	0.2862	***	***	***	***	***	***
ExRein	5091	0.0523	0.0071	0.1145	3850	0.0906	0.0234	0.1585	1285	0.0852	0.0450	0.1238	***	***	***	***		***
Ln Surplus($000)	5091	11.8740	11.6848	1.5581	3850	11.1206	10.9535	1.4265	1285	12.1631	12.1061	1.7171	***	***	***	***	***	***
LobH	5091	0.4285	0.3584	0.2508	3850	0.5029	0.4283	0.2782	1285	0.3827	0.2877	0.2447	***	***	***	***	***	***
GeoH	5091	0.3218	0.1443	0.3382	3850	0.4656	0.3459	0.3625	1285	0.4692	0.3532	0.3614	***	***	***	***		
Longtail	5091	0.6759	0.7117	0.2660	3850	0.7243	0.7723	0.2696	1285	0.7610	0.7818	0.2188	***	***	***	***	***	**
CatExposure	5091	0.2551	0.2111	0.2352	3850	0.2796	0.2039	0.2863	1285	0.3847	0.3919	0.3209	***		***	***	***	

Table 3.2. ICM subsidy and investment efficiency

The sample consists of 10,226 insurer-year observations over the period 2002-2015. The dependent variable in column 1 (2), Δ*Invt_HP (ΔInvt_LP)*, is the first difference of *Invt_HP (Invt_LP)*, which is the proportion of gross premiums written in highly (lowly) profitable lines of business. The partition of highly /lowly profitable lines is based on the median profitability of all consolidated lines of business within each insurer-year observation. The profitability is measured by pre-tax profit excluding investment gains for a given line scaled by the net premiums earned in that line. The dependent variable in column 3, *ΔEff Index*, is the first difference of ICM efficiency index. A higher value of efficiency index suggests higher ICM efficiency. The main explanatory variable *ΔICMSubsidy*, is the first difference of *ICMSubsidy*, which is measured as the net reinsurance ceded to affiliated insurers scaled by total gross premiums written. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. Appendix 3.1 provides all of the variable descriptions.

	(1)	(2)	(3)
VARIABLES	ΔInvt_HP	ΔInvt_LP	ΔEff Index
ΔICMSubsidy*Private	0.1670**	-0.1580**	0.4944*
	(0.0740)	(0.0723)	(0.2619)
ΔICMSubsidy*Mutual	-0.0624	0.1112	-0.0252
	(0.1331)	(0.1313)	(0.4121)
ΔICMSubsidy	-0.0658	0.0159	-0.4462**
	(0.0519)	(0.0512)	(0.2083)
Private	0.0068*	-0.0081**	-0.0129
	(0.0035)	(0.0035)	(0.0123)
Mutual	0.0050	-0.0065*	-0.0099
	(0.0037)	(0.0038)	(0.0108)
ΔExRein	0.0004	-0.0486	-0.2769
	(0.0804)	(0.0815)	(0.3068)
ΔSurplus	0.0273	-0.0183	-0.0342
	(0.0239)	(0.0239)	(0.0726)
ΔLobH	0.2251***	-0.1414*	0.2629
	(0.0841)	(0.0813)	(0.2588)
ΔGeoH	-0.0527	0.0423	0.0766
	(0.0692)	(0.0699)	(0.1783)
ΔLongtail	-0.2372***	0.1795**	-1.0345**
	(0.0875)	(0.0882)	(0.4194)
ΔCatExposure	-0.0207	0.0011	-0.0272
	(0.1062)	(0.1060)	(0.3737)
Observations	10,226	10,226	10,226
R-squared	0.0047	0.0047	0.0047
Year FE	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer
Two-tailed Wald test for the null Hypothesis (p-value)			
ΔICMSubsidy*Private=ΔICMSubsidy*Mutual	0.0887	0.0431	0.1684
ΔICMSubsidy*Private+ΔICMSubsidy=0	0.0737	0.0094	0.7508
ΔICMSubsidy*Mutual+ΔICMSubsidy=0	0.2976	0.2957	0.176

Table 3.3. ICM subsidy and investment risk

The sample consists of 7,675 insurer-year observations over the period 2005-2015. The dependent variables in columns 1-4, are the first difference of scaled investment made in four return-risk group. The scaled investment, *Invt_XPXR*, is measured by the proportion of gross premiums written in each return-risk group. For each insurers and each year, we conduct an independent double sort of the business lines based on the return and volatility of underwriting results. Specifically, we allocate all consolidated lines of business into four risk-return groups (HP/HR, HP/LR, LP/HR, LP/LR), defined as the intersections of two profitability groups (Highly profitable Vs Lowly profitable) and two risk groups (Highly risky Vs Lowly risky). Our partition of HP (highly profitable) and LP (lowly profitable) lines is based on the median profitability of all lines within each insurer-year observation. The profitability is measured by pre-tax profit excluding investment gains for a given line scaled by the net premium earned in that line. Our partition of HR (Highly risky) and LR (Lowly risky) groups is based on the median value of 5-year loss ratio volatility of all lines in each insurer-year observations. The dependent variable in column 5 is the is the first difference of ROA volatility (*UROA Volatility*), which is measured as the standard deviation of underwriting ROA over the most recent 5 years. The main explanatory variable *ΔICMSubsidy*, is the first difference of *ICMSubsidy*, which is measured as the net reinsurance ceded to affiliated insurers scaled by total gross premiums written. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. Appendix 3.1 provides all of the variable descriptions.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	ΔInvt_HPHR	ΔInvt_HPLR	ΔInvt_LPHR	ΔInvt_LPLR	ΔUROA Volatility
ΔICMSubsidy*Private	-0.1133*	0.1659**	0.0256	-0.0234	-0.0070**
	(0.0623)	(0.0734)	(0.0601)	(0.0761)	(0.0030)
ΔICMSubsidy*Mutual	-0.2570***	0.0853	0.2341*	-0.0080	-0.0122**
	(0.0796)	(0.1484)	(0.1282)	(0.1806)	(0.0049)
ΔICMSubsidy	0.1293***	-0.0786*	-0.0196	-0.0484	0.0033*
	(0.0397)	(0.0458)	(0.0390)	(0.0532)	(0.0018)
Private	-0.0088**	0.0053	0.0004	0.0024	0.0001
	(0.0034)	(0.0037)	(0.0033)	(0.0044)	(0.0002)
Mutual	-0.0028	-0.0076	0.0011	0.0041	0.0007**
	(0.0034)	(0.0049)	(0.0036)	(0.0050)	(0.0003)
ΔExRein	0.0571	-0.1391*	-0.0171	0.1374*	0.0033
	(0.0763)	(0.0756)	(0.0662)	(0.0794)	(0.0034)
ΔSurplus	0.0260	0.0206	-0.0012	-0.0468*	-0.0014
	(0.0253)	(0.0226)	(0.0241)	(0.0256)	(0.0011)
ΔLobH	0.0948	0.1529	-0.0664	-0.0500	0.0012
	(0.0738)	(0.0943)	(0.0717)	(0.0901)	(0.0031)
ΔGeoH	-0.0236	-0.1292*	0.1871***	-0.0293	0.0047
	(0.0679)	(0.0764)	(0.0697)	(0.0854)	(0.0032)
ΔLongtail	-0.0063	-0.0889	0.0775	-0.0772	-0.0004
	(0.0744)	(0.0940)	(0.0747)	(0.0937)	(0.0034)
ΔCatExposure	-0.0026	0.0733	-0.0340	-0.1243	0.0022
	(0.0790)	(0.1110)	(0.0814)	(0.1151)	(0.0040)
Observations	7,675	7,675	7,675	7,675	7,856
R-squared	0.0089	0.0076	0.0077	0.0056	0.0228
Year FE	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer
Two-tailed Wald test for the null Hypothesis (p-value)					
ΔICMSubsidy*Private=ΔICMSubsidy*Mutual	0.0932	0.5981	0.1127	0.9324	0.3116
ΔICMSubsidy*Private+ΔICMSubsidy=0	0.7512	0.1334	0.8991	0.1936	0.1209
ΔICMSubsidy*Mutual+ΔICMSubsidy=0	0.0659	0.9622	0.0807	0.7448	0.0507

Table 3.4. Parent Organizational forms and ICMs

The sample consists of 8,578 insurer-year observations over the period 2002-2015 for columns 1 to 3 and 6,361 insurer-year observations over the period 2005-2015 for columns 4 to 7. We only include stock insurers whose ultimate parent is either mutual or stock firms (i.e., we excluded insurers whose ultimate parent is an association or reciprocal exchange, etc.). The depend variables are defined the same as they are in Table 3.2 and Table 3.3. We use the organizational form of the insurer's ultimate parent as the independent variables in our regressions. *Parent Public* equals to one if the insurer's ultimate parent is a stock firm and the ultimate parent is public listed; zero otherwise. *Parent Private* equals to one if the insurer's ultimate parent is a stock firm and the ultimate parent is privately held; zero otherwise. *Parent mutual* equals to one if the insurer's ultimate parent is a mutual firm; zero otherwise. *Parent Public* is the control group. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. Appendix 3.1 provides all of the variable descriptions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	ΔInvt_HP	ΔInvt_LP	ΔEff Index	ΔInvt_HPHR	ΔInvt_HPLR	ΔInvt_LPHR	ΔInvt_LPLR	ΔUROA Volatility
ΔICMSubsidy*Parent Private	0.1965**	-0.1990**	0.7041**	-0.0506	0.1678*	-0.0457	0.0012	-0.0075**
	(0.0904)	(0.0873)	(0.3065)	(0.0787)	(0.0891)	(0.0748)	(0.0905)	(0.0032)
ΔICMSubsidy*Parent Mutual	0.1212	-0.0908	0.2943	-0.1950**	0.0997	0.1157	0.0115	-0.0061
	(0.0982)	(0.0964)	(0.2753)	(0.0841)	(0.0958)	(0.0775)	(0.0976)	(0.0051)
ΔICMSubsidy	-0.0660	0.0158	-0.4542**	0.1277***	-0.0785*	-0.0192	-0.0472	0.0033*
	(0.0521)	(0.0514)	(0.2073)	(0.0398)	(0.0461)	(0.0391)	(0.0534)	(0.0018)
Parent Private	0.0101**	-0.0128***	-0.0086	-0.0097**	0.0140***	-0.0046	0.0027	0.0000
	(0.0047)	(0.0048)	(0.0159)	(0.0044)	(0.0049)	(0.0048)	(0.0059)	(0.0003)
Parent Mutual	0.0026	-0.0023	-0.0184	-0.0093**	-0.0033	0.0064*	0.0028	0.0002
	(0.0038)	(0.0038)	(0.0129)	(0.0041)	(0.0042)	(0.0038)	(0.0052)	(0.0003)
ΔExRein	-0.0285	-0.0208	-0.4005	0.0339	-0.1757**	-0.0135	0.1967**	0.0044
	(0.0879)	(0.0898)	(0.3441)	(0.0831)	(0.0831)	(0.0709)	(0.0860)	(0.0038)
ΔSurplus	0.0255	-0.0144	-0.0409	0.0218	-0.0001	0.0013	-0.0250	-0.0018
	(0.0246)	(0.0246)	(0.0798)	(0.0273)	(0.0231)	(0.0261)	(0.0264)	(0.0012)
ΔLobH	0.1716*	-0.0965	0.2764	0.1017	0.1005	-0.0738	0.0159	-0.0006
	(0.0882)	(0.0853)	(0.2798)	(0.0725)	(0.0970)	(0.0742)	(0.0964)	(0.0033)
ΔGeoH	-0.0164	0.0137	0.1091	-0.0047	-0.1369*	0.1566**	-0.0133	0.0049
	(0.0727)	(0.0738)	(0.1920)	(0.0676)	(0.0788)	(0.0722)	(0.0889)	(0.0034)
ΔLongtail	-0.2292**	0.1802*	-1.0642**	-0.0225	-0.0721	0.1120	-0.1197	0.0022
	(0.0907)	(0.0919)	(0.4463)	(0.0787)	(0.0993)	(0.0732)	(0.0933)	(0.0035)
ΔCatExposure	-0.0154	0.0029	-0.0667	0.0119	0.0724	-0.0161	-0.1670	0.0016
	(0.1077)	(0.1086)	(0.4028)	(0.0863)	(0.1157)	(0.0857)	(0.1160)	(0.0043)
Observations	8,578	8,578	8,578	6,361	6,361	6,361	6,361	6,558
R-squared	0.0059	0.0062	0.0056	0.0085	0.0101	0.0071	0.0066	0.0192
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer	Insurer

Table 3.5. Descriptive statistics of shadow insurance sample

The sample consists of 2,045 insurer-year observations, with 1,181 public insurer year observations, 694 private insurer-year observations and 170 mutual insurer-year observations from 2005-2015. Only insurers using shadow insurance at least once during our sample period 2005-2015 are included. The participation rate is calculated as the insurer-year observations included in our shadow insurance sample scaled by total insurer-year observations of that organizational form during the sample period 2005-2015. All continuous variables are winsorized at the 1% and 99% levels. Test statistics of the t-test and Wilcoxon-test of the differences in insurer characteristics between public and private, public and mutual, and private and mutual are given in superscript ***, **, *denoting statistical significance at 1%, 5% and 10% levels, respectively. Appendix 3.1 provides all of the variable descriptions.

	Publicly-Held Stock				Privately-Held Stock				Mutual				Public Vs Private		Public Vs Mutual		Private Vs Mutual	
	N	Mean	Median	StdDev	N	Mean	Median	StdDev	N	Mean	Median	StdDev	T-test	W-test	T-test	W-test	T-test	W-test
# unique insurers	179				122				20									
Participation rate	29.2%				22.7%				16.6%									
Change in Variables																		
ΔUROA Volatility	1181	-0.0005	-0.0001	0.0121	694	-0.0014	-0.0002	0.0122	170	-0.0008	0.0000	0.0093						
Δshadow ICMSubsidy	1181	0.0007	0.0000	0.0479	694	0.0017	0.0000	0.0821	170	-0.0022	0.0000	0.0186						
ΔRegular ICMSubsidy	1181	0.0021	-0.0002	0.1248	694	-0.0052	-0.0012	0.1363	170	-0.0026	-0.0039	0.0572						
ΔExRein	1181	-0.0011	0.0000	0.0523	694	-0.0023	0.0000	0.0556	170	-0.0025	0.0007	0.0411						
ΔSurplus	1181	0.0434	0.0336	0.1716	694	0.0307	0.0288	0.1209	170	0.0406	0.0471	0.0978	*					**
ΔLobH	1181	0.0011	0.0000	0.0467	694	0.0009	0.0000	0.0454	170	-0.0024	-0.0015	0.0225						
ΔGeoH	1181	0.0008	0.0000	0.0404	694	-0.0062	0.0000	0.0458	170	-0.0008	0.0000	0.0328	***					
ΔLongtail	1181	0.0006	0.0000	0.0443	694	0.0015	0.0000	0.0373	170	0.0024	0.0017	0.0168				**		
ΔCatExposure	1181	0.0003	0.0000	0.0322	694	-0.0003	0.0000	0.0304	170	0.0020	0.0000	0.0210				*		**
UROA Volatility	1181	0.0317	0.0226	0.0298	694	0.0286	0.0228	0.0239	170	0.0242	0.0210	0.0138	**		***		**	
shadow ICMSubsidy	1181	0.0694	0.0000	0.1731	694	0.1790	0.0069	0.2600	170	0.0271	0.0025	0.0627	***		***		***	***
Regular ICMSubsidy	1181	0.0802	0.0530	0.4358	694	-0.0014	-0.0090	0.4393	170	0.0046	0.0115	0.2611	***		**	**		
ExRein	1181	0.0757	0.0380	0.1253	694	0.0904	0.0267	0.1496	170	0.0773	0.0425	0.1067	**					*
Ln Surplus($000)	1181	12.6801	12.5564	1.6218	694	11.6267	11.2982	1.7558	170	12.5803	12.2328	2.2348	***			**	***	***
LobH	1181	0.4390	0.3258	0.2976	694	0.5119	0.4922	0.2660	170	0.3313	0.2681	0.2006	***		***	***	***	***
GeoH	1181	0.2420	0.0943	0.3065	694	0.4206	0.2347	0.3844	170	0.4435	0.3441	0.3580	***		***	***		
Longtail	1181	0.6267	0.6942	0.3164	694	0.6836	0.7531	0.2900	170	0.7206	0.7308	0.2034	***		***	***		
CatExposure	1181	0.1924	0.1181	0.2115	694	0.2866	0.2202	0.2769	170	0.3401	0.2289	0.2983	***		***	***	**	

Table 3.6. Shadow and regular ICM subsidy

The sample consists of 2,045 insurer-year observations, with 1,181 public insurer year observations, 694 private insurer-year observations and 170 mutual insurer-year observations from 2005-2015. Only insurers using shadow insurance at least once during our sample period 2005-2015 are included. In column 1 we exclude mutual insurers and thus only private and public insurers are included. In column 2 all three organizational forms are included. The dependent variables in columns 1-2 are the first difference of underwriting ROA volatility (*UROA Volatility*), which is measured as the standard deviation of underwriting ROA over the past 5 years. Underwriting ROA is the net underwriting income scaled by the insurer's assets. The main explanatory variable *ΔShadow ICMSubsidy*, is the first difference of *Shadow ICMSubsidy*, which is measured as the reinsurance ceded to shadow insurers scaled by total gross premiums written. *ΔRegular ICMSubsidy*, is the first difference of *Regular ICMSubsidy*, which is measured as the reinsurance ceded to non-shadow insurers scaled by total gross premiums written. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors clustered at the insurer level are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. Appendix 3.1 provides all of the variable descriptions.

VARIABLES	(1) ΔUROA Volatility	(2) ΔUROA Volatility
	Exclude mutuals	All three organizational forms
ΔShadow ICMSubsidy*Private	-0.0271**	-0.0263**
	(0.0131)	(0.0131)
ΔShadow ICMSubsidy*Mutual		0.0126
		(0.0393)
ΔRegular ICMSubsidy*Private	-0.0070	-0.0068
	(0.0049)	(0.0049)
ΔRegular ICMSubsidy*Mutual		-0.0093
		(0.0098)
Δshadow ICMSubsidy	0.0243**	0.0239**
	(0.0116)	(0.0116)
ΔRegular ICMSubsidy	0.0031	0.0032
	(0.0032)	(0.0032)
Private	-0.0006	-0.0007
	(0.0005)	(0.0005)
Mutual		-0.0002
		(0.0007)
ΔExRein	0.0116**	0.0110**
	(0.0055)	(0.0053)
ΔSurplus	-0.0002	-0.0005
	(0.0020)	(0.0019)
ΔLobH	-0.0068	-0.0039
	(0.0057)	(0.0057)
ΔGeoH	0.0121	0.0102
	(0.0073)	(0.0069)
ΔLongtail	0.0023	0.0009
	(0.0056)	(0.0056)
ΔCatExposure		
Observations	1,875	2,045
R-squared	0.0267	0.0258
Year FE	Yes	Yes
SE cluster	Insurer	Insurer
Two-tailed Wald test for the null Hypothesis (p-value)		
ΔShadow ICMSubsidy=ΔRegular ICMSubsidy	0.0567	0.0626
ΔShadow ICMSubsidy*Private+ΔShadow ICMSubsidy=0	0.6302	0.6865
ΔRegular ICMSubsidy*Private+ΔRegular ICMSubsidy=0	0.2856	0.3181
ΔShadow ICMSubsidy*Mutual+ΔShadow ICMSubsidy=0		0.3308
ΔRegular ICMSubsidy*Mutual+ΔRegular ICMSubsidy=0		0.5165

Chapter Four: Investor Financial Health and Municipal Bond Liquidity Risk

Abstract

We examine whether the financial health of municipal bond investors can affect the municipal borrowing cost, i.e., the municipal bond yield, especially focusing on the liquidity component. Using the U.S. property and casualty insurance companies as the research setting, we find that the deterioration of the financial health of bond investors raises the liquidity spread of municipal bonds, and this relationship was even stronger during the subprime mortgage crisis. Using Hurricane Sandy as an exogenous shock to the financial health of insurers, we find that the municipal bonds held by insurers suffered loss by the hurricane experience larger increase in liquidity yields in the current and following quarter of Hurricane Sandy.

Keywords: Insurance companies, municipal bonds, risk premium

JEL Classification: G22, G12, H74

1. Introduction

Municipal bond markets provide a mechanism whereby state and local government units can raise money for public purposes such as water and sewer systems, schools, highways and public buildings. Municipal bond markets represent an increasingly important part of the U.S. capital markets. According to the U.S. Securities and Exchange Commission (SEC, 2012), by year 2011, about 44,000 state and local issuers participated in the municipal bond markets with a total face value of $3.7 trillion. The yield of the issued municipal bond equals the tax free rate plus yield spread, where the yield spread mainly consists of three components: default risk, liquidity risk, and tax risk (Longstaff, 2011). Therefore, the change in any of these three components directly affects local governments' financing cost.

The objective of this study is to examine whether and how the financial health of municipal bond investors affects municipal borrowing cost (i.e., the municipal bond yield), especially by focusing on the liquidity component. Although there is a variety of investors participating in the markets, there is scant evidence on how the investor characteristics affect the pricing of municipal bonds.

Theoretical studies show that the asset price is related to investor's financial health. He and Krishnamurthy (2013) argue that the risk premium of assets depends on the financial health of marginal investors. In their theoretical models, marginal investor is a financial intermediary, which faces capital constraint. Risk premia rise when the constraint binds, reflecting the capital scarcity of the marginal investors.

However, He and Krishnamurthy (2013) does not look into the contributions of default risk and liquidity risk to the risk premia. In terms of the liquidity risk, Brunnermeier and Pedersen (2009) show that investors' funding liquidity conditions affect assets' market liquidity. When the funding liquidity is tight, investors become reluctant to take on positions, thus resulting in a lower market liquidity and a higher market volatility, which increase the risk of financing a trade and thus increase the margins of the trade. Therefore, the funding liquidity and the market liquidity are mutually reinforcing.

Liquidity risk of a security is priced by two components, the expected liquidity cost, namely the pure liquidity cost, as well as the covariance of its liquidity with the market liquidity, namely the liquidity risk premium (Acharya and Pedersen, 2005). However, Brunnermeier and Pedersen

(2009) ’s model is silent on which component is attributed to investor’s financial condition. We argue that investor’s financial condition will have a direct effect on the second components, liquidity risk premium due to two reasons. First, during the period of market turmoil, investors with less sound finical condition, which are more likely to face binding capital constraint, tend to fire sell the security they hold. The fire-sold securities usually experience a large price drop, thus resulting in a higher illiquidity cost for this specific security. Meanwhile, a stock market decline and a market-wide liquidity dry-up are highly correlated (Hameed, Kang and Viswanathan, 2010). Therefore, the positive correlation between the illiquidity of a security and the illiquidity of the market is expected to raise the liquidity premium required by other classes of investors.

Second, from the liquidity supply side, the fire-sold securities may not experience a large price drop if there are enough capital supply. However, empirical evidence shows that capital cannot flow to investment opportunities without friction (Mitchell, Pedersen and Pulvino, 2007), for examples in reinsurance markets (Froot and O'Connell, 2008), and in CDS markets (Gabaix, Krishnamurthy and Vigneron, 2007). The municipal bond market is very illiquid compared to U.S. treasuries, corporate bonds, and stock market, and is featured by high transaction costs due to search frictions and market dealer power (Schwert, 2017). In addition, the tax exemption status of municipal bonds discourages institutional investors from participating in the market.[66] All these factors preclude the frictionless supply of capital to municipal bond markets.

We study one specific class of investors, the U.S. property and casualty (P&C) insurance companies, for three reasons. First, the P&C insurance companies are important investors in the municipal bond markets in the U.S. During year 2008-2011, the P&C insurance companies are the fourth largest investors in municipal bonds markets with the ownership around 10 percent, while after 2012, depository institutions becomes the fourth largest investors. Appendix 4.2 shows the ownership of municipal bonds by year. By year 2011, Individual or “retail” investors held the largest share of municipal bonds, accounting for about 48.6%, followed by mutual funds, accounting for about 14.6%, and money market mutual funds, accounting for about 9.61%. (NAIC, 2013). Second, municipal bond investment accounts for the second largest portion of total cash

[66] For example, investors who enjoy tax reduction benefit in almost all asset markets, such as life insurance companies and pension funds, are reluctant to participate in the municipal bond market because they cannot exploit their tax benefit compared to other investors

and invested assets for the P&C insurers. At the year end of 2013, the P&C insurers invest about 21% of total cash and invested assets in municipal bonds, 18% in corporate bonds , and 28% in common stocks (NAIC, 2014). Finally, unlike individual investors and mutual funds, the P&C insurance companies file detailed quarter and annual regulatory financial statement including investment transactions to the National Association of Insurance Commissioners (NAIC), the main regulator of the U.S. insurance industry. This provides us the opportunity to study the effect of financial soundness of investors on the pricing of the liquidity component of municipal bonds.

Following Schwert (2017) by estimating the liquidity component using the transaction data, we decompose the tax-adjusted municipal bonds yield spread into the default component and the liquidity component. We then construct four alternative proxies to measure the financial health of the municipal bond's investors, the average RBC ratio (leverage ratio, operation cash flow to assets ratio and operation cash flow to equity ratio) of P&C insurance companies holding the municipal bond. We then use these proxies to relate the financial health of bond investors to the liquidity component of municipal bond yield spread.

We find that the financial health of bond investors is one determinant of municipal bonds' liquidity spread. The deterioration of the financial health of bond investors raises the liquidity spread. One standard deviation decrease of average leverage ratio raises the liquidity spreads about 1 basis point. We also find that this relationship is even stronger during the subprime mortgage crisis, where financial institutions faced liquidity issues.

One of the main concerns is the reversal causality. P&C insurance companies with sound financial conditions are more likely to purchase more liquid bonds. We attempt to mitigate this concern by using the Hurricane Sandy as one exogenous shock. Hurricane sandy is the second costliest natural disasters in the US history. Because affected insurance companies need to reimburse the claimholders suffered by the disaster, they suffered capital loss exogenously. We find that the municipal bonds held by insurers writing coverage relevant to the hurricane loss experienced a larger increase in the liquidity yield in the current and following quarter of Hurricane Sandy. This result is robust when we use alternative proxies for hurricane exposure. These results show that there is a causal relationship between investor's financial health and bond liquidity spreads.

To investigate how the pure liquidity cost and/or the liquidity premium contribute to the yield spread, we construct the proxies for the pure liquidity cost by using Amihud (2002) measure and the liquidity premium by using the liquidity beta (i.e., the covariance between specific bond's illiquidity and market-wild illiquidity).

We do not find a significant relationship between the pure liquidity cost and the financial health of an investor. However, we find that the financial health of an investor increases the liquidity beta of the bond (i.e., increases the sensitivity to the market liquidity). This result shows that the financial health of investors can affect the liquidity yield through the liquidity premium channel.

Our paper contributes and is related to the literature on the determinants of the yield spread of municipal bonds. Wang, Wu and Zhang (2008) and Ang, Bhansali and Xing (2010) examine the default risk, liquidity risk and tax component of municipal bond yield spread, and find that all three components are priced. Longstaff (2011) demonstrates that tax risk is a systematic asset pricing factors and it helps resolve the muni-bond puzzle.[67] Schwert (2017) finds that the default risk is the most important driver of the municipal spread yields. He further shows that the default risk plays an outsized role due to a high default risk premium relative to the observed low default rate. We show that the financial health status of municipal bond investors affect municipal bond yield spreads through the liquidity component. Our findings help to explain why a cross-variation is observed in municipal bond spreads.

The literature also shows that state characteristics help to explain municipal bonds yield. Novy-Marx and Rauh (2012) find that pension fund loss during the subprime mortgage crisis led to higher municipal bond yields within the state. Gao, Lee and Murphy (Forthcoming) establish that alternative policies on financial distressed municipalities result in a cross-state variation of the municipal bond yields because the different level of creditor protection embedded in the policy upon default events. Butler, Fauver and Mortal (2009) show that state corruption and political connections have strong effects on municipal yields in the primary security markets. Our paper

[67] Municipal bonds are exempt from state income tax but subject to federal income tax rate. Many researchers show that the ratio of municipal bonds yield to corporate bond yields appears to imply marginal tax rates that are much smaller than would be expected given federal income tax rates. This is termed muni-bond puzzle.

shows that investor characteristics also matter in the municipal bonds pricing in addition to the state characteristics.

Finally, we contribute to the literature on how investor base affects asset pricing and firm financing policy. Cella, Ellul and Giannetti (2013) show that investors' different horizons cause the variation in stock performance, especially during the period surrounding the Lehman bankruptcy in 2008. Manconi, Massa and Zhang (2015) find that greater bondholder concentration is associated with a higher corporate bond yield spread. Massa, Yasuda and Zhang (2013) find that the supply uncertainty of the firm's bond investor base has a negative effect on the leverage of the firm. Siriwardane (2016) illustrates that capital loss of CDS sellers increases the CDS spread. Our paper shows that one of investors' characteristics, financial health of the investors, affects municipal bond yields.

The results in our paper imply that fostering a group of investors with strong financial conditions is important to reduce the borrowing cost of states, municipalities, and other local public entities. It is also related to a debate on whether to inject capital to financial intermediaries during a financial crisis. The direct capital infusion to insurance companies and other financial intermediaries help to decrease the risk premium in the asset markets and to stabilize the markets (e.g., see He and Krishnamurthy (2013)'s analysis on MBS markets during the crisis). Finally, as regards to insurance industry, there is a discussion of whether insurance companies will cause spillover effect to other markets or industries, or termed systemic risk (Cummins and Weiss, 2014). Our results suggest that there is a direct link between insurance industry and municipal bonds markets, which has been ignored before. This link should be monitored carefully during both the economic downturn and normal times, as insurance companies are subject not only to systematics risk such as business cycles, but also to catastrophe risk such as natural disasters.

2. Data and Sample construction

We utilize several data sources for our study. Transaction data of municipal bonds are retrieved from the Municipal Securities Rulemaking Board (MSRB).[68] The dataset consists of municipal

[68] The data are downloaded through WRDS.

bonds trade data from the second quarter of year 2005 to the fourth quarter of year 2015. For each trade observation, the dataset includes the bond CUSIP, the date and time of trade, the bond trading price and yield, the issue date and the maturity of the bond and the type of the trade (i.e., whether this trade was a customer purchase from the a broker-dealer, a customer sale to a broker-dealer, or an interdealer trade).

Our second source of data is Lipper's Emaxx municipal bond database. It provides information on the ownership and characteristics of each municipal bond on a quarterly basis from year 1997 to 2013. The bond characteristics recorded in the data include its 8-digit CUSIP, issuer, state of issuance, whether it is fixed coupon bonds or not, current issue amount outstanding, and bond ratings from Moody's, Standard & Poor's and Fitch. It also provides information about whether the bond is callable or not, whether the bond is subject to the alternative minimum tax, whether the bond is US federal taxable or not, whether the bond is pre-refunded or not, and whether the bond has any credit enhancement[69] or not.

The information on P&C insurance companies for the period of 2000-2016 are obtained from the SNL Financial database. SNL Financial collects and organizes data from regulatory filings that P&C insurers file with the NAIC each quarter. It provides information about each insurer's holding of municipal bonds (par value) at the 9-digit CUSIP level. It also provides information on financial statement, including assets and liabilities, cash flows and so on. In addition, it provides information on the RBC ratio, which is used by the insurance regulator to monitor the financial soundness of insurers, which is reported annually.

Our sample starts from the MSRB database. We clean the data following the approach adopted by Schwert (2017). First, for the bond level screening, we remove all transaction observations if the coupon is greater than 20%, or if the maturity is more than 100 years. We also drop bonds with less than 10 transactions in the whole sample period. Second, for the transaction level screening, we drop transactions if the price is less than 50, or the price is above 150. We also exclude transactions if the bonds are with less than one month to maturity. We drop observations that occur after the maturity of the bond.

[69] Credit enhancement includes bond issuer default insurance, letter of credit, etc.

We calculate the municipal bond yield spread and decompose it to the liquidity risk and default risk components on a quarterly basis. We convert the MSRB data to the quarterly basis[70] and then merge it with the Emaxx database to obtain bond characteristics. We only keep observations which appears in both databases. We further restrict our sample to fixed-coupon bonds. We remove bonds that are pre-refunded; remove bonds that are subject to alternative minimum tax or that are federally taxable.

Meanwhile, we clean the insurance company data retrieved from SNL. For bond holding data, we remove the insurer-bond-quarter observations with a negative value on par value hold. We then retrieve financial statement data of insurers for each insurer-bond-quarter observation. Further, we collapse the insurer-bond-quarter observation to bond-quarter level data by weighing averaged using par value held by each insurer. This dataset contains bond-level information on its investors' financial health condition.

After we decompose the bond yield spread into the liquidity and default components, we merge this sample with the dataset containing bond-level investors' financial health condition.

We only include bond-quarter observations with positive P&C insurance company ownership. Our final sample covers from the second quarter of 2006 to the fourth quarter of 2013.[71] It includes 220,665 bond-quarter observations. The sample size varies a little when we use different sets of proxies for bond investor's financial health conditions.

3. Research design and variable constructions

3.1. Municipal bond yield

We calculate the quarter-end bond yield (*Yield*) as the average yield of all trades in the quarter where the bond is traded. If a bond were not trade during the last month of the quarter, it is excluded from that quarter (Dick-Nielsen, Feldhütter and Lando, 2012).

3.2. Decomposing municipal bond yield:

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[70] The conversion procedure is described in section 3.5.

[71] We do not include the first quarter because the observation is too small when we merge the EMaxx database with MSRB database. There is only 33 matched observations in Q1 2006.

Prior literature shows that municipal bond yields consist of default risk, liquidity risk and tax component. Schwert (2017) expresses the yield on tax-exempt municipal bond as

$$y_{it} = (1 - \tau_{s,t})(r_t + \gamma_{j,t} + \psi_{i,t})$$

where *i* denotes the bond; *j* denotes the issuer; *s* denotes the state in which the issuer is located, and *t* denotes the quarter.

The factor $(1 - \tau_{s,t})$ reflects the wedge between tax-exempt and taxable yields. r_t represents the duration matched risk free rate, $\gamma_{j,t}$ represents the default risk and $\varphi_{i,t}$ represents the liquidity component. We define $y_{it}/(1 - \tau_{s,t})$ as the tax-adjusted yield, denoted as ${y_{it}}^{TA}$. We define ${y_{it}}^{TA} - r_t$ as the tax-adjusted yield spread.

The tax factor is calculated as $\left(1 - \tau_{s,t}\right) = (1 - \tau_t^{fed})(1 - \tau_{s,t}^{state})$, where τ_t^{fed} is the top federal income tax rate in year *t* and $\tau_{s,t}^{state}$ is the highest marginal tax rate in state *s* in year *t*.

Following Gao *et al.* (Forthcoming), we measure the duration matched risk free rate r_t by using U.S. treasury yield. We obtain the U.S. treasury yield from Quandl.[72] It also provides daily parameters which can be used to calculate the entire U.S. treasury yield curve. The functional form for the curve is as follows (Nelson Siegel 1987):

$$TYield(D) = \beta_0 + \beta_1(\frac{1 - e^{-D/\tau_1}}{D/\tau_1}) + \beta_2(\frac{1 - e^{-D/\tau_1}}{D/\tau_1} - e^{-D/\tau_1}) + \beta_3(\frac{1 - e^{-D/\tau_2}}{D/\tau_2} - e^{-D/\tau_2})$$

where *TYield*(*D*) is the yield on a treasury bond with duration *D* and ($\beta 0$, $\beta 1$,$\beta 2$,$\beta 3$, $\tau 1$, $\tau 2$) is the daily set of parameters provided by Quandl.

3.3. Yield regression

Following Schwert (2017)'s transaction based method and Dick-Nielsen *et al.* (2012)'s regression method, we run separate regressions for each quarter. The regression model is:

$${y_{it}}^{TA} - r_t = \alpha_0 + \beta_t^{\lambda}\lambda_{i,t} + RatingCategory_{it} + \varepsilon_{it} \quad (1)$$

[72] https://www.quandl.com/data/FED/PARAMS-US-Treasury-BETA-and-TAU-Parameters

where $\lambda_{i,t}$ is the liquidity measure. The construction of the liquidity measure will be presented in section 3.4.

We follow Schwert (2017) by using the 1st percentile liquidity variable, denoted as λ_{1p}, to benchmark the liquidity of very liquidity municipal bonds. The liquidity spread is then estimated as:

$$\psi_{i,t} = \beta_t^{\lambda}(\lambda_{i,t} - \lambda_{1p})$$

Further, we can calculate the default component in the bond yield as:

$$\gamma_{j,t} = y_{it}{}^{TA} - r_t - \psi_{i,t}$$

3.4. Liquidity measures

Schwert (2017) shows that compared to trading variables,[73] liquidity variables contribute most to explain the variation in bonds yields. We follow them by only using the liquidity variables. The liquidity measure includes six measures: Amihud (2002) measure and its standard deviation, imputed roundtrip cost (Feldhuetter, 2012) and its standard deviation, the roll measure (Roll, 1984), and the price dispersion measure (Friewald, Jankowitsch and Subrahmanyam, 2012). The liquidity measure $\lambda_{i,t}$ is defined as

$$\lambda_{i,t} = \sum_{k=1}^{6} \frac{L_{i,t}^k - \mu^k}{\sigma^k}$$

where L^k represents one of the six liquidity measures, and their means μ and standard deviations σ are calculated over the full sample.[74]

3.5. Bond-level investor financial health measures

3.5.1. RBC ratio

[73] Such as turnover, issuer zero-trading days, trades per day.
[74] Schwert (2017) shows that based on the principal analysis, an equally weighted liner combination of these six measures has the strongest power to explain the variation in bonds yield.

We construct four alternative proxies to measures the financial health of the municipal bond investors.

The first measure is the average RBC ratio of P&C insurance companies that hold the municipal bond, which is weighted average of RBC ratio of all P&C insurers holding this municipal bond. It is defined as:

$$AvgRBC_{it} = \sum_{j \in S_{it}} w_{jit} RBC_{jy}$$

where the weight is defined by $w_{jit} = \frac{Par\ Value_{jt}}{\sum_{j \in S_{it}} Par\ amount_{jt}}$; i, j and y denote the bond, the insurer, and the year, respectively.

RBC_{jy} is the RBC ratio of insurer *j* at the end of year *y*. Let S_{it} denote the set of P&C insurers that hold bond *i* at the end of quarter *t*. Let w_{jit} denotes the weight of insurer *i*'s holding in the total par value held by P&C insurers at the end of quarter *t*.

In the U.S. insurance risk-based capital system, capital adequacy is assessed by the RBC ratio, defined as the ratio of total adjusted capital (TAC) to the firm's overall RBC:

$$RBC\ ratio = \frac{Total\ adjusted\ capital(TAC)}{0.5 * Risk-based\ capital(RBC)}$$

where TAC consists primarily of capital (termed surplus in insurance industry) and RBC, calculated by the sum of capital charges of different risk categories, is the required capital that reflects business and asset risks. An insurer with a low RBC ratio will be subject to regulatory action, which incurs significant cost.[75]

The advantage of using the RBC ratio to measure the financial health of P&C insurers is that the measure evaluates the financial condition of an insurer in a comprehensive manner. However, the RBC ratio is reported only annually.

3.5.2. Leverage ratio

[75] There are four levels of regulatory action, depending on an insurer's risk-based capital ratio. The company action level is 150% to 200%, regulatory capital is 100% to 150%, the authorized control level is 70% to 100%, and mandatory control level is below 70%.

The second bond-level measure of the insurers' financial health is based on the leverage ratio (Chen and Wong, 2004; Shiu, 2011), which is calculated as the weighted average of the leverage ratios of all P&C insurers that hold a particular bond. It is defined as:

$$AvgLev_{it} = \sum_{j \in S_{it}} w_{jit} Leverage_{jt}$$

where the leverage ratio is defined by (*Assets-Surplus*)/*Surplus* and calculated each quarter.[76]

3.5.3. Operation cash flow to equity ratio

The third bond-level measure is constructed based on firm's operation cash flow to equity ratio. It is defined as the weighted average of operation cash flow to surplus ratio of all P&C insurers holding this bond:

$$Avg\ Cash\ to\ Assets_{it} = \sum_{j \in S_{it}} w_{jit} Cash\ to\ Assets_{jt}$$

Operation cash flow mainly consists of cash generated from insurers' underwriting business.

Different from the above two measure, It is a flow variable, which describes the adequacy of cash of the investors during the reporting period. The operation cash flow to equity ratio can be obtained on a quarterly basis.

3.5.4. Operation cash flow to assets ratio

The fourth bond-level measure is based on the firm's operation cash flow to assets ratio and is defined as the weighted average of the cash to assets ratio of all P&C insurers holding this bond:

$$Avg\ Cash\ to\ Equity_{it} = \sum_{j \in S_{it}} w_{jit} Cash\ to\ Equity_{jt}$$

3.5.5. The timing issue of bond-level investor financial health measure

To mitigate the time inconsistency problem, we use both the RBC ratio by the end of year *y* or year *y*-1, and weighted either by par value held by the end of quarter *t* or *t-1* to calculate the bond-level weighted average RBC ratio.

[76] Surplus means equity in insurance accounting.

Specifically,

$$AvgRBC2_{it} = \sum_{j \in S_{it-1}} w_{jit-1} RBC_{jy}$$

$$AvgRBC3_{it} = \sum_{j \in S_{it}} w_{jit} RBC_{jy-1}$$

$$AvgRBC4_{it} = \sum_{j \in S_{it-1}} w_{jit-1} RBC_{jy-1}$$

where $w_{jit} = \frac{Par\ amount_{jt}}{\sum_{j \in S_{it}} Par\ amount_{jt}}$ and $w_{jit-1} = \frac{Par\ amount_{j,t-1}}{\sum_{j \in S_{it-1}} Par\ amount_{j,t-1}}$.

In terms of the leverage ratio reported quarterly, we use both the leverage ratio by the end of quarter *t* and *t*-1, and weighted either by par value held by the end of quarter *t* or *t*-1 to calculate the bond level weighted average leverage ratio.

$$AvgLev2_{it} = \sum_{j \in S_{it-1}} w_{jit-1} Lev_{jt}$$

$$AvgLev3_{it} = \sum_{j \in S_{it}} w_{jit} Lev_{jt-1}$$

$$AvgLev4_{it} = \sum_{j \in S_{it-1}} w_{jit-1} Lev_{jt-1}$$

The constructions of the bond-level operation cash to assets ratio and the bond-level operation cash to equity ratio are similar to the construction of the bond-level leverage ratio.

3.6. Regression design

Following prior literature on the determinant of bond yield spread (Ericsson and Renault, 2006; Butler *et al.*, 2009; Dick-Nielsen *et al.*, 2012; Gao *et al.*, Forthcoming), our bond-quarter level regression is specified as follows:

$$LiqSpread_{it} = \alpha_0 + \alpha_i + \alpha_t + \beta Financial\ Health_{it} + \gamma X_{it} + Rating_{it} + \varepsilon_{it} \quad (2)$$

where α_0, α_i, and α_t represent constant, bond *i* fixed effects, quarter *t* fixed effects, respectively. The normally distributed error term is denoted by ε_{it}. The dependent variable $LiqSpread$ is the liquidity component of bond yield spread. Our main variables of interest, *Financial health*, include the average RBC ratio, the average leverage ratio and the average operation cash flow to equity ratio. Because our dependent variable and the financial health measures are at the bond-quarter level, we double cluster the standard errors by bond and quarter.

Prior literature shows that municipal bond yields depend on bond characteristics (Butler *et al.*, 2009; Dick-Nielsen *et al.*, 2012; Gao *et al.*, Forthcoming). The set of control variables X_{it} includes outstanding issue amount at the end of quarter (*LnSize*), the natural logarithm of the number of years to maturity *(LnMaturity*), an indicator variable that takes the value of one if the bond is callable; zero otherwise (*Callable*), and an indicator variable that takes the value of one if the bond has any credit enhancement; zero otherwise (*EnCredit*).[77] Following Schwert (2017), the rating category variable, *rating*, includes indicators for each rating category (AAA, AA, A, BBB, BB and below, Not Rated). In addition, we include the share of par values held by all P&C insurers to total issue amount outstanding (*PCShare*). Note that because we include bond fixed effects in our regression, time invariant bond characteristics, such as whether it is a general obligation bonds or revenue bonds, the coupon rate, type of issuer, type of state etc. is absorbed by the bond fixed effects. It help us to alleviate the data availability concern.

3.7. Descriptive statistics

Our final sample covers from the second quarter of 2006 to the fourth quarter of 2013. Depending on the proxies we choose to measure bond investors' financial health, the size of our sample varies a little from 206,645 to 221,169 bond-quarter observations. We report the summary statistics of the variables including the liquidity and financial health measures in Table 4.1.

For bond characteristics, the average yield is 3.20%, and the average tax-adjusted yield is 5.33%. After the deduction of the maturity matched treasury yield, the average tax-adjusted spread is 2.41%, which breaks down to the default spread 1.58% and the liquidity spread 0.83%. Schwert (2017) reports the average yield in their sample being 2.57% from year 1998 to year 2015, and a lower share of liquidity spread in total tax-adjusted spread. Note that Schwert (2017) includes general obligation bonds of states and large local government in his sample, while our sample includes all the municipal bonds such as revenue bonds which are relatively more risky and

[77] There is variation in *Callable* and *EnCredit* over time within bonds.

illiquid.[78] The average yield in Wang *et al.* (2008)'s sample for years 2000-2004 is 3.88%, and the liquidity spread accounts for 9% to 19% of total yields.

The average share of par value held by P&C insurance companies (*PCShare*) is 20.1%. The average bond's par value outstanding (*LnSize*) is 20.6 (=$e^{9.93}$/1000) $millions. The average years to maturity (*LnMaturity*) is 8.2 (=$e^{2.11}$) years. Around 37% of observations are callable (*Callable*), and 41% of observations have any kind of credit enhancement (*EnCredit*). In terms of credit rating, about 70% of observations have ratings within A-rated category or above, and 22% of the observations are BBB-rated.

For the liquidity cost measures, the average of the Amihud measure is 24% on a $ 1million trade and median roundtrip cost is 0.68%, which is relative higher but comparable to Schwert (2017)'s findings, considering the relative illiquidity of our sample.

In terms of our financial health measures, the mean value of *Avg RBC*, the weighted average RBC ratio of the bond's P&C insurer investors is 13.3. The mean value of *Avg Lev*, the weighted average leverage ratio of the bond's P&C insurer investors is 176%. The mean value of *Avg Cash to Assets*, the weighted average operation cash flow to assets ratio of the bond's P&C insurer investors, is 1%. The mean value of *Avg Cash to Equity*, the weighted average operation cash flow to equity ratio of the bond's P&C insurer investors, is 2.8%. These values varies a little if we weighted by lagged par value held by P&C insurer investors.

4. Empirical Results

4.1. Baseline results

Table 4.2 reports the regression results for Equation (1). In panel A, bond-level financial health of investors is measured by the weighted average of RBC ratio (*Avg RBC*), weighted average of leverage ratio (*Avg Lev*), weighted average of cash-to-assets ratio (*Avg Cash to Assets*), or weighted average of cash-to-equity ratio (*Avg Cash to Equity*). In column 1, the coefficient of *Avg RBC* is negative and significant at 5% level, suggesting bonds held by P&C insurers with a lower

[78] General obligation bonds are backed by the taxing power and/or "full faith and credit" of the issuing entity. Usually they are issued by the states or local governments. Revenue bonds may be backed by revenue-generating projects, such as sales or the revenues of the specific project or enterprise being financed (e.g. an airport or port facility).

RBC ratio (indicating weaker financial health) will have a higher liquidity spread. In column 2, the coefficient of *Avg Lev* is positive and significant at 1% level, indicating bonds held by P&C insurers with a higher leverage ratio will have higher liquidity spread. In columns 3 and 4, the coefficients of *Avg Cash to Assets* and *Avg Cash to Equity* are both negative and significant, suggesting municipal bonds held by P&C insurers with less operation cash flow have a higher liquidity spread. In terms of economic significance, a one-standard-deviation decrease in the average RBC ratio (19.65) increases the municipal bond's yield spread by 0.6 basis points. A one-standard-deviation increase in the average leverage ratio (1.62) increases the municipal bond's yield spread by 0.98 basis points. Overall, these results suggest that the stronger financial health of P&C insurer bondholders is related to a lower liquidity spread.

In terms of the control variables, we find that the percentage of par value held by P&C insurers (*SharePC*) are positive related to the liquidity yield spread. The size of bonds, measured by the logarithm of the issue amount outstanding (*LnSize*), is insignificant. Schwert (2017) and Dick-Nielsen *et al.* (2012) also find insignificant coefficient of the issue amount in their liquidity spread determinant regression. The coefficient on the bond's maturity is positive (*LnMaturity*), consistent with the findings from Longstaff, Mithal and Neis (2005) and Wang *et al.* (2008). It supports the argument made by Schwert (2017) that long-maturity bonds facing a higher transaction cost. The coefficient on *Callable* is not significant. The coefficient on *EnCredit* is negative and significant, suggesting bonds with any credit enhancement, such as bond insurance or Letter of Credit, are more liquid. The coefficients on rating category dummies are not significant.

In columns 5-8, we replace the dependent variable with the default spreads (*DftSpread*). Among our financial health measures, only *Avg Lev* is significant and negative, suggesting municipal bonds held by investors with a higher leverage ratio have higher liquidity spread. The insignificance of other financial health measures highlights the contribution of the bondholders' financial health particularly to liquidity spreads.

In terms of other control variables, the percentage of par value held by P&C insurers (*SharePC*) are positive related to municipal bonds' default spreads. The size of bonds, measured by the logarithm of the issue amount outstanding (*LnSize*), is negative related to default yields, suggesting that bonds with a larger issue amount outstanding have lower default spreads. This is consistent with findings from prior literature (Wang *et al.*, 2008; Butler *et al.*, 2009). The coefficient on the bond's maturity (*LnMaturity*) is insignificant. The coefficients on *Callable* and *EnCredit* are both significant and negative, indicating callable bonds and bonds with bond insurance or any other credit enhancement have lower default spreads. The coefficients on rating categories BBB-rated or above are significant and indicate municipal bonds with higher ratings have lower default spreads.

We replace the financial health measures in Panels B-D. In Panel B we use the average of the current financial health ratio weighted by the lagged par value held by the P&C insurers (e.g., *Avg RBC2*). Similarly, in Panels C and D, we use the average of the lagged financial health ratio weighted by the current par value held by the P&C insurers (e.g., *Avg RBC3*) and that weighted by the lagged par value (e.g., *Avg RBC4*) instead of the current par value, respectively.

The consistent results for the alternative measures lend supports to our argument that stronger financial health of municipal bonds' investors is related to lower liquidity yields.

4.2. Results during the Lehman Brothers crisis

We argue that the negative relationship between the financial health of municipal bonds' investors and bonds' liquidity will be intensified during a financial crisis. First, as theoretically showed by Brunnermeier and Pedersen (2009) and He and Krishnamurthy (2013), the effect of marginal investor's capital on market illiquidity is nonlinear. A margin change in investors' capital has a lager effect on market liquidity when the investor's capital level is low. A financial crisis adversely affects insurers' assets because of their intensive investment in capital markets and also make it difficult for them to raise capital from the markets. Therefore, their capital levels tend to drop during a crisis. Second, capital suppliers require a higher liquidity risk premium during a market turmoil. Because securities held by financially weak P&C insurers are more likely to be subjected to fire sale during a crisis, a stronger negative relationship between bond investors' financial health and liquidity spread is expected during a crisis period.

Literature shows that the crisis after the bankruptcy of Lehman Brothers is more intensified, featured by increased liquidity needs of financial institutions (Baba and Packer, 2009). To capture the effect of the financial crisis after the bankruptcy of Lehman brothers, we prepare an indicator variable *Crisis Lehman* that takes the value of one for the period from the third quarter of 2008 to the second quarter of 2009, and zero otherwise (Acharya and Mora, 2015). We evaluate the crisis effect by including the interaction term between our bond-level financial health measures and *Crisis Lehman* in the regression (2).

Table 4.3 reports the result, the coefficients of the interaction terms for *Avg Lev*, *Avg Cash to Assets*, and *Avg Cash to Equity* are significant. Those results suggest that the negative relationship between investor financial health and liquidity spreads is stronger during crisis period. The insignificance of the coefficient of *Crisis Lehman**Avg RBC* might be caused by the fact that the RBC ratio is report annually and cannot change as frequently as other financial ratios. [79] It provides evidence that during financial crisis the relationship between bondholder's finical health and liquidity spread become stronger.

5. Using Hurricane Sandy as an exogenous shock

We argue that a stronger financial health of bond investors helps to reduce the municipal bond liquidity spread. One of the main concerns is the endogeneity, where insurers with a stronger financial health condition might prefer investing in municipal bonds of higher liquidity. However, prior literature shows that holding of a higher capital level is associated with more risk-taking in insurance industry (e.g., Cummins and Sommer, 1996; Baranoff and Sager, 2002; Cheng and Weiss, 2013), suggesting that insurance company investors with sufficiently large capital seeks high yields in bonds investment, featured by high risk and less liquidity.

To further address the concern of endogeneity, we use Hurricane Sandy as an exogenous shock. Large insured losses incurred by Hurricane Sandy depleted the capital of affected insurers, because insurance firms need to reimburse their policyholders after the damage. This exogenous shock provides us with an opportunity to investigate how municipal bonds liquidity yields changed after their bondholders suffer from capital loss, which led to weaker financial health.

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[79] We also use alternative measures *Avg RBC(2,3,4)*, *Avg Lev(2,3,4)*, *Avg Cash to Assets(2,3,4)*, and *Avg Cash to Equity(2,3,4)* for insurers' financial health. The results are upon request. We note that the statistical significance of the interaction term is consistent across different specifications.

Hurricane Sandy (October 30-31, 2012) is the second costliest natural disaster in the U.S. history, and the costliest natural disaster during our sample period, from year 2006 to 2013. It caused 67.6 billion dollars damage and 159 people killed.[80] While occurrence of hurricanes are fairly predictable, the amount of damage is not, especially for such a costly natural disaster.[81]

5.1. Research design

5.1.1 Measurement

In the insurance literature, homeowner's lines are regarded as most prone to hurricane disasters (Cheng and Weiss, 2012). For each insurer, we measure its exposure to Hurricane Sandy by its share of direct premiums written in homeowner multiple peril line in affected states to its total direct premiums written (*DPW Exposure*). Specifically, *DPW Exposure* is calculated as

$$DPW\ Exposure_i = \frac{\sum_s\ DPW\ in\ homeowner\ line_{is,2012}}{DPW_{i,2012}}, s \in \text{ States affected by Sandy}$$

where *i* indicates insurer and *s* indicates state.

We convert the insurer level *DPW Exposure* to the bond level measure by calculating the weighted average of *DPW Exposure* of all P&C insurers holding this municipal bond at the third quarter of year 2012. It is defined as

$$Avg\ DPW\ Sandy_{\ i} = \sum_{j \in S_{it}} w_{jit} DPW\ Exposure_i$$

where *t* denotes Q3 2012; *i* denotes the bond ; and *j* denotes the insurer. Let S_{it} denote the set of P&C insurers who holds bond *i* at the end of Q3 2012. Let w_{jit} denote the share of insurer *i*'s holding in the total par value held by all P&C insurers at that quarter as defined above.

5.1.2. Treatment and control group

Our sample consists of all municipal bonds held by any P&C insurance company at the end of Q3 2012, the quarter before Hurricane Sandy. We define treatment group as bonds with a positive *Avg*

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[80] See NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2016). https://www.ncdc.noaa.gov/billions/

[81] Hurricane Katrina and Sandy are commonly used as exogenous shock in the literature (Barrot and Sauvagnat, 2016; Bernile et al., 2016).

DPW Sandy at Q3 2012, namely the bonds held by any P&C investor who has positive exposure to Hurricane Sandy. Our control group consists of bonds with zero *Avg DPW Sandy*.

5.1.3. Regression model

We implement a standard difference-in-differences test to investigate how the investors' deterioration in financial health due to incurred losses by Hurricane Sandy affected the bonds' liquidity yields. The regression model is specified as:

$$LiqSpread_{it} = \alpha_0 + \alpha_i + \alpha_t + \beta\ Treat_i * Post_t + \gamma X_{it} + Rating_{it} + \varepsilon_{it} \quad (3)$$

The treatment variable *Treat* is a dummy variable that takes the value of one if bond *i*'s *Avg DPW Sandy* is positive, and zero otherwise. *Post* is a time dummy that takes the value of one if an observation falls the Hurricane sandy quarter (the fourth quarter of year 2012), and zero otherwise.

The variable of interest is the interaction term *Treat*Post*. The parameter β captures the change in the liquidity spreads of the bonds held by hurricane-affected insurers relative to the bonds held by hurricane-unaffected insurers after Hurricane Sandy. The estimated coefficient β is expected to be positive, indicating that capital loss of bond investors increased the liquidity spreads of the bonds they invested in. Similar to equation (2), we control for firm characteristics X_{it}, as well as bond and quarter fixed effects, and report robust standard error double clustered by bond and quarter.

One weakness of this regression specification is that *Treat* is a category variable, thus information about exposure to Hurricane Sandy is not fully utilized. We thus use the continuous variable *Avg DPW Sandy* in addition to *Treat* as the treatment variable in our regression.

5.2. Sample and descriptive statistics

Our sample is based on the prior sample used in section 4.1. We only include period ±4 quarters around Hurricane Sandy (i.e., the period from Q4 2011 to Q4 2013). We then restrict the sample to all municipal bonds held by any P&C insurance company at the end of Q3 2012, the quarter before the Hurricane sandy. This final sample consists of 69,340 bond-quarter observations.

Table 4.4 reports the descriptive statistics of our sample by treatment and control groups. We find that compared to the control group, bonds in the treatment group tend to have lower liquidity yield spreads, higher default spreads, and a larger ownership of P&C investors (*PCShare*). The two-sample *t*-tests show that these differences are significant. The mean value of *Avg DPW Sandy*, i.e. the weighted average of Sandy Exposure among the bond's P&C investors is 1.56%.

5.3. Empirical results

Table 4.5 presents the regression results. The dependent variable in columns 1 and 3 are liquidity spread and that in columns 2 and 4 are default spread. The treatment variable is *Treat* in columns 1 and 2 and *Avg DPW Sandy* in columns 3 and 4. In column 1, we find that the estimated coefficient on *Treat×Post* is positive and significant at the 1% level, suggesting a positive effect of capital loss on bond liquidity yield spread. This result support our argument that the deterioration of investor's financial health leads to increase in the municipal bond liquidity spreads. The economic magnitude is also sizeable. For example, the coefficient on *Treat×Post* is 0.029 in column 1 indicates that bonds held by affected insurers experienced an increase of the liquidity spread by 2.9 basis points after the hurricane hit, compared to control bonds. In columns (2), we use default spread as depend variables. The coefficient on *Treat×Post* is also significant, suggesting there is significant difference in default spreads between control and treatment groups before and after Sandy.

In columns 3 and 4, we replace the treatment variable with the continuous treatment variable *Avg DPW Sandy*. We find that the coefficient on the post-hurricane interaction terms is significant and positive in the liquidity spread regression in column 3, while it is insignificant in the default spreads regression in column 4. Thus, the results for liquidity spreads are consistent. Taken together, these results indicate that there is a causal relationship between investor financial heath and bonds' liquidity spreads.

One may concern about the effect of the fire-sale of hurricane affected P&C insurers on the increased liquidity spread. We conduct following tests to investigate this issue. First, we divide our treated bonds into two groups based on whether this bond is sold by the hurricane-affected insurers, the coefficient estimates on *Treat×Post* are significant in both groups, suggesting our results cannot be fully explained by fire-sale story (See Appendix 4.3). Second, we change our dependent variables to pure liquidity cost measures, i.e., Amihud measures, IRC measures and Roll measures. We find the coefficient on *Treat×Post* is not highly significant in the group where bonds are sold by hurricane affected insurers. The result implies affected insurers have not fire sold the municipal bonds they hold. (See Appendix 4.4).

5.4. The Pre-treatment Trends

The validity of difference-in-differences estimation depends on the parallel trends assumption: in the absent of Hurricane Sandy, treated bonds' liquidity yield spreads would have evolved in the similar manner to that of control bonds. This assumption requires a similar trend in yield spreads during the pre-treatment period for both the treatment and control groups. Following the method by Hong and Kacperczyk (2010), we present the results that investigate the pre-treatment trend between the treated group and control group in Table 4.6. In particular, we estimate the following regression:

$$LiqSpread_{it} = \alpha_0 + \alpha_i + \alpha_t + \sum_{t=1}^{7} \beta_t \, Treat_i * Dummy_t + \gamma X_{it} + Rating_{it} + \varepsilon_{it} \tag{4}$$

The dependent variables is liquidity spread. We assign $t \in [1, 7]$ which labels the quarters from Q1 2012 to Q4 2013 and define seven dummies that indicate the corresponding quarters. Q4 2011 is the baseline quarter. The coefficients on variables from *Treat × Q1 2012* to *Treat × Q3 2012* indicate whether there is any difference in the liquidity trend between the treatment group and the control group prior to Hurricane Sandy. The set of control variables are the same as those included in regression (3). Using the same specifications as in regression (3), we include bond and quarter fixed effects, and errors are double clustered by bond and quarter.

Table 4.6 reports the results. We observe that the coefficients on variables from *Treat × Q4 2011* to *Treat × Q3 2012* are close to zero and not statistically significant. These results suggest that the parallel trend assumption of the difference-indifferences approach is not violated. The impact starts to show up from the hurricane quarter and continues to the following quarter: the coefficients on *Treat × Q4 2012* and *Treat × Q1 2013* variables are significantly positive. Overall, Table 4.6 shows that the treated group and the control group share a similar trend in liquidity spread prior to the impact of Sandy, thus supporting the parallel trends assumption associated with the difference-in-differences estimation. The estimated coefficient in column 2 suggests they DID setting may not be valid for the default spread regression. Overall, these results suggests a causal effect between investors' financial health and municipal bond liquidity spreads.

6. The channel of increase in liquidity spreads

According to the liquidity-adjusted capital asset pricing model by Acharya and Pedersen (2005), bond liquidity spreads consist of two components: the pure liquidity cost (i.e., expected liquidity cost) and liquidity risk premium (i.e., the covariance of bond liquidity and market liquidity, or termed as liquidity commonality in related literature). Adopting their model, we argue that investor's financial condition can affect bond's liquidity spread through the second component, liquidity risk premium.[82] In this section, we directly test the roles of these two components played in the increase in liquidity spreads.

6.1. Pure liquidity cost

We replace the dependent variables with liquidity cost variables in equation (2) and have the following regression model:

$$Liq\ Cost\ Measures_{it} = \alpha_0 + \alpha_i + \alpha_t + \beta Avg\ RBC_{it} + \gamma X_{it} + Rating_{it} + \varepsilon_{it} \qquad (5)$$

Following Acharya and Pedersen (2005), we first measure the pure liquidity cost using Amihud (2002) measure. We also include other liquidity cost measures used by prior literature (Dick-Nielsen *et al.*, 2012; Schwert, 2017), including imputed roundtrip cost, the roll measure, and the price dispersion measure.

Our sample is the same as the sample in section 4.1. Table 4.7 reports the results. We fail to find significant coefficients on *Avg RBC* across alternative liquidity cost measures. Overall, these results suggest there is no strong relationship between the finical health of bonds investors and pure liquidity cost.

6.2. Liquidity premium

6.2.1. Measurement

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[82] See our discussion in introduction.

We further investigate the liquidity premium channel. Similar to Acharya and Pedersen (2005) and Kamara, Lou and Sadka (2008), we construct two alternative measures for bond-quarter level liquidity commonality.

We first calculate the Amihud measure for each municipal bond on each trade day, and then use the change in Amihud measure as our daily liquidity measure. The change is either calculated by the log transformation or the first different. Specifically, for each bond *i* on trade day *d*, we define $\Delta ILLIQ_{id}$, the change in bond's liquidity as either $\Delta ILLIQ_{id} = Amihud_{id} - Amihud_{id-1}$ or $\Delta ILLIQ2_{id} = \log(Amihud_{id}/Amihud_{id-1})$. We further define the market's change in illiquidity, $\Delta ILLIQ_{md}$ ($\Delta ILLIQ2_{md}$) as the daily cross-sectional average of $\Delta ILLIQ_{id}$ ($\Delta ILLIQ2_{id}$).[83]

For each quarter, we run the following time-series regression to estimate the sensitivity of bond's liquidity for each bond *i*:

$$\Delta ILLIQ_{id} = a + \beta_i \Delta ILLIQ_{md} + \varepsilon_{id} \qquad (6)$$

where β_i measures the sensitivity of changes in bond *i*'s liquidity to changes in aggregate liquidity. In order to increase the credibility of the estimation of liquidity β, we require that there are at least 20 observations in the regression (6). In a similar fashion, we construct β_2, which is based on $\Delta ILLIQ2_{id}$.

6.2.2. Regression model and Results

Since the municipal bond markets is highly illiquid, the number of observations that can be used for the test drops dramatically.[84] Table 4.8 reports the summary statistics. All continues variables are winsorized at the 1% and 99% level. All The average observation has liquidity β of 0.98 and liquidity β_2 0.81. Liquidity β ranges from -23 to 28, and liquidity β_2 ranges from -14 to 17.

We replace the dependent variables in regression (2) with our liquidity β variables:

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[83] We calculate the market liquidity based on the MSRB sample before its merge to Emaxx. This procedure makes sure that we correctly calculate the market-wide liquidity. There are about 6000 municipal bonds each day to calculate the market liquidity.

[84] The significant drop in the number of observations is due to the following reasons. First, many municipal bonds are not traded on consecutive days. Therefore, when we calculate the change in liquidity, many observations are missing. Second, we require 20 observations in each quarter to estimate the liquidity β.

$$Liq\ \beta_{it}\ = \alpha_0 + \alpha_i + \alpha_t + \beta Avg\ RBC_{it} + \gamma X_{it} + Rating_{it} + \varepsilon_{it} \tag{7}$$

Table 4.9 shows the results. We measure the financial health of bond investors using the bond-level average RBC ratio. The coefficients on *Avg RBC* are significant and negative in columns 1 and 2, which support our hypothesis that investors' financial health affect liquidity premium through the liquidity premium channel. Also, the coefficients almost remain significant and negative for alternative measures of financial health: *Avg RBC*2, *Avg RBC*3 and *Avg RBC*4.

7. Conclusion

In this paper we study the relationship between investors' financial health and the municipal bond liquidity spreads. Using P&C insurance companies as the representative investors, we find that increased investor finical health can causally reduce the liquidity spreads of municipal bonds, which supports that prior theoretical work's prediction that assets pricing depends on investor's financial health status (Brunnermeier and Pedersen, 2009; He and Krishnamurthy, 2013). We further investigate the channel through which investors' financial health affect liquidity spreads. We find that the higher ownership of finically weak insurers is related to higher liquidity risk Beta, which suggests that other investors will require a higher risk premium for the bond held by investors of weak finical health.

The results in our paper imply that fostering a group of investors of strong financial conditions is important for the development of municipal bond markets. It also lends support to the government aid to financial intermediaries during crisis. As shown by He and Krishnamurthy (2013), the direct capital infusion to financial intermediaries help to decrease the risk premium in the asset markets and stabilize the markets. Our paper is also related to the discussion on whether insurance industry can cause systemic risk. The results support Cummins and Weiss (2014)'s argument that insurers have a spillover effect on other markets through the asset side (i.e., their investment holdings). We suggest this potential risk is not only restricted to the period of financial crisis, but also normal times, because P&C insurers are subject to catastrophe risk such as hurricanes, earthquakes and other natural disasters.

Reference

Acharya, V.V., Mora, N., 2015. A crisis of banks as liquidity providers. The Journal of Finance 70, 1-43

Acharya, V.V., Pedersen, L.H., 2005. Asset pricing with liquidity risk. Journal of Financial Economics 77, 375-410

Amihud, Y., 2002. Illiquidity and stock returns: Cross-section and time-series effects. Journal of Financial Markets 5, 31-56

Ang, A., Bhansali, V., Xing, Y., 2010. Taxes on tax-exempt bonds. The Journal of Finance 65, 565-601

Baba, N., Packer, F., 2009. From turmoil to crisis: Dislocations in the fx swap market before and after the failure of lehman brothers. Journal of International Money and Finance 28, 1350-1374

Baranoff, E.G., Sager, T.W., 2002. The relations among asset risk, product risk, and capital in the life insurance industry. Journal of Banking and Finance 26, 1181-1197

Brunnermeier, M.K., Pedersen, L.H., 2009. Market liquidity and funding liquidity. Review of Financial Studies 22, 2201-2238

Butler, A.W., Fauver, L., Mortal, S., 2009. Corruption, political connections, and municipal finance. Review of Financial Studies 22, 2873-2905

Cella, C., Ellul, A., Giannetti, M., 2013. Investors' horizons and the amplification of market shocks. Review of Financial Studies 26, 1607-1648

Chen, R., Wong, K.A., 2004. The determinants of financial health of asian insurance companies. Journal of Risk and Insurance 71, 469-499

Cheng, J., Weiss, M.A., 2012. The role of rbc, hurricane exposure, bond portfolio duration, and macroeconomic and industry-wide factors in property-liability insolvency prediction. Journal of Risk and Insurance 79, 723-750

Cheng, J., Weiss, M.A., 2013. Risk-based capital and firm risk taking in property-liability insurance. Geneva Papers on Risk and Insurance-Issues and Practice 38, 274-307

Cummins, J.D., Sommer, D.W., 1996. Capital and risk in property-liability insurance markets. Journal of Banking and Finance 20, 1069-1092

Cummins, J.D., Weiss, M.A., 2014. Systemic risk and the u.S. Insurance sector. Journal of Risk and Insurance 81, 489-528

Dick-Nielsen, J., Feldhütter, P., Lando, D., 2012. Corporate bond liquidity before and after the onset of the subprime crisis. Journal of Financial Economics 103, 471-492

Ericsson, J., Renault, O., 2006. Liquidity and credit risk. The Journal of Finance 61, 2219-2250

Feldhuetter, P., 2012. The same bond at different prices: Identifying search frictions and selling pressures. Review of Financial Studies 25, 1155-1206

Friewald, N., Jankowitsch, R., Subrahmanyam, M.G., 2012. Illiquidity or credit deterioration: A study of liquidity in the us corporate bond market during financial crises. Journal of Financial Economics 105, 18-36

Froot, K.A., O'Connell, P.G.J., 2008. On the pricing of intermediated risks: Theory and application to catastrophe reinsurance. Journal of Banking and Finance 32, 69-85

Gabaix, X., Krishnamurthy, A., Vigneron, O., 2007. Limits of arbitrage: Theory and evidence from the mortgage-backed securities market. Journal of Finance 62, 557-595

Gao, P., Lee, C., Murphy, D., Forthcoming. Municipal borrowing costs and state policies for distress municipalitie. Journal of Financial Economics

Hameed, A., Kang, W., Viswanathan, S., 2010. Stock market declines and liquidity. Journal of Finance 65, 257-293

He, Z., Krishnamurthy, A., 2013. Intermediary asset pricing. American Economic Review 103, 732-770

Hong, H., Kacperczyk, M., 2010. Competition and bias. The Quarterly Journal of Economics 125, 1683-1725

Kamara, A., Lou, X., Sadka, R., 2008. The divergence of liquidity commonality in the cross-section of stocks. Journal of Financial Economics 89, 444-466

Longstaff, F.A., 2011. Municipal debt and marginal tax rates: Is there a tax premium in asset prices? The Journal of Finance 66, 721-751

Longstaff, F.A., Mithal, S., Neis, E., 2005. Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market. The Journal of Finance 60, 2213-2253

Manconi, A., Massa, M., Zhang, L., 2015. Bondholder concentration and credit risk: Evidence from a natural experiment. Review of Finance 20, 127-159

Massa, M., Yasuda, A., Zhang, L., 2013. Supply uncertainty of the bond investor base and the leverage of the firm. Journal of Financial Economics 110, 185-214

Mitchell, M., Pedersen, L.H., Pulvino, T., 2007. Slow moving capital. American Economic Review 97, 215-220

NAIC, 2013. Update on municipal bonds held by the u.S. Insurance industry. NAIC's Capital Markets Bureau, National Association of Insurance Commissioners

NAIC, 2014. Year-end 2013 insurance industry investment portfolio asset mixes. NAIC's Capital Markets Bureau, National Association of Insurance Commissioners

Novy-Marx, R., Rauh, J.D., 2012. Fiscal imbalances and borrowing costs: Evidence from state investment losses. American Economic Journal: Economic Policy 4, 182-213

Roll, R., 1984. A simple implicit measure of the effective bid-ask spread in an efficient market. Journal of Finance 39, 1127-1139

Schwert, M., 2017. Municipal bond liquidity and default risk. Journal of Finance 72, 1683-1722

SEC, 2012. Report on the municipal securities market. U.S. Securities and Exchange Commission

Shiu, Y.-M., 2011. Reinsurance and capital structure: Evidence from the united kingdom non-life insurance industry. Journal of Risk and Insurance 78, 475-494

Siriwardane, E., 2016. Concentrated capital losses and the pricing of corporate credit risk. In: Harvard Business School Finance Working Paper. Harvard Business School

Wang, J., Wu, C., Zhang, F.X., 2008. Liquidity, default, taxes, and yields on municipal bonds. Journal of Banking and Finance 32, 1133-1149

Appendix 4.1. Variable Definition

Bond Characteristics

Bond Yield: The quarter-end yield is calculated as the average yield for all trades on the last day in the quarter where the bond traded. If a bond did not trade during the last month of the quarter, it is excluded from that quarter.

Tax-adjusted yield: Bond Yield adjusted for the top statutory state and federal income tax rate.

Tax-adjusted spread: *Tax-adjusted yield* minus the yield of the same duration US treasury on the same day as the yield is measured.

LiqSpread: The bond's liquidity spread.

DftSpread: The bond's default spread. The sum of the bond's liquidity spread and default spread is the tax-adjusted yield spread, which is equal to the difference between the municipal bond yield and the same duration US treasury yield.

PCShare: The share of outstanding par value held by all P&C insurance companies.

LnSize: Natural logarithm of the bond's par value outstanding. Par value outstanding is in $ thousands.

LnMaturity: Natural logarithm of the bond's years to maturity.

Callable: A dummy variable. It equals to one if the bond is callable.

EnCredit: A dummy variable. It equals to one if the bond has any credit enhancement, such as bond insurance, letters of credit and so on.

Rating: Rating dummies are from Moody's ratings.

Liquidity measures

The construction of following liquidity measures is following the work of Schwert (2017).

Amihud Measure: The daily Amihud (2002) measure is defined as

$$Amihud_{it} = \frac{1}{N_t}\sum_{j=1}^{N_t}\frac{\left|\frac{P_j - P_{j-1}}{P_{j-1}}\right|}{Q_j}$$

where N_t is the number of returns on day t, P_j is the price of the bond at trade *j*, and Q_j is the par value of trade *j*. We require at least two transactions on a given day to estimate the Amihud measure. Quarterly estimates of the Amihud measure are obtained by taking the median of the daily estimates in a quarter.

Amihud Risk: The standard deviation of daily Amihud Measure in a quarter.

Imputed Roundtrip Cost (IRC): Feldhuetter (2012) suggests that if two or three trades occur in a given bond with the same trade size on the same day, this is called an imputed round-trip trade, the cost of which is given by:

$$IRC_{it} = (P_{max} - P_{min}) / P_{min}$$

where P_{max} is the highest price and P_{min} is the lowest price in the imputed round-trip trade. Higher values of the imputed round-trip cost imply higher transaction costs. Quarterly estimates of the imputed round-trip cost are obtained by taking the mean of the daily estimates in a quarter.

IRC Risk: The standard deviation of daily IRC in a quarter.

Price Dispersion: The daily price dispersion measure (Friewald *et al.*, 2012) is defined as

$$Dispersion_{it} = \sqrt{\frac{1}{\sum_{j=1}^{N_t} Q_j} \sum_{j=1}^{N_t} (P_j - M_t)^2 Q_j}$$

where N_t is the number of trades on day t, P_j is the price of the bond at trade j, Q_j is the par value of trade j, and M_t is the volume-weighted average price of the bond. Quarterly estimates of the price dispersion measure are obtained by taking the mean of the daily estimates in a quarter.

Roll Measure: The daily Roll measure (Roll, 1984) is defined as

$$Roll_{it} = 2\sqrt{-Cov(\Delta P_j, \Delta P_{j-1})}$$

where P_j is the price at trade j and the measure is set to zero when the co-variance between successive price movements is positive. We estimate the Roll measure on each day there is at least one trade, using a trailing 30-day window. We discard estimates for which at least four trades do not occur in the window. Quarterly estimates of the Roll measure are obtained by taking the median of the daily estimates in a quarter.

Liquidity Commonality measures:

Liq β: we define $\Delta ILLIQ_{id}$, the change in bond's liquidity, as $\Delta ILLIQ_{id} = Amihud_{id} - Amihud_{id-1}$. We define the market's change in illiquidity, $\Delta ILLIQ_{md}$ as the daily cross-sectional average of $\Delta ILLIQ_{id}$. Each quarter, we run the following time-series regression for each bond i:

$$\Delta ILLIQ_{id} = a + \beta_i \Delta ILLIQ_{md} + \varepsilon_{id}$$ and β_i is the Liq β.

Liq β2: we define $\Delta ILLIQ_{id}$, the change in bond's liquidity, as $\Delta ILLIQ2_{id} = \log(Amihud_{id}/Amihud_{id-1})$. We define the market's change in illiquidity, $\Delta ILLIQ2_{md}$ as the daily cross-sectional average of $\Delta ILLIQ2_{id}$. Each quarter, we run the following time-series regression for each bond i:

$$\Delta ILLIQ2_{id} = a + \beta2_i \Delta ILLIQ2_{md} + \varepsilon_{id}$$ and $\beta2_i$ is the Liq β2.

Treatment variables:

DPW Exposure: The insurer level hurricane exposure is calculated as

$$DPW\ Exposure_i = \frac{\sum_s\ DPW\ in\ homeowner\ line_{is,2012}}{DPW_{i,2012}}, s \in\ States\ affected\ by\ Sandy$$

Avg DPW Sandy: The bond-level hurricane exposure is defined as

$Avg\ DPW\ Sandy_i = \sum_{j \in S_{it}} w_{jit} DPW_i$ where $w_{jit} = \frac{Par\ amount_{jt}}{\sum_{j \in S_{it}} Par\ amount_{jt}}$ and t= the third quarter of year 2012

i indicates bond, j indicate insurer and *s* indicates state

Treat: A dummy variable. It equals one if *Avg DPW Sandy* is positive , and zero otherwise.

Financial Health Measures

Avg RBC: The average of current RBC ratio weighted by the current par value held by each P&C insurer.

Avg Lev: The average of current leverage ratio weighted by the current par value held by each P&C insurer. Leverage ratio is the liability-to-surplus ratio.

Avg Cash to Assets: The average of current operation cash to assets ratio weighted by the current par value held by each P&C insurer.

Avg Cash to Equity: The average of current operation cash to equity ratio weighted by the current par value held by each P&C insurer.

Avg RBC2: The average of lagged RBC ratio weighted by the current par value held by each P&C insurer.

Avg Lev2: The average of lagged leverage ratio weighted by the current par value held by each P&C insurer. Leverage ratio is the liability-to-surplus ratio.

Avg Cash to Assets2: The average of lagged operation cash to assets ratio weighted by the current par value held by each P&C insurer.

Avg Cash to Equity2: The average of lagged operation cash to equity ratio weighted by the current par value held by each P&C insurer.

Avg RBC3: The average of current RBC ratio weighted by the lagged par value held by each P&C insurer.

Avg Lev3: The average of current leverage ratio weighted by the lagged par value held by each P&C insurer. Leverage ratio is the liability-to-surplus ratio.

Avg Cash to Assets3: The average of current operation cash to assets ratio weighted by the current par value held by each P&C insurer.

Avg Cash to Equity3: The average of current operation cash to equity ratio weighted by the current par value held by each P&C insurer.

Avg RBC4: The average of lagged RBC ratio weighted by the lagged par value held by each P&C insurer.

Avg Lev4: The average of lagged leverage ratio weighted by the lagged par value held by each P&C insurer. Leverage ratio is the liability-to-surplus ratio.

Avg Cash to Assets4: The average of lagged operation cash to assets ratio weighted by the current par value held by each P&C insurer.

Avg Cash to Equity4: The average of lagged operation cash to equity ratio weighted by the current par value held by each P&C insurer.

Appendix 4.2: Top municipal bond investors' holdings

	2008		2009		2010		2011		2012	
	$Bil	Share	$Bil	Share	$Bil	Share	$Bil	Share	$Bil	Share
Household retail investors	1,722.0	48.96%	1,829.1	49.81%	1,873.3	49.67%	1,807.7	48.60%	1,656.5	44.60%
Mutual funds	389.4	11.07%	478.8	13.04%	525.5	13.93%	541.2	14.55%	627.4	16.89%
P&C insurers	381.9	10.86%	369.4	10.06%	348.3	9.23%	331.0	8.90%	327.6	8.82%
US-chartered depository institu	221.9	6.31%	224.3	6.11%	254.6	6.75%	297.3	7.99%	363.1	9.78%
Money market Mutual funds	509.5	14.49%	440.1	11.98%	386.7	10.25%	357.3	9.61%	336.7	9.06%
Life insurers	47.1	1.34%	73.1	1.99%	112.3	2.98%	121.6	3.27%	131.2	3.53%
Closed-end funds	77.9	2.21%	81.2	2.21%	81.6	2.16%	83.1	2.23%	86.3	2.32%
Remainder	167.6	4.77%	176.5	4.81%	189.5	5.02%	180.1	4.84%	185.7	5.00%
Total	3,517.3	100.00%	3,672.5	100.00%	3,771.8	100.00%	3,719.3	100.00%	3,714.5	100.00%

Source: Capital Markets Special Reports, Update on Municipal Bonds Held by the U.S. Insurance Industry, NAIC (2013)

Appendix 4.3:

The sample consists of bond-quarter observations during the period ±4 quarters around Hurricane Sandy (Q4 2012), i,e., the period from Q4 2011 to Q4 2013. We then restrict the sample to all municipal bonds held by any P&C insurance company at the end of third quarter of year 2012, the quarter before the Hurricane sandy. The dependent variable is liquidity spreads. *Treat* is as dummy variable. *Treat* equals to one if the bond is held by any P&C insurance companies who write business in Sandy-affected states in year 2012, otherwise it is zero. We further partition the treated group into two groups based on whether they are sold by affected insurers or not. *G1Treat* are the treated bonds sold by the affected insurers during the hurricane shock quarter and the following quarter. *G2Treat* are the treated bonds not sold by the affected insurers during the hurricane shock quarter or the following quarter. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors double clustered by bond and quarter are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The variable description is in Appendix 4.1.

	(1)	(2)
Dependent Variables	LiqSpread	LiqSpread
Treated Group	G1: Bonds sold by affected insurers	G2: Bonds not sold by affected insurers
Post*G1 Treat	0.0290***	
	(0.0083)	
Post*G2 Treat		0.0332*
		(0.0148)
PCShare	0.0223	0.0692
	(0.0481)	(0.0576)
LnSize	-0.0998	-0.0026
	(0.0882)	(0.0818)
LnMaturity	0.1963*	0.1973
	(0.1025)	(0.1065)
Callable	-0.0739	-0.0130
	(0.1842)	(0.1810)
EnCredit	-0.0005	-0.0939
	(0.0546)	(0.0698)
Observations	67,077	39,444
R-squared	0.6917	0.6951
Cusip FE	Yes	Yes
Quarter FE	Yes	Yes
Rating FE	Yes	Yes
SE cluster	Cusip & Qtr	Cusip & Qtr

Appendix 4.4:

The sample consists of bond-quarter observations during the period ±4 quarters around Hurricane Sandy (Q4 2012), i,e., the period from Q4 2011 to Q4 2013. We then restrict the sample to all municipal bonds held by any P&C insurance company at the end of third quarter of year 2012, the quarter before the Hurricane sandy. The dependent variable are four alternative liquidity measures. *Treat* is as dummy variable. *Treat* equals to one if the bond is held by any P&C insurance companies who write business in Sandy-affected states in year 2012, otherwise it is zero. We further partition the treated group into two groups based on whether they are sold by affected insurers or not. *G1Treat* are the treated bonds sold by the affected insurers during the hurricane shock quarter and the following quarter. *G2Treat* are the treated bonds not sold by the affected insurers during the hurricane shock quarter or the following quarter. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors double clustered by bond and quarter are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The variable description is in Appendix 4.1.

	(1)	(2)	(3)	(4)
Dependent Variables	Amihud Measure	IRC	Price Dispersion	Roll Measure
Treated Group		G1: Bonds sold by affected insurers		
Post*G1 Treat	0.0038	0.0002**	0.0045*	0.0261*
	(0.0044)	(0.0000)	(0.0024)	(0.0139)
PCShare	0.0475	0.0001	-0.0209	0.2282
	(0.0393)	(0.0005)	(0.0190)	(0.1282)
LnSize	-0.2091**	-0.0003	0.0010	-0.0157
	(0.0810)	(0.0007)	(0.0218)	(0.1154)
LnMaturity	0.0046	0.0000	-0.0055	0.1639***
	(0.0157)	(0.0001)	(0.0061)	(0.0279)
Callable	-0.1230	-0.0006	0.0229	-0.0050
	(0.1543)	(0.0010)	(0.0611)	(0.2961)
EnCredit	0.0077	0.0002	0.0365	-0.0044
	(0.0507)	(0.0004)	(0.0225)	(0.0907)
Observations	68,958	68,958	68,958	68,958
R-squared	0.4982	0.6056	0.6292	0.5250
Cusip FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes
Rating FE	AAA-Rated	AAA-Rated	AAA-Rated	AAA-Rated
SE cluster	Cusip & Qtr	Cusip & Qtr	Cusip & Qtr	Cusip & Qtr

Appendix 4.3, Continued

	(5)	(6)	(7)	(8)
Dependent Variables	Amihud Measure	IRC	Price Dispersion	Roll Measure
Treated Group	G2: Bonds not sold by affected insurers			
Post*G2 Treat	0.0091	-0.0003**	0.0055	0.0886*
	(0.0131)	(0.0001)	(0.0077)	(0.0387)
PCShare	0.0417	0.0004	0.0345	0.0066
	(0.0457)	(0.0005)	(0.0244)	(0.1395)
LnSize	-0.1386*	0.0004	0.0209	0.0317
	(0.0713)	(0.0007)	(0.0195)	(0.0981)
LnMaturity	0.0068	0.0000	-0.0071	0.1679***
	(0.0150)	(0.0002)	(0.0053)	(0.0328)
Callable	-0.1185	-0.0005	0.0205	0.2667*
	(0.1521)	(0.0010)	(0.0580)	(0.1224)
EnCredit	0.0060	0.0004	0.0136	0.0217
	(0.0663)	(0.0005)	(0.0304)	(0.1725)
Observations	40,709	40,709	40,709	40,709
R-squared	0.5043	0.6122	0.6318	0.5292
Cusip FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes
Rating FE	AAA-Rated	AAA-Rated	AAA-Rated	AAA-Rated
SE cluster	Cusip & Qtr	Cusip & Qtr	Cusip & Qtr	Cusip & Qtr

Table 4.1. Descriptive statistics

The sample consists of 220,655 bond-quarter observations, from the Q2 2006 to Q4 2015, with 35,223 unique bonds. All continuous variables are winsorized at the 1% and 99% levels. The variable description is in Appendix 4.1.

	N	Mean	Median	StdDev	Min	Max
Bond Characteristics						
Yield (%)	220,665	3.2016	3.3400	1.4505	0.3000	6.6500
Tax-adjusted Yield (%)	220,665	5.3321	5.5540	2.4187	0.4959	11.1429
Tax-adjusted Spread (%)	220,665	2.4112	2.1326	1.6449	-1.6408	7.8978
LiqSpread (%)	220,665	0.8341	0.6952	0.6214	0.0328	2.9023
DftSpread (%)	220,665	1.5771	1.4194	1.4486	-2.4208	6.4406
PCShare	220,665	0.2012	0.1392	0.1958	0.0011	0.8410
LnSize	220,665	9.9343	9.9050	1.0901	7.2896	12.6115
LnMaturity	220,665	2.1070	2.2779	0.8972	-0.7940	3.3993
Callable	220,665	0.3789	0	0.4851	0	1
EnCredit	220,665	0.4155	0	0.4928	0	1
Rating						
AAA-Rated	220,665	0.0017	0	0.0415	0	1
AA-Rated	220,665	0.1895	0	0.3919	0	1
A-Rated	220,665	0.5165	1	0.4997	0	1
BBB-Rated	220,665	0.2199	0	0.4142	0	1
BB and Below	220,665	0.0653	0	0.2471	0	1
No rate	220,665	0.0070	0	0.0833	0	1
Liquidity measures						
Amihud Measure (Per $million)	220,665	0.2438	0.1192	0.3720	0.0000	3.6924
Amihud Risk	220,665	0.4291	0.2497	0.5144	0.0000	2.7932
Imputed Roundtrip Cost	220,665	0.0068	0.0057	0.0051	0.0000	0.0302
IRC Risk	220,665	0.0057	0.0052	0.0040	0.0000	0.0188
Price Dispersion	220,665	0.2918	0.2449	0.2182	0.0000	1.3548
Roll Measure	220,665	1.4547	1.3042	1.0628	0.0000	5.5059
Financial Health Measures						
Avg RBC	220,665	13.3235	8.4648	19.6536	2.3356	154.5101
Avg Lev	220,665	1.7662	1.6186	1.0288	0.0922	6.5339
Avg Cash to Assets	220,665	0.0100	0.0100	0.0231	-0.0781	0.0972
Avg Cash to Equity	220,665	0.0280	0.0250	0.0761	-0.2768	0.3537
Avg RBC2	221,169	13.0132	8.3213	19.2504	2.4601	153.1545
Avg Lev2	221,169	1.7729	1.6281	1.0240	0.0975	6.4902
Avg Cash to Assets2	221,169	0.0105	0.0103	0.0233	-0.0763	0.1000
Avg Cash to Equity2	221,169	0.0297	0.0257	0.0758	-0.2615	0.3555
Avg RBC3	206,645	14.1092	8.5280	22.9247	2.4116	180.3017
Avg Lev3	206,645	1.7768	1.6273	1.0270	0.0986	6.5068
Avg Cash to Assets3	206,645	0.0093	0.0098	0.0230	-0.0826	0.0921
Avg Cash to Equity3	206,645	0.0252	0.0244	0.0758	-0.3055	0.3209
Avg RBC4	206,941	13.1068	8.3889	19.0473	2.4208	150.1530
Avg Lev4	206,941	1.7904	1.6367	1.0407	0.1058	6.7091
Avg Cash to Assets4	206,941	0.0101	0.0101	0.0231	-0.0776	0.0972
Avg Cash to Equity4	206,941	0.0284	0.0253	0.0765	-0.2790	0.3524

Table 4.2. Investors' Financial Health and Municipal Bonds' liquidity spreads

The dependent variables in columns 1-4 are liquidity spreads, and the dependent variables in columns 5-8 are default spreads. *Avg RBC* is the average RBC ratio across the bond's P&C insurers weighted by their holdings of this bond. *Avg Lev* is the average leverage ratio across the bond's P&C insurers weighted by their holdings of this bond. *Avg Cash to Assets* is the average operation cash flow to assets ratio across the bond's P&C insurers weighted by their holdings of this bond. *Avg Cash to Equity* is the average operation cash flow to equity ratio across the bond's P&C insurers weighted by their holdings of this bond. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors double clustered by bond and quarter are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The variable description is in Appendix 4.1.

Panel A.

In panel A, the financial health measures *Avg RBC, Avg Lev, Avg Cash to Assets* and *Avg Cash-to-Equity* are calculated as the average of current financial ratio weighted by the current par value held by each P&C insurer. The sample consists of 220,665 bond-quarter observations from the Q2 2006 to Q4 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variables	LiqSpread				DftSpread			
Financial Health Measures								
Avg RBC	-0.0003**				0.0001			
	(0.0001)				(0.0003)			
Avg Lev		0.0093***				0.0206***		
		(0.0033)				(0.0070)		
Avg Cash to Assets			-0.2339***				0.1178	
			(0.0650)				(0.1152)	
Avg Cash to Equity				-0.0747***				0.0358
				(0.0192)				(0.0357)
Bond Characteristics								
PCShare	0.1297***	0.1212***	0.1302***	0.1303***	0.3912***	0.3667***	0.3911***	0.3911***
	(0.0190)	(0.0188)	(0.0189)	(0.0190)	(0.0469)	(0.0458)	(0.0473)	(0.0473)
LnSize	-0.0492	-0.0492	-0.0496	-0.0495	-0.4229***	-0.4227***	-0.4228***	-0.4228***
	(0.0306)	(0.0306)	(0.0305)	(0.0305)	(0.0802)	(0.0802)	(0.0802)	(0.0802)
LnMaturity	0.2302***	0.2308***	0.2308***	0.2308***	-0.0594	-0.0585	-0.0597	-0.0597
	(0.0396)	(0.0396)	(0.0396)	(0.0395)	(0.0478)	(0.0479)	(0.0479)	(0.0479)
Callable	-0.0220	-0.0221	-0.0220	-0.0220	-0.3562***	-0.3565***	-0.3562***	-0.3562***
	(0.0293)	(0.0292)	(0.0292)	(0.0292)	(0.0678)	(0.0678)	(0.0679)	(0.0679)
EnCredit	-0.0348**	-0.0347**	-0.0352**	-0.0351**	-0.1540***	-0.1536***	-0.1539***	-0.1539***
	(0.0134)	(0.0134)	(0.0134)	(0.0134)	(0.0314)	(0.0313)	(0.0313)	(0.0314)
AAA-Rated	-0.1687	-0.1681	-0.1691	-0.1695	-2.1453***	-2.1425***	-2.1452***	-2.1450***
	(0.1142)	(0.1141)	(0.1144)	(0.1144)	(0.3506)	(0.3513)	(0.3507)	(0.3508)
AA-Rated	-0.1458	-0.1451	-0.1463	-0.1468	-2.0380***	-2.0349***	-2.0378***	-2.0376***
	(0.1134)	(0.1134)	(0.1136)	(0.1137)	(0.3543)	(0.3550)	(0.3544)	(0.3545)
A-Rated	-0.0912	-0.0907	-0.0917	-0.0921	-1.7255***	-1.7226***	-1.7253***	-1.7251***
	(0.1127)	(0.1127)	(0.1129)	(0.1130)	(0.3520)	(0.3527)	(0.3521)	(0.3522)
BBB-Rated	-0.0278	-0.0273	-0.0282	-0.0286	-0.9216**	-0.9187**	-0.9215**	-0.9213**
	(0.1120)	(0.1120)	(0.1122)	(0.1123)	(0.3504)	(0.3511)	(0.3505)	(0.3506)
BB and Below	-0.0096	-0.0083	-0.0097	-0.0103	0.0224	0.0263	0.0224	0.0227
	(0.1205)	(0.1204)	(0.1207)	(0.1207)	(0.3395)	(0.3402)	(0.3394)	(0.3396)
Observations	220,665	220,665	220,665	220,665	220,665	220,665	220,665	220,665
R-squared	0.6812	0.6813	0.6813	0.6813	0.6599	0.6599	0.6599	0.6599
Cusip FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr d &	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr

Panel B

In panel B, the financial health measures *Avg RBC2*, *Avg Lev2*, *Avg Cash to Assets2* and *Avg Cash-to-Equity2* are calculated as the average of lagged financial ratio weighted by the current par value held by each P&C insurer. The sample consists of 221,169 bond-quarter observations from the Q2 2006 to Q4 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variables	LiqSpread				DftSpread			
Financial Health Measures								
Avg RBC2	-0.0003**				0.0000			
	(0.0001)				(0.0003)			
Avg Lev2		0.0093***				0.0296***		
		(0.0026)				(0.0064)		
Avg Cash to Assets2			-0.1233*				0.1776	
			(0.0633)				(0.1217)	
Avg Cash to Equity2				-0.0388*				0.0755*
				(0.0200)				(0.0392)
Bond Characteristics								
PCShare	0.1309***	0.1232***	0.1328***	0.1329***	0.3902***	0.3569***	0.3911***	0.3912***
	(0.0190)	(0.0183)	(0.0191)	(0.0191)	(0.0469)	(0.0474)	(0.0469)	(0.0469)
LnSize	-0.0489	-0.0489	-0.0491	-0.0490	-0.4231***	-0.4224***	-0.4230***	-0.4231***
	(0.0306)	(0.0305)	(0.0306)	(0.0307)	(0.0804)	(0.0804)	(0.0804)	(0.0804)
LnMaturity	0.2302***	0.2309***	0.2306***	0.2306***	-0.0605	-0.0591	-0.0608	-0.0609
	(0.0396)	(0.0395)	(0.0396)	(0.0396)	(0.0481)	(0.0481)	(0.0482)	(0.0482)
Callable	-0.0220	-0.0220	-0.0220	-0.0220	-0.3559***	-0.3562***	-0.3559***	-0.3559***
	(0.0292)	(0.0292)	(0.0291)	(0.0292)	(0.0679)	(0.0679)	(0.0679)	(0.0680)
EnCredit	-0.0346**	-0.0344**	-0.0347**	-0.0346**	-0.1540***	-0.1535***	-0.1538***	-0.1538***
	(0.0134)	(0.0134)	(0.0135)	(0.0135)	(0.0313)	(0.0312)	(0.0313)	(0.0313)
AAA-Rated	-0.1694	-0.1686	-0.1694	-0.1693	-2.1460***	-2.1440***	-2.1459***	-2.1459***
	(0.1144)	(0.1145)	(0.1143)	(0.1143)	(0.3505)	(0.3502)	(0.3505)	(0.3505)
AA-Rated	-0.1465	-0.1457	-0.1465	-0.1465	-2.0387***	-2.0362***	-2.0386***	-2.0386***
	(0.1136)	(0.1137)	(0.1136)	(0.1135)	(0.3542)	(0.3540)	(0.3542)	(0.3542)
A-Rated	-0.0920	-0.0913	-0.0921	-0.0921	-1.7250***	-1.7226***	-1.7249***	-1.7249***
	(0.1130)	(0.1130)	(0.1129)	(0.1128)	(0.3517)	(0.3515)	(0.3517)	(0.3517)
BBB-Rated	-0.0281	-0.0273	-0.0281	-0.0281	-0.9216**	-0.9194**	-0.9216**	-0.9216**
	(0.1122)	(0.1123)	(0.1122)	(0.1121)	(0.3503)	(0.3501)	(0.3503)	(0.3503)
BB and Below	-0.0103	-0.0088	-0.0102	-0.0103	0.0237	0.0280	0.0237	0.0239
	(0.1205)	(0.1206)	(0.1204)	(0.1203)	(0.3393)	(0.3390)	(0.3393)	(0.3392)
Observations	221,169	221,169	221,169	221,169	221,169	221,169	221,169	221,169
R-squared	0.6815	0.6816	0.6815	0.6815	0.6599	0.6600	0.6599	0.6599
Cusip FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr d &	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr

Panel C

In panel C, the financial health measures *Avg RBC3*, *Avg Lev3*, *Avg Cash to Assets3* and *Avg Cash-to-Equity3* are calculated as the current financial ratio weighted by the lagged par value held by each P&C insurer. The sample consists of 206,645 bond-quarter observations from the Q2 2006 to Q4 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variables	LiqSpread				DftSpread			
Financial Health Measures								
Avg RBC3	-0.0004***				-0.0001			
	(0.0001)				(0.0002)			
Avg Lev3		0.0055*				0.0261***		
		(0.0029)				(0.0066)		
Avg Cash to Assets3			-0.1675**				0.0840	
			(0.0695)				(0.1218)	
Avg Cash to Equity3				-0.0525**				0.0230
				(0.0207)				(0.0399)
Bond Characteristics								
PCShare	0.1033***	0.1008***	0.1050***	0.1050***	0.4161***	0.3936***	0.4168***	0.4167***
	(0.0225)	(0.0228)	(0.0223)	(0.0224)	(0.0496)	(0.0486)	(0.0498)	(0.0497)
LnSize	-0.0580*	-0.0578*	-0.0580*	-0.0581*	-0.4274***	-0.4269***	-0.4273***	-0.4273***
	(0.0322)	(0.0321)	(0.0321)	(0.0321)	(0.0846)	(0.0845)	(0.0846)	(0.0845)
LnMaturity	0.2137***	0.2142***	0.2142***	0.2142***	-0.0594	-0.0584	-0.0595	-0.0594
	(0.0398)	(0.0397)	(0.0397)	(0.0397)	(0.0474)	(0.0473)	(0.0474)	(0.0474)
Callable	-0.0277	-0.0278	-0.0278	-0.0278	-0.3529***	-0.3530***	-0.3529***	-0.3529***
	(0.0291)	(0.0291)	(0.0291)	(0.0291)	(0.0689)	(0.0689)	(0.0689)	(0.0689)
EnCredit	-0.0330**	-0.0329**	-0.0332**	-0.0331**	-0.1570***	-0.1562***	-0.1569***	-0.1570***
	(0.0133)	(0.0133)	(0.0133)	(0.0133)	(0.0313)	(0.0312)	(0.0313)	(0.0313)
AAA-Rated	-0.1981*	-0.1980*	-0.1988*	-0.1991*	-2.2117***	-2.2066***	-2.2120***	-2.2118***
	(0.1059)	(0.1058)	(0.1059)	(0.1059)	(0.3668)	(0.3676)	(0.3668)	(0.3668)
AA-Rated	-0.1778	-0.1776	-0.1785	-0.1789*	-2.1054***	-2.1002***	-2.1056***	-2.1055***
	(0.1052)	(0.1052)	(0.1052)	(0.1053)	(0.3713)	(0.3721)	(0.3713)	(0.3713)
A-Rated	-0.1165	-0.1165	-0.1174	-0.1177	-1.7943***	-1.7894***	-1.7946***	-1.7944***
	(0.1048)	(0.1047)	(0.1048)	(0.1049)	(0.3683)	(0.3691)	(0.3683)	(0.3683)
BBB-Rated	-0.0528	-0.0528	-0.0536	-0.0539	-0.9924**	-0.9872**	-0.9927**	-0.9925**
	(0.1039)	(0.1038)	(0.1039)	(0.1039)	(0.3685)	(0.3693)	(0.3684)	(0.3685)
BB and Below	-0.0237	-0.0228	-0.0238	-0.0243	-0.0556	-0.0489	-0.0559	-0.0556
	(0.1115)	(0.1114)	(0.1115)	(0.1115)	(0.3584)	(0.3594)	(0.3583)	(0.3584)
Observations	206,645	206,645	206,645	206,645	206,645	206,645	206,645	206,645
R-squared	0.6868	0.6868	0.6868	0.6868	0.6545	0.6546	0.6545	0.6545
Cusip FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr

Panel D

In panel D, the financial health measures *Avg RBC4*, *Avg Lev4*, *Avg Cash to Assets4* and *Avg Cash-to-Equity4* are calculated as the lagged financial ratio weighted by the lagged par value held by each P&C insurer. The sample consists of 206,941 bond-quarter observations from the Q2 2006 to Q4 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variables	LiqSpread				DftSpread			
Financial Health Measures								
Avg RBC4	-0.0002*				-0.0002			
	(0.0001)				(0.0003)			
Avg Lev4		0.0052**				0.0352***		
		(0.0025)				(0.0062)		
Avg Cash to Assets4			-0.0813				0.1271	
			(0.0657)				(0.1225)	
Avg Cash to Equity4				-0.0250				0.0621
				(0.0208)				(0.0396)
Bond Characteristics								
PCShare	0.1050***	0.1014***	0.1058***	0.1059***	0.4166***	0.3863***	0.4180***	0.4180***
	(0.0225)	(0.0228)	(0.0225)	(0.0225)	(0.0495)	(0.0498)	(0.0498)	(0.0498)
LnSize	-0.0581*	-0.0580*	-0.0581*	-0.0581*	-0.4308***	-0.4296***	-0.4309***	-0.4309***
	(0.0323)	(0.0323)	(0.0324)	(0.0324)	(0.0848)	(0.0848)	(0.0848)	(0.0848)
LnMaturity	0.2141***	0.2145***	0.2144***	0.2144***	-0.0603	-0.0587	-0.0603	-0.0604
	(0.0397)	(0.0397)	(0.0398)	(0.0398)	(0.0477)	(0.0476)	(0.0477)	(0.0477)
Callable	-0.0277	-0.0277	-0.0277	-0.0277	-0.3533***	-0.3535***	-0.3532***	-0.3532***
	(0.0293)	(0.0293)	(0.0292)	(0.0292)	(0.0686)	(0.0686)	(0.0686)	(0.0686)
EnCredit	-0.0329**	-0.0328**	-0.0330**	-0.0330**	-0.1577***	-0.1566***	-0.1577***	-0.1576***
	(0.0134)	(0.0133)	(0.0134)	(0.0134)	(0.0312)	(0.0311)	(0.0312)	(0.0312)
AAA-Rated	-0.1981*	-0.1979*	-0.1987*	-0.1987*	-2.2100***	-2.2058***	-2.2104***	-2.2104***
	(0.1059)	(0.1062)	(0.1060)	(0.1060)	(0.3664)	(0.3663)	(0.3666)	(0.3666)
AA-Rated	-0.1777	-0.1775	-0.1783	-0.1783	-2.1052***	-2.1008***	-2.1056***	-2.1056***
	(0.1052)	(0.1055)	(0.1054)	(0.1053)	(0.3709)	(0.3708)	(0.3711)	(0.3711)
A-Rated	-0.1168	-0.1167	-0.1175	-0.1175	-1.7932***	-1.7892***	-1.7937***	-1.7936***
	(0.1048)	(0.1050)	(0.1049)	(0.1049)	(0.3678)	(0.3677)	(0.3681)	(0.3681)
BBB-Rated	-0.0537	-0.0536	-0.0543	-0.0543	-0.9918**	-0.9876**	-0.9923**	-0.9923**
	(0.1039)	(0.1042)	(0.1041)	(0.1040)	(0.3681)	(0.3679)	(0.3683)	(0.3683)
BB and Below	-0.0245	-0.0238	-0.0249	-0.0250	-0.0544	-0.0474	-0.0546	-0.0545
	(0.1115)	(0.1118)	(0.1116)	(0.1116)	(0.3582)	(0.3581)	(0.3583)	(0.3583)
Observations	206,941	206,941	206,941	206,941	206,941	206,941	206,941	206,941
R-squared	0.6867	0.6867	0.6867	0.6867	0.6543	0.6545	0.6544	0.6544
Cusip FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr

Table 4.3. Investors' Financial Health and Municipal Bonds' liquidity spreads during Lehman Crisis

The dependent variables are liquidity spreads. *Crisis Lehman* is a dummy variable which equal to one from period Q3 2008 to Q2 2009, and equal to zero otherwise. *Avg RBC* is the average RBC ratio across the bond's P&C insurers weighted by their holdings of this bond. *Avg Lev* is the average Leverage ratio across the bond's P&C insurers weighted by their holdings of this bond. *Avg Cash to Assets* is the average operation cash flow to assets ratio across the bond's P&C insurers weighted by their holdings of this bond. *Avg Cash to Equity* is the average operation cash flow to equity ratio across the bond's P&C insurers weighted by their holdings of this bond. All continuous variables are winsorized at the 1^{st} and 99^{th} percentiles. Robust standard errors double clustered by bond and quarter are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The variable description is in Appendix 4.1.

	(1)	(2)	(3)	(4)
Dependent Variables		LiqSpread		
Financial Health Measures				
Avg RBC*Crisis Lehman	-0.0002			
	(0.0002)			
Avg RBC	-0.0002**			
	(0.0001)			
Avg Lev*Crisis Lehman		0.0106**		
		(0.0050)		
Avg Lev		0.0066**		
		(0.0025)		
Avg Cash to Assets*Crisis Lehman			-0.3444**	
			(0.1556)	
Avg Cash to Assets			-0.1824**	
			(0.0736)	
Avg Cash to Equity*Crisis Lehman				-0.0920**
				(0.0437)
Avg Cash to Equity				-0.0580**
				(0.0218)
Bond Characteristics				
PCShare	0.1296***	0.1194***	0.1293***	0.1293***
	(0.0190)	(0.0190)	(0.0188)	(0.0188)
LnSize	-0.0493	-0.0498	-0.0496	-0.0496
	(0.0306)	(0.0305)	(0.0305)	(0.0305)
LnMaturity	0.2302***	0.2309***	0.2308***	0.2308***
	(0.0396)	(0.0395)	(0.0395)	(0.0395)
Callable	-0.0220	-0.0220	-0.0220	-0.0220
	(0.0293)	(0.0293)	(0.0292)	(0.0292)
EnCredit	-0.0348**	-0.0349**	-0.0351**	-0.0350**
	(0.0134)	(0.0134)	(0.0134)	(0.0133)
AAA-Rated	-0.1688	-0.1683	-0.1692	-0.1695
	(0.1142)	(0.1143)	(0.1143)	(0.1144)
AA-Rated	-0.1459	-0.1452	-0.1464	-0.1467
	(0.1134)	(0.1136)	(0.1136)	(0.1136)
A-Rated	-0.0913	-0.0907	-0.0918	-0.0921
	(0.1128)	(0.1129)	(0.1129)	(0.1129)
BBB-Rated	-0.0280	-0.0273	-0.0283	-0.0285
	(0.1121)	(0.1122)	(0.1121)	(0.1122)
BB and Below	-0.0096	-0.0082	-0.0099	-0.0104
	(0.1205)	(0.1206)	(0.1206)	(0.1207)
Observations	220,665	220,665	220,665	220,665
R-squared	0.6812	0.6813	0.6813	0.6813
Cusip FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes
SE cluster	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr

Table 4.4. Descriptive statistics for the test using Hurricane Sandy as an exogenous shock

The sample consists of 69,340 bond-quarter observations during the period ±4 quarters around Hurricane Sandy (Q4 2012), i,e., the period from Q4 2011 to Q3 2013. We then restrict the sample to all municipal bonds held by any P&C insurance company at the end of third quarter of year 2012, the quarter before the Hurricane sandy. One Bond held by any P&C insurance companies who write business in Sandy-affected states in year 2012 are categorized into treatment group, otherwise it is categorized into control group. The variable description is in Appendix 4.1.

	Control				Treat				
	N	Mean	Median	StdDev	N	Mean	Median	StdDev	Mean T test
LiqSpread (%)	37,181	0.8027	0.6642	0.6187	32,159	0.7732	0.6411	0.5847	0.030***
DftSpread (%)	37,181	1.2657	1.1386	1.4412	32,159	1.2927	1.1595	1.4329	-0.027**
PCShare	37,181	0.1354	0.0734	0.1588	32,159	0.2292	0.1818	0.1887	-0.094***
Avg DPW Sandy	37,181	0	0	0	32,159	0.0156	0.0050	0.0272	-0.016***
LnSize	37,181	9.7997	9.7779	1.0285	32,159	10.3280	10.2831	1.0642	-0.528***
LnMaturity	37,181	2.1028	2.2877	0.9028	32,159	2.1140	2.2703	0.9054	-0.011
Callable	37,181	0.6416	1	0.4795	32,159	0.6354	1	0.4813	0.006*
EnCredit	37,181	0.3436	0	0.4749	32,159	0.2930	0	0.4552	0.051***

Table 4.5. Investors' Financial Health and Bonds' liquidity spreads using Hurricane Sandy as an exogenous shock

The sample consists of 69,340 bond-quarter observations during the period ±4 quarters around Hurricane Sandy (Q4 2012), i,e., the period from Q4 2011 to Q4 2013. We then restrict the sample to all municipal bonds held by any P&C insurance company at the end of third quarter of year 2012, the quarter before the Hurricane sandy. The dependent variables in columns 1 and 3 are liquidity spreads, and the dependent variables in columns 2 and 4 are default spreads. In columns 1-2, *Treat* is as dummy variable. *Treat* equals to one if the bond is held by any P&C insurance companies who write business in Sandy-affected states in year 2012, otherwise it is zero. In columns 3-4, we use one continuous proxy *Avg DPW Sandy* for *Treat*. *Avg DPW Sandy* is the average hurricane exposure (*DPW Exposure*) across the bond's P&C insurers weighted by their holdings of this bond. *DPW Exposure* is an insurer level variable. It is defined as the proportion of direct premiums written of homeowner multiple peril line in Sandy affected states in the total direct premiums written. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors double clustered by bond and quarter are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The variable description is in Appendix 4.1.

	(1)	(2)	(3)	(4)
Dependent Variables	LiqSpread	DftSpread	LiqSpread	DftSpread
	Treat is dummy		Teart=Avg DPW Sandy	
Post*Treat	0.0290***	0.0301**	0.7017***	0.4506
	(0.0079)	(0.0128)	(0.1998)	(0.3274)
PCShare	0.0572	0.0705	0.0557	0.0691
	(0.0387)	(0.1134)	(0.0387)	(0.1137)
LnSize	-0.0552	-0.1765	-0.0549	-0.1760
	(0.0856)	(0.2976)	(0.0858)	(0.2974)
LnMaturity	0.1881	-0.1488	0.1880	-0.1488
	(0.1023)	(0.1502)	(0.1024)	(0.1503)
Callable	0.0276	0.4275	0.0302	0.4302
	(0.1685)	(0.6778)	(0.1687)	(0.6764)
EnCredit	-0.0121	-0.1425	-0.0128	-0.1430
	(0.0605)	(0.1841)	(0.0606)	(0.1841)
AA-Rated	0.0226	0.0288	0.0224	0.0287
	(0.0288)	(0.0515)	(0.0286)	(0.0516)
A-Rated	0.0660*	0.2134**	0.0654*	0.2129**
	(0.0349)	(0.0700)	(0.0348)	(0.0702)
BBB-Rated	0.0437	0.8990***	0.0432	0.8984***
	(0.0456)	(0.1453)	(0.0453)	(0.1455)
BB and Below	0.0258	1.5744***	0.0259	1.5746***
	(0.0743)	(0.4301)	(0.0742)	(0.4305)
Observations	69,340	69,340	69,340	69,340
R-squared	0.6925	0.6944	0.6925	0.6944
Cusip FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes
Rating Benchmark	AAA-Rated	AAA-Rated	AAA-Rated	AAA-Rated
SE cluster	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr

Table 4.6. Pre-treatment Trend

This table investigates the pre-treatment trends between the treated group and control group. The dependent variable in column 1 is the liquidity yield spread. The sample consists of 69,340 bond-quarter observations during the period ±4 quarters around Hurricane Sandy (Q4 2012), i,e., the period from Q4 2011 to Q4 2013. The dependent variable in column 2 is the default yield spread. *Treat* is as dummy variable. *Treat* equals to one if the bond is held by any P&C insurance companies who write business in Sandy-affected states in year 2012, otherwise it is zero. The indicator variables, Q1 2012–Q4 2013, flag corresponding quarters, respectively. Q4 2011 is the baseline quarter. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors double clustered by bond and quarter are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The variable description is in Appendix 4.1.

Dependent Variables	(1) LiqSpread	(2) DftSpread
Treat*Q4 2011	-0.0014	0.0314**
	(0.0070)	(0.0127)
Treat*Q1 2012	-0.0088	0.0320*
	(0.0075)	(0.0166)
Treat*Q2 2012	0.0098	0.0054
	(0.0083)	(0.0208)
Treat*Q3 2012	0.0290**	0.0474*
	(0.0092)	(0.0208)
Treat*Q4 2012	0.0249**	0.0097
	(0.0086)	(0.0220)
Treat*Q1 2013	0.0015	0.0440*
	(0.0090)	(0.0212)
Treat*Q2 2013	-0.0154	-0.0136
	(0.0093)	(0.0197)
Treat*Q3 2013	-0.0165	0.0267
	(0.0093)	(0.0202)
PCShare	0.0526	0.0687
	(0.0389)	(0.1147)
LnSize	-0.0549	-0.1770
	(0.0852)	(0.2971)
LnMaturity	0.1882	-0.1488
	(0.1023)	(0.1502)
Callable	0.0216	0.4233
	(0.1712)	(0.6800)
EnCredit	-0.0124	-0.1424
	(0.0608)	(0.1841)
AA-Rated	0.0222	0.0275
	(0.0289)	(0.0518)
A-Rated	0.0656*	0.2119**
	(0.0348)	(0.0706)
BBB-Rated	0.0436	0.8978***
	(0.0457)	(0.1461)
BB and Below	0.0247	1.5731***
	(0.0740)	(0.4306)
Observations	69,340	69,340
R-squared	0.6944	0.6944
Cusip FE	Yes	Yes
Quarter FE	Yes	Yes
Rating Benchmark	AAA-Rated	AAA-Rated
SE cluster	Bond & Qtr	Bond & Qtr

Table 4.7. Investors' Financial Health and Bonds' pure liquidity cost

The sample period is from Q2 2006 to Q4 2015. The dependent variables are alternative measures for pure liquidity cost. The dependent variables in columns 1, 5, 9 and 13 are Amihud measures. The dependent variables in columns 2,6,10 and 14 are Imputed roundtrip costs. The dependent variables in columns 3,7,11 and 15 are Price dispersion. The dependent variables in columns 4,8,12 and 16 are Roll measure. We have four alternative financial health measures: *Avg RBC*, *Avg RBC2 Avg RBC3* and *Avg RBC4. Avg RBC* is calculated as the current insurer RBC ratio weighted by the current par value held by each P&C insurer. *Avg RBC2* is calculated as the lagged insurer RBC ratio weighted by the current par value held by each P&C insurer. *Avg RBC3* is calculated as the current insurer RBC ratio weighted by the lagged par value held by each P&C insurer. *Avg RBC4* is calculated as the lagged insurer RBC ratio weighted by the lagged par value held by each P&C insurer. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors double clustered by bond and quarter are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The variable description is in Appendix 4.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variables	Amihud Measure	IRC	Price Dispersion	Roll Measure	Amihud Measure	IRC	Price Dispersion	Roll Measure
	Avg RBC				Avg RBC2			
Health Measure	-0.0001	-0.0000	-0.0000	0.0001	-0.0001	-0.0000	-0.0000	-0.0001
	(0.0001)	(0.0000)	(0.0000)	(0.0002)	(0.0001)	(0.0000)	(0.0000)	(0.0003)
PCShare	0.0823***	0.0008***	0.0267***	0.1417***	0.0839***	0.0008***	0.0272***	0.1427***
	(0.0152)	(0.0002)	(0.0073)	(0.0408)	(0.0151)	(0.0002)	(0.0072)	(0.0408)
LnSize	-0.1291***	-0.0004	0.0155**	0.0787*	-0.1288***	-0.0004	0.0154**	0.0782*
	(0.0301)	(0.0002)	(0.0075)	(0.0385)	(0.0301)	(0.0002)	(0.0075)	(0.0386)
LnMaturity	0.0258***	0.0007***	0.0363***	0.2149***	0.0258***	0.0007***	0.0364***	0.2144***
	(0.0076)	(0.0001)	(0.0057)	(0.0242)	(0.0076)	(0.0001)	(0.0057)	(0.0241)
Callable	0.0212*	0.0003**	0.0068	0.0961**	0.0214*	0.0003**	0.0068	0.0958**
	(0.0117)	(0.0001)	(0.0052)	(0.0403)	(0.0117)	(0.0001)	(0.0052)	(0.0402)
EnCredit	0.0317***	0.0003***	0.0060	0.0740***	0.0315***	0.0003***	0.0061	0.0753***
	(0.0069)	(0.0001)	(0.0041)	(0.0268)	(0.0067)	(0.0001)	(0.0041)	(0.0266)
Observations	220,665	220,665	220,665	220,665	221,169	221,169	221,169	221,169
R-squared	0.4491	0.5486	0.5705	0.4507	0.4493	0.5490	0.5709	0.4509
Cusip FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr

Continued:

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent Variables	Amihud Measure	IRC	Price Dispersion	Roll Measure	Amihud Measure	IRC	Price Dispersion	Roll Measure
	Avg RBC3				Avg RBC4			
Health Measure	-0.0000	-0.0000	-0.0001**	0.0002	-0.0000	0.0000	-0.0000	0.0005*
	(0.0001)	(0.0000)	(0.0000)	(0.0002)	(0.0001)	(0.0000)	(0.0000)	(0.0003)
PCShare	0.0702***	0.0006***	0.0267***	0.0476	0.0703***	0.0006***	0.0267***	0.0480
	(0.0161)	(0.0002)	(0.0076)	(0.0427)	(0.0163)	(0.0002)	(0.0077)	(0.0432)
LnSize	-0.1314***	-0.0004*	0.0130	0.0783*	-0.1311***	-0.0005*	0.0131	0.0780*
	(0.0315)	(0.0003)	(0.0081)	(0.0392)	(0.0318)	(0.0003)	(0.0082)	(0.0390)
LnMaturity	0.0179**	0.0005***	0.0350***	0.1773***	0.0180**	0.0005***	0.0352***	0.1772***
	(0.0075)	(0.0001)	(0.0058)	(0.0216)	(0.0075)	(0.0001)	(0.0058)	(0.0218)
Callable	0.0185	0.0002*	0.0081	0.0808**	0.0188	0.0002*	0.0082	0.0818**
	(0.0115)	(0.0001)	(0.0053)	(0.0389)	(0.0115)	(0.0001)	(0.0053)	(0.0390)
EnCredit	0.0317***	0.0003***	0.0050	0.0778***	0.0323***	0.0003***	0.0049	0.0780***
	(0.0069)	(0.0001)	(0.0040)	(0.0273)	(0.0068)	(0.0001)	(0.0041)	(0.0274)
Observations	206,645	206,645	206,645	206,645	206,941	206,941	206,941	206,941
R-squared	0.4541	0.5548	0.5717	0.4581	0.4540	0.5547	0.5714	0.4583
Cusip FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr

Table 4.8. Descriptive statistics for the liquidity commonality measures

The sample size differs when we use alternative measures for bonds' commonality, *Liq β* or *Liq β2*. The variable description is in Appendix 4.1. All continuous variables are winsorized at the 1st and 99th percentiles.

	N	Mean	Median	StdDev	Min	Max
Liq β	3,559	0.9777	0.3645	8.3844	-23.0936	28.8853
Liq β2	2,992	0.8051	0.6915	5.8879	-14.9038	17.1367
LiqSpread (%)	3,559	1.4966	1.5116	0.6255	0.0328	2.9023
DftSpread (%)	3,559	2.3619	2.2793	1.6618	-2.4208	6.4406
PCShare	3,559	0.0661	0.0377	0.0832	0.0011	0.8410
LnSize	3,559	12.0730	12.2270	0.5674	9.4100	12.6115
LnMaturity	3,559	2.9423	3.1183	0.5990	-0.7940	3.3993
Callable	3,559	0.5735	1	0.4946	0	1
EnCredit	3,559	0.3894	0	0.4877	0	1
Avg RBC	3,559	12.1783	8.36502	18.1088	2.335631	154.5101
Avg RBC2	3,563	11.8340	8.410607	17.1558	2.460142	153.1545
Avg RBC3	3,275	12.8507	8.271412	20.8069	2.411576	180.3017
Avg RBC4	3,275	11.9707	8.297138	17.4115	2.420751	150.153

Table 4.9. Investors' Financial Health and Bonds' liquidity commonality

The sample period is from Q2 2006 to Q4 2015. The sample size differs when we use two alternative bonds' commonality measures, *Liq β* or *Liq β2* and four alternative financial health measures: *Avg RBC, Avg RBC2 Avg RBC3* and *Avg RBC4.* Robust standard errors double clustered by bond and quarter are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. All continuous variables are winsorized at the 1st and 99th percentiles. Robust standard errors double clustered by bond and quarter are reported in parentheses. The superscripts ***, **, and * indicate significance at the 1%, 5% and 10% level, respectively. The variable description is in Appendix 4.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variables	Liq β	Liq β2	Liq β	Liq β2	Liq β	Liq β2	Liq β	Liq β2
Avg RBC	-0.0396**	-0.0265**						
	(0.0185)	(0.0111)						
Avg RBC2			-0.0372*	-0.0325**				
			(0.0187)	(0.0133)				
Avg RBC3					-0.0226**	-0.0134		
					(0.0107)	(0.0094)		
Avg RBC4							-0.0434**	-0.0355**
							(0.0161)	(0.0163)
PCShare	-3.8862	-6.1605	-3.7508	-6.0990	-2.8705	-4.7431	-2.9367	-5.2064
	(3.5054)	(4.4509)	(3.4884)	(4.4469)	(4.3222)	(4.7352)	(4.3065)	(4.8247)
LnSize	-5.8881	-5.7878***	-5.8813	-5.7692***	-8.6949*	-5.5623**	-8.6703*	-5.5264**
	(3.5736)	(0.9975)	(3.5766)	(0.9987)	(4.5258)	(2.3857)	(4.5310)	(2.4086)
LnMaturity	0.8453	0.9173	0.7572	0.9223	0.6269	0.9083	0.6713	0.9159
	(0.9322)	(1.4192)	(0.9255)	(1.4144)	(0.9618)	(1.2568)	(0.9714)	(1.2659)
Callable	0.9182	-0.3815	0.9467	-0.3708	0.9442	-0.5656	0.9608	-0.5600
	(0.6907)	(0.5332)	(0.6880)	(0.5304)	(0.8011)	(0.5217)	(0.7966)	(0.5263)
EnCredit	0.8411	1.7506	0.9004	1.7220	1.0834	2.2700	1.1913	2.4252
	(1.9414)	(1.5385)	(1.9047)	(1.5428)	(1.9769)	(1.8336)	(1.9603)	(1.7953)
Observations	3,559	2,900	3,563	2,903	3,275	2,677	3,275	2,677
R-squared	0.1905	0.1951	0.1900	0.1955	0.1936	0.1861	0.1946	0.1872
Cusip FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SE cluster	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr	Bond & Qtr

Chapter Five: Conclusion

My thesis discusses the investment portfolio of P&C insurance companies, focusing on the return and risk. I also investigate the spillover effect of P&C insurance firm's investment portfolio.

We realize that the approximately 5,000 U.S. insurance companies comprise a large proportion of institutional investors in the U.S. financial markets, and they play an indispensable role in the U.S. investment ecology. Therefore, it becomes increasingly important to understand how insurance companies invest and what the economic consequence is. My thesis attempts to provide some answers to these questions. We find that capital regulations, organizational forms are all important factors in determining P&C insurance company's investment strategy, which have strong effect on firm-level risk and group-level internal capital allocation.

Compared to life insurance industry, more focus is paid on the liability side instead of the asset sides for P&C insurance companies. My thesis encourages for a deeper study of the investment portfolio of P&C insurance companies, where insufficient attentions have been paid.