ESSAYS IN THE ECONOMICS OF U.S. PROPERTY-CASUALTY INSURANCE INDUSTRY

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by

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ABSTRACT

This dissertation consists of two topics. Chapter 1 explores the relationship between U.S. Property-Casualty (P/C) insurers' underwriting risk, investment risk, and leverage risk, using data from 1998 to 2013. I test the trade-off hypothesis using a simultaneous equation model framework with partial adjustment effects. The three equations model intend to examine the interrelations between insurers' leverage and two measures of firm risks: underwriting risk and investment risk. The empirical evidence, various to different sample periods and model specifications, suggests there is no significant relationship existing between insurers' underwriting risk and investment risk. But these two types of risks are both significantly and negatively related to the leverage ratio. The overall results imply that insurers tend to tradeoff leverage risk and underwriting risk/investment risk, but it appears that they have not taken an integrated approach between the total level of underwriting risk and investment risk yet.

The second part of this dissertation empirically investigates the impact of credit risk on insurers' reinsurance demand, using data on the U.S. P/C insurance industry from 2000 to 2014. I mainly explore how insurers' credit rating status and downgrade risk affects their reinsurance demand. Using a two-stage least square (2SLS) regression model, I find that low-rated insurers are associated with a higher utilization of reinsurance. In addition, insurers that are downgraded in the previous year tend to have a higher reinsurance demand than the others. Results also show that downgraded group-affiliated insurers tend to significantly increase their internal reinsurance demand from the group-affiliated members while decreasing the purchase of external reinsurance significantly. In general, I find that insurers' reinsurance demand is affected by their credit rating and downgrade risk.

THIS DISSERTATION IS DEDDICATED TO MY ALWAYS ENCOURAGING, CARING AND FAITHFUL PARENTS

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CHAPTER 1

THE RELATIONSHIP BETWEEN UNDERWRITING RISK, INVESTMENT RISK, AND LEVERAGE IN U.S. PROPERTY-CASUALTY INSURANCE INDUSTRY

1.1. Introduction

Insurers are always balancing between two primary goals: one is to limit their risk exposure created by the underwriting business, the other is to invest the premiums they earn from underwriting activities to gain profits. This process usually involves multiple types of risks, including underwriting risk, investment risk, operational risk, and leverage risk, etc.[1] As documented in prior literature, insurers' total risk reflects a combination of underwriting risk, investment risk, and leverage risk. Underwriting risk is associated with the uncertainty of insurance contract losses; investment risk arises from the investment activities that generate investment income; and leverage risk is critical to an insurer because it is related to the solvency of an insurer (Ho, Lai and Lee, 2013). The focus of this study is to analyze how these three types of risks: underwriting risk, investment risk, and leverage risk, are related after controlling for exogenous firm characteristics.

The motivations of this study are three-fold. First, due to a globalization trend, the world economy has become increasingly interconnected, resulting in more intense interactions between underwriting businesses and investment activities. For example, as reported in Achleitner et al. (2002), some big insurers suffered heavy losses due to the dual risk exposure to the aviation industry risk, which impacted both underwriting and

[1] Prior studies use various terminologies to describe insurance firms' major risk. For example, assets/investment risks and liabilities/product/underwriting risks. In this study, I adopt the terms underwriting risk and investment risk.

investment risk. Second, the importance of understanding the relationship between underwriting risk and investment risk was further aroused after the 9-11 terrorism attack, which triggered tremendous losses (over U.S. $40 billion) to insurance companies and severely affected the capital market, thus negatively affecting both insurers' underwriting gains and investment returns. Third, some catastrophic events and natural disasters cause direct shocks to insurers' underwriting business and indirect disruptions to the capital market, especially in the regions where there are highly-clustered businesses. Under such circumstances, the management of underwriting risk and investment risk represents major aspects of an insurer's business operations. And it is worthwhile and interesting to analyze how these risks are related.

Traditionally, underwriting is insurers' core business activity, in which they take on risks in exchange for premiums. The differences between earned premiums and the sum of discounted claim payments and operating expenses represents insurers' underwriting profits. Underwriting risk arises when the actual and incurred insurance claims and expenses deviate from the expected values that determine the premium level, thereby leading to fluctuations in underwriting profit. High fluctuations and uncertainties in underwriting results represents underwriting risk.

As a common practice, insurers make investments to gain returns, thereby introducing investment risk. U.S. P/C insurers invest in diversified portfolios of financial assets, including government and corporate bonds, common stocks, preferred stocks, real estate, and mortgage loans. Among those investments, some categories are riskier than others. Investment in risky assets on average generates higher investment return, but excessive asset risk-taking also subjects insurers to a more volatile investment environment, which potentially weakens their ability to pay back claims or can even threaten their survival. Therefore, insurers' underwriting and investment risk-taking decision are complicated decisions, and may involve mutual influences on each other.

In addition to underwriting risk and investment risk, leverage is a source of risk to insurers' operations. As documented in Fier, McCollough and Carson (2013), leverage may be considered beneficial or costly depending on the level of leverage utilized. A high leverage level allows insurers to maximize the firm value from tax shield benefits and an insolvency put option, but too much leverage ratio would also increase the probability of insolvency or reduce the value of the firm, creating bankruptcy risk. Considering such a two-way effect of leverage, I will examine how the leverage ratio is related to insurers' investment risk and underwriting risk. Insurers with higher leverage should be more cautious and conservative regarding their investment activities. Similarly, insurers with a more volatile or risky underwriting business profile may be less likely to operate at a higher leverage. Therefore, I will model the relationship between insurers' underwriting risk, investment risk, and leverage simultaneously in this study.

This study makes several contributions to the literature. First, it provides a more rigorous investigation of the relationship between U.S. P/C insurers' underwriting risk, investment risk and leverage using a large sample and controlling for firm-specific characteristics. I examine not only the impact of investment risk on underwriting risk but also the impact of underwriting risk on investment risk. Additionally, I add the leverage ratio in this model to further explore the relationship between these three types of risk. This research question is especially important since it helps to explore whether insurers have adopted an integrated approach to choosing the level of overall desired risk.

Second, the sample period is from 1998 to 2013, and covers the post 9-11 terror attack period, thus allowing me to examine the relationship between insurers' underwriting risk, investment risk and leverage with a sub-sample analysis. After the terror attack, many researchers have argued that the insurance industry may have neglected or underestimated the relationship between underwriting risk and investment risk. Therefore, evidence for the linkage between insurers' underwriting and investment risks is of significant interest to regulators, investors, policyholders and insurance managers. Zou et al. (2012) use data from 1994 to 2000 to analyze the relationship between insurers' underwriting risk and investment risk prior to the 9-11 terror attack, and their results suggest that such a linkage is positive but very weak. With more recent data, this study will re-examine the relationship between these risks and address how insurers' risk-taking behavior changed after the 9-11 terror attack.

The remainder of this essay is organized as follows. In Section 2, I review and discuss the related literature. Section 3 describes research design and hypothesis development. Section 4 introduces data and sample selection criteria, while section 5 explains the methodology and variable definitions. In Section 6, I report the empirical results. Finally, section 7 summarizes the findings and discusses the practical implications.

1.2. Literature Review

Financial institutions' risk-taking behavior has aroused significant research interests, and the relationship between capital and risk has been well established. In the banking literature, some researchers propose a positive relationship between capital and risk based on the capital buffer theory and agency theory. For example, Shrieves and Dahl (1992) find a positive relationship between changes in risk and capital for U.S. commercial banks. A negative relation between capital and risk, on the other hand, is also plausible and is consistent with the hypothesis that deposit insurance for banks and guarantee funds for insurers induce greater risk taking at lower capital levels (Cummins, 1998). The deposit insurance or guarantee funds provide last-resort protection when insurers are unable to fulfill their contractual commitments. In the case of failure, the costs are borne by all guarantee fund members. In line with this argument, Jacques and Nigro (1997) report a negative relationship between risk and capital, supporting the moral hazard hypothesis which maintains that the insurance guaranty fund is like a put option held by stockholders that give them incentives to exploit their subsidy.

In the insurance field, most of the empirical evidence on the relationship between capital and risk substantiates a positive relationship between capital and risk. Cummins and Sommer (1996) report a positive relationship between capital and the aggregate risk for P/C insurers. Shim (2010) also documents that changes in capital and risk are significantly and positively related, implying that insurers' capital and risk choices are interdependent and their adjustments in capital and risk occur in the same direction to maintain the probability of insolvency at a desired level. Mankai and Balgecem (2015) review the interactions between reinsurance, capital, and risk for property-liability insurance industry. They find that insurers' risk taking is positively related to capital, while reinsurance is negatively related to capital.

Some other insurance studies discuss the interactions between underwriting risk, investment risk, and capital simultaneously. Baranoff and Sager (2002) examine the relationship between capital, asset risk and product risk simultaneously in the life insurance sector from 1993 to 1997. They advance a positive relationship between insurers' underwriting risk and investment risk. Another relevant and important study by Cheng and Weiss (2013) investigates the relationship between capital and two types of risks: underwriting risk and investment risk, for property-liability insurers from 1993 to 2007. Using a simultaneous equation model, their results suggest that risk and capital are positively correlated, so that capital increases are associated with increases in investment risk and underwriting risk.

Compared to the rich volume of literature on the relationship between capital and risk, there is relatively little research exclusively focusing on the relationship between underwriting risk and investment risk. The empirical findings are mixed for existing studies. To the best of my knowledge, Hammond et al. (1976) were the first to provide a direct test of the relationship between underwriting and investment risks in the P/C insurance industry. They document a negative relationship between underwriting risk and investment risks using data on 26 insurers from 1952 to 1967. They conclude that P/C insurance managers may choose an overall desired level of risk by trading off underwriting risk against investment risk. However, their univariate analysis fails to control for any relevant factors related to underwriting risk, and their underwriting risk measure is crude.[2] Zou et al. (2010) revisit this research question and find that there is no significant relationship between insurers' underwriting risk and investment risk prior to the 9-11 terror attack. They believe that insurers might have overlooked the linkage between underwriting risk and investment risk. This is consistent with findings in Achleitner, Biebels, and Wichels (2002), which conclude that the insurance industry may have largely managed investment risk in isolation from underwriting risk.

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[2] Hammond et al. (1976) measure underwriting risk as ratio of net premium to net worth.

The research question of whether insurers continuously balance their asset risk and underwriting risk has also received attention from prior researchers. For example, Jawadi and Sghaier (2009) argue that insurers continually modify their reasoning and reactions, and adjust their prices based on financial variable deviations. Chen, Yao, and Yu (2010) claim that insurers' underwriting risk has a strong impact on their risk-taking in corporate bond investments.[3] Ren et al. (2008) show that underwriting costs and insolvency risks faced by insurers are expected to be greater in hard markets than soft markets, and therefore insurers may take on more asset risks during soft markets and discharge them in hard markets. Following this study, Ren et al. (2011) show that insurers' investment risk-taking behavior is affected by the underwriting cycle. Stock insurers more actively reallocate assets in underwriting cycles than mutual insurers.

This research also relates to the internal capital market (ICM) literature which analyzes firm's capital structure and examines how insurers' investment risk, underwriting risk-taking, and leverage affect the capital structure. ICM also plays an important role in understanding insurers' risk-taking decisions. To illustrate, Powell and Sommer (2007) model the purchase of internal and external reinsurance using simultaneous equations using a sample of group-affiliated insurers. They document the structural differences in the use of internal and external reinsurance where external reinsurance is motivated by ceding catastrophic risk, and they find cost-based differences in internal and external capital. Following this study, Powell, Sommer, and Eckles (2008) analyze the relationship between investment, capital and underwriting exposure simultaneously, and they find that ICM plays a significant role in investment behavior and increases investment growth for

[3] Chen, Yao and Yu (2010) define underwriting risk as the standard deviation of underwriting income.

affiliated insurers, supporting the hypothesis that the ICM is efficient. Fier, McCullough, and Carson (2013) examine the relationship between deviations from target capital structure and internal capital market activity. This study provides some empirical evidence that affiliated insurance companies actively manage their capital structure, and ICM activity is used to manage deviations from the target leverage.

Furthermore, Cummins and Weiss (2016) review the theoretical and empirical evidence on the optimal capital structure, the impact of underwriting cycles, and ICMs on insurers' capital. As indicated in this study, property-liability insurers have optimal capital structures and behave according to the trade-off theory of capital structure. They also investigate whether insurers have optimal capital structures and whether they engage in timely adjustment to their leverage targets when leverage departs from the optimum. My current study expands the prior literature in that I will analyze whether insurers actively engage in adjustments to the target underwriting risk level, target investment risk level and target leverage level simultaneously.

Based on the above discussion, although there have already been extensive studies focusing on the relationship between capital and risk, the relationships between insurers' underwriting risk and investment risk has not fully investigated. The research on the interactions between underwriting risk, investment risk, and leverage risk is even more sparse. And this study intends to fill this gap with a joint analysis of these variables.

1.3. Hypothesis Development

The above literature discussion provides some support for the interdependence between underwriting risk, investment risk, and leverage risk. To explore the relationship between them, I propose the trade-off hypothesis, which predicts a negative relationship between these three different types of risks.[4]

The theoretical foundations underlying the tradeoff hypothesis are the finite risk framework and bankruptcy cost avoidance theory (Baranoff and Sager, 2003; Cummins and Sommer, 1996; Shrieves and Dahl, 1992). Bankruptcy cost avoidance theory contends that to maintain a healthy solvency status, insurers' orientation towards risky asset investment could be offset by a less risky underwriting risk to reduce the likelihood of failure. This argument is in line with the finite risk paradigm which predicts that insurers prefer to limit their overall total risk and operate at a finite level of leverage to avoid bankruptcy costs. Some early empirical work lends some support to this prediction. As mentioned earlier, Hammond et al. (1976) and Hammond and Shilling (1978) argue that P/C insurers' underwriting risk and investment risk are not independent, but insurers may control the overall risk by trading off one type of risk against the other.

Insurers may modify their investment risk profile based on the underwriting risk. Under the asset-liability matching (ALM) strategy, the business an insurer undertakes consists of different lines, and those lines are associated with different levels of risk. Such business composition would naturally affect insurers' capital liquidity and investment portfolio. Consequently, the riskiness of insurers' underwriting business may directly or indirectly affect a firm's asset investment risk-taking strategies. To illustrate, when the loss ratio is highly volatile, insurers become more uncertain about the potential claim payments in the future, and should behave conservatively in asset risk-taking. Some prior empirical

[4] Although much existing literature predict a negative relationship between underwriting risk and investment risk, the alternative prediction of a positive relationship also remains plausible. For example, Sloan, Hoerger, and Hassan (1990) claim that an increase in loss volatility of claims generates higher risk. But in this study, my null hypothesis predicts a negative relationship between underwriting risk and investment risk based on more recent studies and empirical evidence.

results support this prediction. For example, Ren et al. (2011) analyze how insurers' underwriting results affect their investment risk-taking. They show that the increases in the loss ratio, which is a measure for underwriting risk, lead to a drop in investment in common stocks, which is a proxy for investment risk-taking. This provides some empirical evidence that insurers tend to trade off their underwriting risk and investment risk to achieve an optimal level of overall risk.

Furthermore, investment risk also affects insurers' underwriting risk. Theoretically, insurers with a higher level of investment risk normally experience more uncertainty in surplus, therefore they tend to adjust their underwriting criteria to better manage underwriting risk and overall risk. Combining the above findings, I develop a tradeoff hypothesis which argues that insurers with higher underwriting (investment) risk are less likely to take on excessive investment (underwriting) risk. And there exists a negative relationship between insurers' underwriting risk and investment risk.

> ***Hypothesis 1****:* Insurers' underwriting risk and investment risk are negatively related to each other, everything else being equal.

In addition to underwriting risk and investment risk, leverage is also a key consideration in insurers' capital structure and risk-taking decisions. Prior studies argue firms actively manage the level of leverage given the cost and benefits of leverage (Cheng and Weiss, 2012; Fier, McCollough, and Carson, 2013). An increase in the leverage ratio signals increasing financial risk, and highly leveraged insurers are more exposed than others to the risk of insolvency. Staking and Babbel (1995) maintain that increased leverage reduces the surplus and increases the likelihood of financial distress. Shiu (2011) confirms this point by arguing that highly leveraged insurers are exposed to a higher likelihood of insolvency and higher expected bankruptcy costs. In line with the finite risk framework, a high leverage ratio indicates that the company has to rely more on having adequate reserve funds, which may potentially limit their incentive or capacity in underwriting and investment risk-taking. Therefore, firms with higher underwriting risk or investment risk may be concerned about their bankruptcy or insolvency risk and thus decrease the leverage ratio. It is expected that firm's leverage ratio is negatively related to underwriting risk and investment risk.

Additionally, higher capital adequacy is represented by lower leverage ratio. Since most prior literature documents a positive relationship between capital and risk, it is reasonable to expect a negative relationship between leverage and risk. Therefore, insurers with a higher leverage ratio are less likely to take on excessive risk on underwriting side and investment side.

Based on the above discussions, I develop Hypothesis 2, which predicts the relationship between leverage and underwriting/investment risk is negative.

> ***Hypothesis 2:*** Insurers' leverage ratio is negatively related to underwriting risk and investment risk, everything else being equal.

Two sub-hypotheses describing the relationship between underwriting risk and leverage, investment risk and leverage respectively is described as follows:

> ***Hypothesis 2a:*** Insurers' underwriting risk is negatively related to the leverage ratio, everything else being equal.

> ***Hypothesis 2b:*** Insurers' investment risk is negatively related to the leverage ratio, everything else being equal.

1.4. Data and Sample Selection

The data for this study is mainly taken from the National Association of Insurance Commissioners (NAIC) database and *Best's Key Rating Guide*. Most of the firm-level data is obtained from the NAIC, except for organizational form data and rating data, which is taken from *Best's Key Rating Guide*.[5] In addition, I include the volatility of S&P 500 index variable to capture the impact of capital market volatility, and this historical data is derived from S&P official website.

The time span of this study is from 1998 to 2013, 16 years in total. The analysis is at the individual firm level. The sample includes only insurers that meet the following criteria: those that contain data for all the variables under consideration and have positive values for total assets, net premium written, and surplus. To remove outliers, I analyzed the studentized residuals and observations with studentized residuals in excess of four were deleted. Then, I also Winsorize data at the 1% and 99% quantiles. The remaining number of observations is 16,296. The firms in the sample account for more than 80% of industry assets. The final dataset is an unbalanced panel.

1.5. Model

Following Baranoff and Sager (2002), Cheng and Weiss (2013), and Cummins and Sommer (1996), I adopt a simultaneous equation model (SEM) to examine the relationship between insurers' underwriting risk, investment risk and leverage. SEM is widely used to study the joint determination of major corporate decisions, firm performance, and firm characteristics, etc.

Prior literature suggests that firms will make partial adjustment towards a given target capital structure rather than immediate, complete adjustment because adjustments are costly. The partial-adjustment model proposes the existence of an unobservable target. Incorporating partial adjustment is necessary because insurers may not be able to adjust

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[5] The NAIC company codes provided by the Best's Rating data are used to link these two data sets. These codes are available for nearly 85% of the companies in the NAIC database. Because *Best's Key Rating Guide* Data losses information on insurers' with NAIC code below 10000.

their underwriting risk, investment risk and leverage position to the desired level instantaneously, due to market imperfections, information asymmetries, and time lags in claim handling. Instead, discretionary changes are proportional to the differences between the current target levels and the actual levels observed in the last period. Change in underwriting risk, investment risk, and leverage could be expressed as:

$$UR_{i,t} - UR_{i,t-1} = \gamma_1[UR^*_{i,t} - UR_{i,t-1}] + \varepsilon_{i,t} \quad (1)$$

$$IR_{i,t} - IR_{i,t-1} = \gamma_2[IR^*_{i,t} - IR_{i,t-1}] + \upsilon_{i,t} \quad (2)$$

$$Lev_{i,t} - Lev_{i,t-1} = \gamma_3[Lev^*_{i,t} - Lev_{i,t-1}] + \omega_{i,t} \quad (3)$$

where $UR_{i,t}$ = the observed underwriting risk of insurer i at time t;

$IR_{i.t}$ = the observed investment risk of insurer i from at time t;

$Lev_{i.t}$ = the observed leverage of insurer i at time t;

$UR^*_{i,t}$ = insurer i's target level of underwriting risk at time t;

$IR^*_{i,t}$ = insurer i's target level of investment risk at time t;

$Lev^*_{i,t}$ = insurer i's target level of leverage at time t;

$\varepsilon_{i,t}, \upsilon_{i,t}, \omega_{i,t}$ = random exogeneous shocks to underwriting risk, investment risk, and leverage, respectively;

$\gamma_1, \gamma_2, \gamma_3$ = coefficients for partial adjustment factors.

There exists a target level of underwriting risk, investment risk, and leverage risk for each insurer, and it is assumed that the underwriting risk, investment risk, and leverage ratio levels are influenced by each other, as well as some other firm-specific characteristic variables. Therefore, the target risk levels are a function of the observed risk levels, and exogenous factors, which could be written in the following form:

$$UR^*_{i,t} = a_0 + a_1 IR_{i,t} + a_2 Lev_{i,t} + \mathbf{aX_{i,t}} + \mu_{i,t} \quad (4)$$

$$IR^*_{i,t} = b_0 + b_1 UR_{i,t} + b_2 Lev_{i,t} + \mathbf{bY_{i,t}} + \phi_{i,t} \quad (5)$$

$$Lev^*_{i,t} = c_0 + c_1 UR_{i,t} + c_2 IR_{i,t} + \mathbf{cZ_{i,t}} + \xi_{i,t} \tag{6}$$

where **X, Y, Z** = a vector of exogenous factors that affect underwriting risk, investment risk and leverage respectively.

Combining the above equations by linear algebra (substituting equation (1) (2) (3) into (4) (5)(6)), we can then get the following models specifying the variables to explain the determinants of underwriting risk, investment risk and leverage risk, as follows:

$$UR_{i,t} = \alpha_0 + (1- \gamma_1)UR_{i,t-1} + \alpha_1 IR_{i,t} + \alpha_2 Lev_{i,t} + \boldsymbol{\alpha} \mathbf{X_{i,t-1}} + \tau_{i,t} \tag{7}$$

$$IR_{i,t} = \beta_0 + (1- \gamma_2)IR_{i,t-1} + \beta_1 UR_{i,t} + \beta_2 Lev_{i,t} + \boldsymbol{\beta} \mathbf{X_{i,t-1}} + \sigma_{i,t} \tag{8}$$

$$Lev_{i,t} = \eta_0 +(1- \gamma_3)Lev_{i,t-1} + \eta_1 IR_{i,t-1} + \eta_2 UR_{i,t} + \boldsymbol{\eta} \mathbf{X_{i,t-1}} + \theta_{i,t} \tag{9}$$

The focus of this study is to analyze how underwriting risk, investment risk, and leverage affects each other. Estimating the equations individually ignores the problem of potential endogeneity between the three response variables. This violates the condition of no correlation between exogenous variables and the error terms. Therefore, I use a three-stage least square (3SLS) model to estimate the above equations. 3SLS is a full-information estimation technique that estimates all the parameters simultaneously, and it is preferred to two-stage least squares because of its efficiency in incorporating cross-equation correlations. According to Intriligator (1978), 3SLS estimation is advantageous in helping eliminate serial correlation problems in the error terms.

In addition, I use a lagged structure for the exogeneous control variables. From the perspective of the partial-adjustment model, it is reasonable to view the lagged variables as pre-determined quantities in setting the target for the next year, and therefore they are treated as exogenous. Both year-fixed effects and firm-fixed effects are added in every equation, according to the Breusch-Pagan Lagrange Multiplier test and Hausman test.

Hypothesis 1 and Hypothesis 2 would be supported if the coefficients of risk and leverage variables are all negative and significant. The reduced-form equations can be written in the following way:

$$UR_{it} = \alpha_0 + \alpha_1 UR_{it-1} + \alpha_2 IR_{i,t} + \alpha_3 Lev_{i,t} + \alpha_4 Reins_{i,t-1} + \alpha_5 Size_{i,t-1} + \alpha_6 Age_{i,t-1} + \alpha_7 Stock_{i,t-1}$$
$$+\alpha_8 Group_{i,t-1} + \alpha_9 HHI_{i,t-1} + \alpha_{10} GHHI_{i,t-1} + \alpha_{11} Rating_{i,t-1} + \alpha_{12} RBC_{i,t-1} + \alpha_{13} Cat_{i,t-1} + u_i + v_t + \varepsilon_{it} \quad (10)$$

$$IR_{it} = \beta_0 + \beta_1 IR_{it-1} + \beta_2 UR_{i,t} + \beta_3 Lev_{i,t} + \beta_4 Reins_{i,t-1} + \beta_5 Size_{i,t-1} + \beta_6 Age_{i,t-1} + \beta_7 Stock_{i,t-1}$$
$$+\beta_8 Group_{i,t-1} + \beta_9 HHI_{i,t} + \beta_{10} GHHI_{i,t} + \beta_{11} Rating_{i,t-1} + \beta_{12} RBC_{i,t-1} + \beta_{13} S\&P_{i,t} + u_i + v_t + \varepsilon_{it} \quad (11)$$

$$Lev_{it} = \gamma_0 + \gamma_1 Lev_{it-1} + \gamma_2 UR_{i,t} + \gamma_3 IR_{i,t} + \gamma_4 Reinsurance_{i,t} + \gamma_5 Size_{i,t-1} + \gamma_6 Age_{i,t-1} + \gamma_7 Stock_{i,t-1}$$
$$+\gamma_8 Group_{i,t-1} + \gamma_9 HHI_{i,t-1} + \gamma_{10} GHHHI_{i,t-1} + \gamma_{11} RBC_{i,t-1} + \gamma_{12} Rating_{i,t-1} + \gamma_{13} Growth_{i,t-1} + u_i + v_t + \varepsilon_{it} \quad (12)$$

where IR = the percentage of invested assets into common stocks, preferred stocks, and mortgages;

UR = natural logarithm of standard deviation of the combined ratio over the past three-year period;

Lev = net premiums written divided by policyholders' surplus;

Reins = reinsurance premiums ceded divided by direct premiums written plus reinsurance premiums assumed;

Size = natural logarithm of total admitted assets;

Age = natural logarithm of number of years that an insurer is in operation;

Stock = dummy variable equals one if the insurer is a stock company and zero otherwise;

Group = dummy variable equals one if the insurer is a single unaffiliated company and zero otherwise;

RBC = total adjusted capital divided by company action level RBC;

Rating = A dummy variable equals to one if the insurer is rated equal or above B+ by A.M. Best;

HHI = Herfindahl index of premiums written by business lines;

GHHI = Herfindahl index of premiums written by states;

Cat = premiums written from homeowners line in the Gulf area and coastal states and the earthquake line divided by total premiums written;

Growth = change in net premium written from year t to year t-1;

S&P = annualized standard deviation of monthly return for S&P 500 index;

u_i = firm-fixed effects;

v_t = year-fixed effects;

ε_{it} = random error term.

1.5.1. Identifying variables of SEM

3SLS is a system estimator in which the number of endogenous variables is equal to the number of equations. By assumption, insurers determine the level of underwriting risk, investment risk, and leverage endogenously and simultaneously. The endogeneity issues between the three response variables require at least one identification variable in each equation. The choice of instrumental variables is based on discussions in prior literature and existing theories.

In the underwriting risk equation, I use catastrophe risk exposure as the identifying variable, which is a proxy for insurers' underwriting risk exposure, since firms that write more business in catastrophe-prone areas are more likely to suffer from a catastrophe shock or face highly fluctuating underwriting income. A positive relationship is expected between catastrophe risk exposure and underwriting risk. But by assumption, the catastrophe risk exposure is independent of leverage ratio or investment risk-taking decisions, such as how much asset to invest in the common stock or mortgage-backed securities. Following the method used in Powell and Sommer (2007), I define the catastrophe risk variable as the proportion of an insurer's premiums in the earthquake line nationwide and in the homeowners line in the Gulf area and east coast states.[6]

In the investment risk equation, I include the volatility of the S&P 500 index as the identifying variable. It is defined as the annualized standard deviation of monthly returns for the S&P 500 index, measuring the financial market volatility. The S&P 500 index volatility may affect insurers' investment risk-taking decisions directly, but it is not expected to be related to underwriting risk or leverage ratio since the P/C insurers' business are uncorrelated with financial market volatility. It is hypothesized that the volatility of the S&P 500 index is negatively related to insurers' investment risk since in years with higher fluctuations, the insurers' risk-taking strategy should be more cautious.

In the leverage equation, the identifying variable I use is the premium growth rate, which is measured as the change in net premiums written from year t-1 to year t. Premium growth is expected to affect insurers' leverage ratio in a positive way because the premiums received are liabilities for firms, and premium growth will lead to an increase in leverage as a result of liabilities increase and surplus decrease (Browne et al, 1999; Fier, McCullough, and Carson, 2013). And I also speculate that firms' premium growth rate is exogeneous to their asset investment strategy or underwriting risk.

In addition to the above discussed identifying variables, I also include the one-period lagged value for the three response variables as the excluding variable in each equation, respectively. To examine the relevance and the validity of the instrumental variables, I perform Kleibergen-Paap rk LM test for under-identification check and Wald F test for weak instrument issue check. Then I perform a Hansen J test for overidentification.

1.5.2. Measuring Investment Risk

[6] The Gulf area and east coast states include Florida, South Carolina, Texas, Alabama, and Missouri.

Insurers invest in diversified types of assets. The primary measure of insurers' investment risk-taking is proportion of risky assets invested (asset risk), which normally includes investment in long-term, unpredictable and highly volatile assets. Shiu (2011) classifies assets into seven categories: stocks, government bonds, corporate bonds, real estate, mortgage loans, cash and other invested assets, and non-invested assets. The riskiness of an insurer's invested assets reported in the balance sheet may vary across types.

Theoretically, all investments have a risk: stocks have price risk but bonds also pose interest rate risk, duration risk, and yield risk. Compared with bonds, stocks are riskier because of their striking differences from bonds: according to the Statutory Accounting Principles (SAP), bond value is based on a bond's amortization cost where any premium or discount is amortized over its remaining life. However, the value of common stock is determined based on the per-share market values shown in the NAIC Valuation of Securities Manual.[7] Therefore, although bond values could decline and expose insurers to financial risk, stock investments are believed to be associated with higher volatility risk and market price risk. This is also posited in the extant literature. For instance, Pottier and Sommer (1999) find that an increased ratio of junk bonds and common stocks in invested assets presents a riskier investment portfolio that affects an insurer's rating negatively.

Following the literature, I define investment risk as invested assets in common stock, preferred stock and mortgage, divided by total assets.[8] In the robustness check, I use an alternative measure for investment risk, which is the proportion of invested assets in common stock, preferred stock, mortgage-backed securities, plus low-rated bonds (class 4

[7] Note that most states have statutory rules and regulations that limit investment in each asset type. If an insurer's investment exceeds the limitations, the excess is a non-admitted asset and is charged against policyholders' surplus.

[8] See Harrington and Danzon (1994), Gaver and Pottier (2005), and Zou et al. (2010).

to class 6 rated bonds using the NAIC rating).

1.5.3. Measuring Underwriting Risk

In the insurance literature, the measurement of underwriting risk is based on the appreciation and evaluation of risk characteristics in each line of business. According to Williamson (1985), risky lines are more complex, volatile and uncertain whereas the less risky lines are simpler, uniform, more explicit and predictable. Similar to the method used in Ho, Lai, and Lee (2013) and Lamm-Tennant and Starks (1993), I define underwriting risk as the natural logarithm of the standard deviation of insurers' combined ratios over the past three-year period. This proxies for the fluctuations of insurers' underwriting income. Higher standard deviations of the combined ratio indicate higher uncertainty and therefore higher risk.

As a robustness test, I follow the method used in Cheng and Weiss (2013), and Mankai and Balgecem (2015), and define underwriting risk using the proportion of net premiums written in the risky lines of business, which includes commercial auto liability, allied lines, earthquake, surety, theft, inland marine, fire, international, boiler and machinery, reinsurance, and medical malpractice occurrence.[9] According to Cheng and Weiss (2013), these are defined as risky lines because they have high net premiums written (NPW) risk factor loadings based on the RBC formula.[10] Regan (1997) analyzed insurers' risk classification according to their underwriting complexity in the portfolio, and exposure to the environmental uncertainty.[11] She found that the complexity is significantly higher in

[9] This definition of underwriting risk excludes premium written in non-risky lines: farmowners, ocean marine, mortgage guaranty, financial guaranty, group accident and health, workers' compensation, other liability, products liability, aircraft, fidelity, credit, and auto physical damage.
[10] Such measurement assumes RBC formula can identify risky lines.
[11] According to Regan (1997), complexity is defined as proportion of the firm's business in complex lines, which are identified by survey and audit expenditures divided by net premiums written.

certain lines where independent agents tend to dominate, including commercial auto liability, general liability, surety, theft, boiler, and medical malpractice occurrence, etc. These lines are thereby considered riskier, and the underwriting profitability in are also more uncertain since insurers' ability to meet future obligations are less predictable.

1.5.4. Measuring Leverage

The dependent variable for the third equation is leverage, defined as net premiums written divided by policyholder's surplus. Leverage can magnify both gains and losses, providing a direct measure of insurers' financial risk. Insurers can use leverage to generate higher value, but higher leverage may also increase the propensity for destroying the firm value, if the company fails.

1.5.5. Control Variables

This section discusses control variables, including firms' size, firm age, group affiliation dummy, stock dummy, reinsurance utilization, risk-based capital (RBC) ratio, rating grade, line-of-business Herfindahl (HHI), and geographical Herfindahl (GHHI).

Firm size is measured as the natural logarithm of an insurer's total net admitted assets. Large insurance firms are expected to exhibit lower risks for several reasons. As indicated in Cummins and Xie (2008), large and more diversified firms are good at gaining economies of scale and reducing the unit cost of production. Moreover, according to the law of large numbers, the expected loss becomes more predictable as the insured pool tends to be larger and more diversified, which requires less capital per policy written from insurers. It is expected that larger insurers are associated with lower underwriting risk. As for investment risk-taking, larger insurers are expected to be more capable of paying losses, therefore possibly engaging more in investment risk-taking. Also, for larger firms, the bankruptcy and financial distress cost is lower than that for smaller firms. In this way, larger insurers require less capital than smaller firms, suggesting a positive relationship between leverage and firm size.

Firm age is also included in the model to provide further control for cross-sectional differences in growth opportunities, as well as expertise in underwriting and investment risk-taking. It reflects an insurer's experience and ability to survive. Insurers with a long history are assumed to be more adaptable to insurance cycles and sophisticated at dealing with difficult market conditions and can therefore sustain stable growth and survive hard times. Firm age is measured as the natural logarithm of an insurer's number of operating years since inception. There is no clear expectation of how firm age affects the risk level.

Another important factor is reinsurance. Insurers may cede premiums to reinsurers to remove some of the risks off their balance sheets. Following Cummins Feng, and Weiss (2012), I define reinsurance as the ratio of reinsurance premiums ceded to the sum of direct premiums written and reinsurance assumed. Theoretically, by ceding reinsurance, insurers can reduce marginal costs and are able to issue more policies or to take on more underwriting risks (Cole and McCullough, 2006). Cummins et al. (2008) show that the optimal use of reinsurance can improve shareholder value by substituting for equity, which thereby reduces the cost of capital and increases returns from underwriting activities. It is expected that the utilization of reinsurance would decrease firms' underwriting risk.

The impact of reinsurance usage on investment risk taking has also been discussed in literature. Mankai and Balgecem (2015) find reinsurance is positively related to risk-taking. In theory, the utilization of reinsurance releases insurers' capital and enables them to take on more risk and I also expect to see a positive relationship between reinsurance and investment risk-taking. Furthermore, leverage and reinsurance is expected to be positively related. Prior studies predict that reinsurance is a substitute for surplus (Cole and McCullough, 2006; Garven and Lamm-Tennant, 2003). If this holds, firms with higher reinsurance would be associated with lower surplus and have higher leverage as a result. Therefore, I also expect that reinsurance and leverage are positively related.

In addition, I also add two diversification variables in my model. Insurers with a higher level of business concentration should be associated with a higher level of underwriting risk than firms with diversified sources of premium income. To control for the effect of business and geographical concentration, I add two Herfindahl index variables: HHI and GHHI.[12] The Herfindahl indexes are based on net premiums written by lines of business and states, respectively.[13] Firms with a lower Herfindahl index should demonstrate a more diversified premium composition, either in line-of-business written or in geographic areas involved, and this might enable insurers to pursue riskier investment in stock markets. Conversely, Mayers and Smith (1988) argue that operating across many geographic areas requires firms to have greater managerial discretion, therefore incurring higher monitoring costs and resulting in decreased financial performance. Therefore, how business and geographic concentration affects firms' risk-taking and leverage cannot be predicted a priori.

The RBC ratio addresses capital adequacy and signifies the degree of regulatory pressure. Risk-based capital is defined by the NAIC as a method of measuring the

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[12] These two Herfindahl Indexes are widely used as control variables in the literature. See Mayers and Smith (1988, 1994), and Pottier and Sommer (1997).

[13] They are calculated as: $HHI = \sum_{i=1}^{N} s_i^2$ and $GHHI = \sum_{i=1}^{N} s_j^2$, where s_i = the proportion of net premiums written in line i divided by total net premiums; and s_j = the proportion of net premium written in state j divided by total net premiums.

minimum amount of capital appropriate for a reporting entity to support its overall business operations in consideration of its size and risk profile. RBC ratio is calculated by the following formula:

$$RBC\ ratio = \frac{Total\ Adjusted\ Capital}{Company\ Action\ Level\ RBC} = \frac{Total\ Adjusted\ Capital}{2 * Authorized\ Control\ Level\ RBC}$$

RBC represents the theoretical amount of capital needed to absorb the risks of running the business, and it is a regulatory measure of firm’s financial strengthen. An RBC ratio greater than one implies that the insurer maintains sufficient capital for their business than the amount required by regulators. Therefore, it is expected that the sign of the RBC ratio variable is positive in underwriting risk and investment risk equations since higher capital adequacy is expected to expand firms’ risk-taking capacity, and negative in the leverage equation, since greater level of capital should reduce the leverage ratio.

Furthermore, rating is an overall measurement of an insurer’s financial quality. I include it in the simultaneous regression model and aim to test whether the rating grade is related to insurer’ risk-taking strategies. To measure it quantitatively, I divide insurers into two groups according to their rating grade: the high-rated insurers and the low-rated insurers. A.M. Best ratings are broadly grouped into two categories, “secure” or “vulnerable.” Ratings between A++ and B+ are considered “secure,” whereas all ratings below B+ are considered “vulnerable.” At this stage, it is not clear how rating grade affects insurers’ risk-taking behavior or leverage.

Finally, I added to dummy variables to control for organizational form and group affiliation. First dummy variable describes insurers’ organizational form. The sample used in the current study includes insurers organized as mutual firms and stock firms, which are two primary types of organizational forms in U.S. P/C insurance industry.[14] The stock dummy variable is assigned the value of one if the firm is a stock insurer, and zero otherwise. Mayers and Smith (1990) suggest that organizational form affects insurers' risk-taking behavior. Stock insurers have easier access to the capital market and more opportunities to participate in investment activities. Mutual insurers, on the other hand, face higher costs of raising new capital than stock insurers in the presence of financial distress due to their limited access to the capital market and this might restrict them from taking on risky investments.[15] Furthermore, managerial discretion problems differ between stock and mutual insurers.[16] In agency theory, risk-taking is inversely related to the degree of separation between managers and owners, which predicts that stock insurers are more likely to take on risks than mutual insurers. On the other hand, Doherty and Dionne (1993) suggest that mutual insurers that combine policyholder and owner claims should result in a more efficient risk-sharing arrangement than stocks. In this way, mutual insurers should be associated with riskier behaviors. Therefore, the systematic differences between those two types of business organizations may be related to a firm's investment risk and underwriting risk.

As for the relationship between organizational form and leverage, either a positive or a negative relationship is possible. On one hand, a positive relationship is expected if the stock insurers hold lower levels of capital due to their greater access to the capital

[14] Reciprocals are also included in the mutual type since mutual and reciprocal have similar owner–manager agency problems. There are also other organizational forms and ownership structures existing in the insurance industry, including Lloyds and risk retention groups (RRGs). I exclude these types because they are relatively rare and uninfluential in the U.S. P/C market. According to the NAIC records, Lloyds only accounts for less than 1 percent of total P/C premiums, and RRGs' market share is even lower.

[15] See discussions in Mayers and Smith, 1988, 1992, 1994; Harrington and Niehaus, 2002.

[16] Jensen and Meckling (1976) suggest that managers who are not closely monitored or whose objectives are not aligned with those of the owners may take value-reducing actions.

market, thereby resulting in a positive relationship between leverage and stock dummy (Harrington and Niehaus, 2002). On the other hand, a negative relationship is also possible if stock insurers choose to maintain at a higher level of capitalization due to their higher degree of owner-policyholder conflicts, compared with the mutual insurers (Fier, McCollough, and Carson, 2013; Lamm-Tennant and Starks, 1993).

The group affiliation dummy is assigned the value of one if the insurer belongs to a group of insurers under the common ownership, and zero otherwise. Over 70 percent of U.S. P/C insurers are group-affiliated members. Whether an insurer is independent or group-affiliated may affect firms' choice of underwriting risk, investment risk, and leverage risk. Affiliated insurers are less exposed to capital constraints because of possible funding help from other affiliated firms within the group and may therefore afford to bear more risks (Cummins and Sommer, 1996).

Table 1.1 below displays the variable used in this chapter and their definitions.

Table 1.1: Variable Definitions

Variable	Definition
Endogenously Variables	
Investment Risk	Percentage of invested assets into common stock, preferred stocks, and mortgage-backed securities
Underwriting Risk	Natural logarithm of standard deviation of insurers' combined ratio over the three-year period
Leverage Ratio	Net premiums written divided by policyholders' surplus
Exogeneous Variables	
Reinsurance Utilization	Reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed
Firm Size	Natural logarithm of firm's total admitted asset
Firm Age	Natural logarithm of number of years that an insurer is in operation
Stock Dummy	A dummy variable equals to one if the insurer is a stock company and zero otherwise
Group Dummy	A dummy variable equals to one if the insurers is single unaffiliated company and zero otherwise
RBC Ratio	Total adjusted capital divided by company action level RBC
Rating Grade	A dummy variable equals to one if the insurer is rated equal or above B+ by A.M. Best
HHI	Herfindahl index of net premiums written by business lines
GHHI	Herfindahl index of net premiums written by geographical states
Catastrophe Risk Exposure	Premiums written from homeowners line in Gulf area and coastal states and earthquake line divided by total premiums written
Premium Growth	Change in net premium written from year t-1 to year t
S&P 500 Volatility	Annualized standard deviation of monthly return for S&P 500 index

This table presents annual statistics for variables used in this study. The sample period is from 1998 to 2013. The sample consists of 16,296 year-firm observations.

1.6. Empirical Results

1.6.1. Summary Statistics

Table 1.2 reports the summary statistics (means, standard deviations, minimums, and maximum values) of all the variables. As we can see from Table 1.2, during the sample period, U.S. P/C insurers, on average, invested 23.5% of their assets in common stocks, preferred stock, and mortgage-backed securities. Underwriting risk is measured as the natural logarithm of the standard deviation for an insurer's combined ratio over past three-year period, and it has a mean of 1.832.

Table 1.2: Summary Statistics, 1998 to 2013

Variable	Mean	STD	Min	Max
Investment Risk	0.235	0.436	0	1
Underwriting Risk	1.830	0.937	0	4.966
Net Leverage	2.514	1.278	0.100	4.600
Firm Size	17.845	2.503	4.317	24.062
Firm Age	3.546	0.907	0	5.442
Reinsurance	0.379	0.284	0	1
Stock Dummy	0.735	0.442	0	1
Group Dummy	0.727	0.445	0	1
RBC Ratio	4.691	2.539	0.3	9.802
Rating	0.774	0.418	0	1
Catastrophe Risk	0.016	0.277	0	1
Premium Growth	0.137	0.459	-0.850	1.144
HHI	0.409	0.269	0	1
GHHI	0.530	0.379	0	1
S&P 500 Volatility	0.728	0.419	0.171	1.879
Number of Obs.		16296		

Note: This table presents annual statistics for variables used in this study. The sample period is from year 1998 to 2013. The sample consists of 16,296 year-firm observations for the analysis.

1.6.2. Analysis of Results

The main research question of this study is to explore the relationship between insurers' underwriting risk, investment risk, and leverage risk. Table 1.3 presents the results using the full sample based on the simultaneous equations model.

The results for underwriting risk (equation 10) show that underwriting risk is negatively related to leverage ratio, and it is significant at the 1% level. The coefficient is -0.225, which implies that a one-unit increase in the leverage ratio would lead to a 0.225 unit of decrease in underwriting risk, measured as the standard deviation of the combined ratio over the past three years. The coefficient on the investment risk is positive but not significant. The results provide partial evidence for the tradeoff hypothesis in that firms with higher leverage ratios are associated with lower underwriting risk. And I interpret the results as lending some support to the finite risk theory. Insurers have an overall control over their total risk and tend to trade off the underwriting risk against the leverage risk, but there is no direct evidence showing that they tend to tradeoff the underwriting risk against investment risk.

The results from estimating equation (11), the investment risk equation, show that insurers' investment risk-taking is negatively and significantly related to the leverage ratio too, implying that insurers with a higher leverage risk on average undertake less risk on the investment side. To be specific, since the coefficient is -0.071, one-unit increase in the leverage ratio would lead to -0.071 unit decrease in risky asset investments. In addition, the coefficient on underwriting risk is positive but not significant again, showing that there is no empirical evidence supporting the relationship between insurers' underwriting risk and investment risk. The trade-off effect is only found between investment risk and the leverage ratio according to the results on in Table 1.3.

The results from estimating equation (12), the leverage equation, reinforce the findings that leverage is negatively and significantly related to both underwriting risk and investment risk, suggesting that firms with higher underwriting risk and investment risk would prefer to operate at a lower level of leverage. The coefficients for underwriting risk and investment risk is -0.071 and -0.656, respectively, indicating that one-unit increase in underwriting risk would lead to 0.071 unit decrease in the leverage ratio, whereas one-unit increase in investment risk would lead to 0.656 unit decrease in the leverage ratio.

In summary, I find that the leverage ratio is significantly and negatively related to underwriting risk and investment risk, suggesting trade-off interactions. But there is no significant relationship found between underwriting risk and investment risk. The significance and sign of the response variables are consistent among all three equations. Therefore, the trade-off hypothesis is supported. Within the trade-off hypothesis, only Hypothesis 2, which predicts a negative relationship between leverage and two types of risks: underwriting risk and investment risk, is substantiated. But the negative relationship between underwriting risk and investment risk is not found during this sample period. This is consistent with Zou et al. (2012), who also claim that insurers have overlooked the correlations between underwriting risk and investment risk.

In all three equations, the coefficients on the lagged underwriting risk, lagged investment risk, and lagged leverage variables reveal the speed of partial adjustment.[17] There are all significant and the values are between 0 and 1. The coefficient on lagged underwriting risk value is 0.445, and this implies that the partial adjustment speed is 0.555. Therefore, insurers take approximately 2 years to adjust to their target level of underwriting risk. This could be interpreted partly by P/C insurers' short-term contracts. The duration of many P/C insurance contracts run for 1-2 years, which gives insurers the opportunity to

[17] The partial adjustment speed is defined as 1-the coefficient of lagged underwriting risk, investment risk, and leverage, respectively

adjust their underwriting risk accordingly. The coefficient on the lagged investment risk is approximately 0.16, indicating that the time needed to adjust to the target investment risk is much more rapid, partly due to the lower cost of adjusting an investment portfolio in theory. In addition, the coefficient on the lagged leverage ratio is 0.64 and the partial adjustment speed for leverage is around three years.

The identifying variables in the three equations all carry the expected signs and are significant. The coefficient on catastrophe risk exposure variable is positive and significant, which shows that firms with a higher exposure to catastrophe risk have a higher underwriting risk. The S&P 500 index volatility variable bears a negative and significant coefficient, supporting the expectation that in years of high fluctuations, insurers invest less in risky assets. Lastly, in the leverage equation, the growth opportunity variable is positive and significant. So, firms with a higher premium growth rate tend to have a higher leverage ratio partly because increased business has a negative impact on surplus initially. The results on instrumental variables check are presented in Table 1.3 as well. In the first stage, both Kleibergen-Paap rk LM test and Kleibergen-Paap rk Wald test have a significant p-value, rejecting the null hypothesis that the instrument is jointly insignificant or weak.[18] Furthermore, the Hansen J test statistic is insignificant, therefore the overidentifying restrictions are valid. Both instrumental variables' relevance and erogeneity have been confirmed.

The reminder of this section discusses results relating to the control variables. In the underwriting risk equation, firm age is negatively related to insurers' underwriting risk. This indicates that older insurers have a lower fluctuation in underwriting income, partly

[18] The first stage regression results are not reported in the paper but the test for instruments are presented along with the second stage regression results.

due to their rich experience in underwriting. But firm age is positively and significantly related to investment risk, indicating that firms' investment risk increases by years of operation. And this may be explained as follows: firms may become more proficient in investment and are able to take on more risk as they become more mature. In the investment and leverage equation, I find firm size is positively and significantly related to investment risk and leverage. This is consistent with expectation that larger insurers have a higher capacity to take on investment risk. Also, larger insurers may maintain higher leverage ratios since less capital is required to remain solvent (Fier, McCollough, and Carson, 2013).

The reinsurance variable is positive and significant in the underwriting risk equation, and negative in the investment risk equation. This is consistent with expectations that firms that purchase more reinsurance are better able to digest underwriting risk. The high rating dummy variable is negative and significant in all equations except the investment risk equation, showing that insurers with a poor financial strength rating have higher underwriting risk and leverage than other firms. And this confirms that insurers with good financial strength rating tend to take less underwriting risk and leverage risk to protect their franchise value. Stock insurers on average have lower underwriting risk than mutual firms. Unexpectedly, the coefficient on stock dummy in investment risk equation is negative and significant, indicating that the stock insurers tend to have a less aggressive investment strategy than mutual firms. Group-affiliated insurers on average take on less investment risk and have a lower leverage ratio. In addition, I also report a negative relationship between the RBC ratio and investment risk, underwriting risk, and leverage.

Table 1.3: 3SLS Regression Results for the Relationship Between Insurers' Investment Risk, Underwriting Risk, and Leverage, 1998 to 2013

Dependent Variable	Underwriting $Risk_t$ Coefficient [T-Stat]	Investment $Risk_t$ Coefficient [T-Stat]	$Leverage_t$ Coefficient [T-Stat]
Underwriting $Risk_t$		0.001	-0.071***
		[0.23]	[-4.21]
Investment $Risk_t$	0.648		-0.656***
	[1.36]		[-4.01]
$Leverage_t$	-0.225***	-0.071***	
	[-13.91]	[-21.77]	
$Reinsurance_{t-1}$	0.211***	-0.063***	0.927***
	[7.11]	[-7.47]	[2.75]
Firm $Size_{t-1}$	0.015*	0.032***	0.041***
	[1.92]	[20.55]	[5.01]
Firm Age_{t-1}	-0.036***	0.024***	-0.018
	[-3.22]	[7.75]	[-1.42]
Stock $Dummy_{t-1}$	-0.052**	-0.039***	0.011
	[-2.29]	[-6.05]	[1.45]
Group $Dummy_{t-1}$	-0.007	-0.029***	-0.036*
	[-0.35]	[-4.94]	[-1.65]
$Rating_{t-1}$	-0.243***	-0.006	-0.132***
	[-11.74]	[-1.01]	[-5.71]
HHI_{t-1}	0.266***	-0.024**	-0.155***
	[8.29]	[-2.47]	[-4.38]
$GHHI_{t-1}$	0.016	0.028***	0.018
	[0.68]	[4.16]	[0.72]
RBC $Ratio_{t-1}$	-0.030***	-0.014***	-0.023***
	[-7.92]	[-15.58]	[-5.76]
Cat $Risk_{t-1}$	0.627***		
	[2.33]		
Premium $Growth_{t-1}$			0.033***
			[6.74]
S&P500 $Volatility_t$		-4.124***	
		[-94.24]	
Underwriting $Risk_{t-1}$	0.445***		
	[63.08]		
Investment $Risk_{t-1}$		0.159***	
		[21.39]	
$Leverage_{t-1}$			0.637***
			[51.43]
Intercept	2.563***	4.250***	1.559***
	[14.86]	[93.99]	[8.44]
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

Table 1.3: Continued

Dependent Variable	Underwriting Risk$_t$ Coefficient [T-Stat]	Investment Risk$_t$ Coefficient [T-Stat]	Leverage$_t$ Coefficient [T-Stat]
$\chi 2$	6934.29	23852.21	17245.94
Adjusted-R^2	0.280	0.590	0.513
Kleibergen-Paap rk LM Stat	43.49***	223.96***	14.94***
Wald F Stat	21.79***	57.12***	17.23***
Hansen J Stat	7.13	1.55	2.02
Number of Obs.:		16296	

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and * respectively. Investment risk is measured as percentage of invested assets in common stock, preferred stock and mortgage-backed securities; Underwriting risk is measured natural logarithm of standard deviation of insurers' combined ratio over the three-year period; Leverage is net premiums written divided by policyholders' surplus; Reinsurance usage is measured as reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Firm size is measured as natural log of total admitted asset; Firm age is measured as the natural logarithm of insurers' operational year; RBC ratio is measured as total adjusted capital divided by company action level RBC; Rating is a dummy variable equals to one if the insurer is rated above B+; Catastrophe Risk Exposure is premiums written from homeowners line in Gulf area and coastal states and earthquake line divided by total premiums written; Stock Dummy equals to one if firm is a stock insurer; Group Dummy equals to one if the insurers is an affiliated company and zero otherwise; HHI is Herfindahl index of net premiums written by business lines; GHHI is Herfindahl index of net premiums written by states; Premium growth is change in net premium written from year t-1 to year t; Volatility of S&P 500 Index is the annual volatility rate of S&P 500 index. Instrument relevance is tested via a Kleibergen-Paap rk LM test and Wald test in the first-stage regression. The Hansen J test evaluates the validity of the instruments.

The 9-11 terror attack event has aroused attention on the relationship between underwriting and investment activities. The unprecedented simultaneous shock to both insurers' asset and liability risks revealed the potential correlation between underwriting and investment risks, which was previously underestimated. To test that, in a sub-sample analysis, I use only a sample after the 9-11 terror attack, which is from year 2002 to year 2013. The results are presented in Table 1.4. Based on this table, I find that there is still no significant relationship existing between underwriting risk and investment risk in the post 9-11 era. And the leverage ratio is proven again to be negatively related to investment risk and underwriting risk. Other results are similar to main regression results. Therefore, based on the subsample analysis, after the 9-11 terror attack, insurers still may have neglected the relationship between underwriting risk and investment risk. There is no direct evidence showing an increased correlation between insurers' underwriting risk and investment risk.

Table 1.4: 3SLS Regression Results: Relationship Between Insurers' Investment Risk, Underwriting Risk, and Leverage after 9-11, 2002-2013

Dependent Variable	Underwriting $Risk_t$ Coefficient [T-Stat]	Investment $Risk_t$ Coefficient [T-Stat]	$Leverage_t$ Coefficient [T-Stat]
Underwriting $Risk_t$		-0.001 [-0.81]	-0.122*** [-7.37]
Investment $Risk_t$	-0.154 [-1.07]		-0.969*** [-11.72]
$Leverage_t$	-0.168*** [-9.83]	-0.030*** [-16.82]	
$Reinsurance_{t-1}$	0.237*** [8.16]	-0.025*** [-7.80]	0.004 [0.13]
Firm $Size_{t-1}$	0.013** [2.11]	0.005*** [8.26]	0.058*** [8.54]
Firm Age_{t-1}	-0.024** [-2.17]	0.006*** [5.17]	-0.021* [-1.76]
Stock $Dummy_{t-1}$	-0.048** [-2.32]	-0.018*** [8.36]	0.018 [0.77]
Group $Dummy_{t-1}$	-0.025 [-1.07]	0.006*** [2.75]	-0.003 [-0.14]
$Rating_{t-1}$	-0.143*** [-6.93]	-0.005*** [-2.13]	-0.166*** [-6.98]
HHI_{t-1}	0.212*** [6.70]	-0.006* [-1.68]	-0.172*** [-4.83]
$GHHI_{t-1}$	0.024 [1.03]	0.001 [0.42]	0.071*** [2.71]
RBC $Ratio_{t-1}$	-0.030*** [-5.88]	-0.008*** [-14.64]	-0.096*** [-21.05]
Cat $Risk_{t-1}$	0.111*** [4.14]		
Premium $Growth_{t-1}$			0.307*** [17.27]
S&P 500 $Volatility_t$		-0.672*** [-6.25]	
Underwriting $Risk_{t-1}$	0.491*** [64.81]		

Table 1.4: Continued

Dependent Variable	Underwriting $Risk_t$ Coefficient [T-Stat]	Investment $Risk_t$ Coefficient [T-Stat]	$Leverage_t$ Coefficient [T-Stat]
Investment $Risk_{t-1}$		0.668***	
		[112.66]	
$Leverage_{t-1}$			0.489***
			[48.88]
Intercept	1.514***	0.792***	1.634***
	[11.55]	[6.61]	[11.27]
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
$\chi 2$	6578.76	25912.20	12569.36
Adjusted-R^2	0.378	0.674	0.507
Kleibergen-Paap LM Stat	223.91***	223.96***	14.41***
Wald F Stat	57.10***	57.12***	10.92***
Hansen J Test	7.94	6.24	5.84
Number of Obs.:		12302	

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and *, respectively.

Investment risk is measured as percentage of invested assets in common stock, preferred stock and mortgage-backed securities; Underwriting risk is measured natural logarithm of standard deviation of insurers' combined ratio over the three-year period; Leverage is net premiums written divided by policyholders' surplus; Reinsurance usage is measured as reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Firm size is measured as natural log of total admitted asset; Firm age is measured as the natural logarithm of insurers' operational year; RBC ratio is measured as total adjusted capital divided by company action level RBC; Rating is a dummy variable equals to one if the insurer is rated above B+; Catastrophe Risk Exposure is premiums written from homeowners line in Gulf area and coastal states and earthquake line divided by total premiums written; Stock Dummy equals to one if firm is a stock insurer; Group dummy equals to one if the insurers is an affiliated company and zero otherwise; HHI is Herfindahl index of net premiums written by business lines; GHHI is Herfindahl index of net premiums written by states; Premium growth is change in net premium written from year t-1 to year t; Volatility of S&P 500 Index is the annual volatility rate of S&P 500 index.

Instrument relevance is tested via a Kleibergen-Paap rk LM test and Wald test in the first-stage regression. The Hansen J test evaluates the validity of the instruments.

In addition to the subsample analysis, I also perform another set of robustness check by using the full sample and adding the year dummy for post 9-11 event and interacts it with all the independent variables.[19] The results are presented in Table 1.5. As a result, I find that the interaction terms of post 9-11 dummy and main variables of interest (underwriting risk, investment risk, and leverage) are not significant. This shows that the relationship between underwriting risk, investment risk, and leverage before and after the 9-11 event does not change much. The results are also consistent with subsample analysis.

Furthermore, to check whether insurers' risk-taking behavior changes in the aftermath of the recent global financial crisis, I use a similar procedure: I add a post financial-crisis dummy variable and interact it with all independent variables in the model.[20] The results are displayed in Table 1.6. As we can see, the interaction terms of the post financial-crisis dummy and the main explanatory variables are only significant between leverage and underwriting risk, and leverage and investment risk. And the sign of these coefficients is all negative. This indicates that after the financial crisis, there is an increasingly negative relationship between leverage and underwriting risk/investment risk. But still, I did not find any significant change between underwriting risk and investment risk before and after the financial crisis. With more recent data available, future studies would be more interesting if we expand the sample period to more recent years.

[19] I add a Post 9-11 Dummy variable for years after the 9-11 terror attack, which is from year 2002 to 2013.
[20] Similarly, I add a post financial crisis dummy (Post FC Dummy) for post 2008-2009 financial crisis years: which is from year 2010 to 2013.

Table 1.5: 3SLS Regression Results: Relationship Between Insurers' Investment Risk, Underwriting Risk, and Leverage with Post 9-11 Dummy, 1998-2013

Dependent Variable	Underwriting Risk$_t$ Coefficient [T-Stat]	Investment Risk$_t$ Coefficient [T-Stat]	Leverage$_t$ Coefficient [T-Stat]
Underwriting Risk$_t$		-0.005 [-1.21]	-0.679*** [-4.25]
Investment Risk$_t$	-0.487 [-1.68]		-0.080*** [-4.32]
Leverage$_t$	-0.176*** [-12.17]	-0.067*** [-22.58]	
Reinsurance$_{t-1}$	0.241** [2.53]	-0.288*** [-11.50]	-0.072 [-0.61]
Firm Size$_{t-1}$	-0.014 [-0.61]	0.914*** [25.77]	0.075*** [3.59]
Firm Age$_{t-1}$	-0,038 [-1.32]	0.055*** [6.85]	-0.053 [-1.49]
Stock Dummy$_{t-1}$	-0.233*** [-3.25]	-1.115*** [-5.69]	-0.006 [-0.07]
Group Dummy$_{t-1}$	0.081 [1.10]	-0.268*** [-15.05]	-0.217** [-2.50]
Rating$_{t-1}$	-0.472*** [-6.67]	0.156*** [7.98]	0.080 [0.92]
HHI$_{t-1}$	0.757*** [8.10]	-0.131*** [-4.94]	-0.289** [-2.52]
GHHI$_{t-1}$	0.113 [1.59]	0.084*** [4.17]	0.044 [0.50]
RBC Ratio$_{t-1}$	-0.012* [-1.77]	-0.017*** [-9.21]	-0.040*** [-4.97]
Cat Risk$_{t-1}$	0.168*** [4.68]		
Premium Growth$_{t-1}$			0.039*** [7.16]
S&P 500 Volatility$_t$		-0.432*** [-3.61]	
Underwriting Risk$_{t-1}$	0.457*** [33.31]		
Investment Risk$_{t-1}$		0.182*** [25.52]	
Leverage$_{t-1}$			0.602*** [52.06]
UR*Post 9-11 Dummy		1.421 [1.892]	-1.382 [-0.34]

Table 1.5: Continued

Dependent Variable	Underwriting Risk$_t$ Coefficient [T-Stat]	Investment Risk$_t$ Coefficient [T-Stat]	Leverage$_t$ Coefficient [T-Stat]
IR*Post 9-11 Dummy	-0.140		1.114
	[-0.07]		[1.09]
Lev*Post 9-11	0.280	3.76	
Dummy	[1.46]	[1.862]	
Reinsurance*Post 9-	-0.020	-0.432***	6.465***
11 Dummy$_{t-1}$	[-0.21]	[-17.11]	[4.66]
Size*Post 9-11	0.026	0.716***	-1.532***
Dummy$_{t-1}$	[1.58]	[16.34]	[-4.03]
Age* Post 9-11	-0.002	1.315***	-1.337***
Dummy	[-0.06]	[17.37]	[-3.69]
Stock*Post 9-11	0.202***	1.197***	3.896
Dummy	[2.72]	[13.35]	[0.88]
Group* Post 9-11	-0.088	-2.208***	4.497***
Dummy	[-1.19]	[-15.30]	[3.99]
Rating*Post 9-11	0.248***	7.478***	-6.761***
Dummy	[3.31]	[18.14]	[-5.65]
HHI*Post 9-11	-0.539***	-8.815***	7.907***
Dummy	[-5.43]	[-18.03]	[6.01]
GHHI*Post 9-11	-0.114	-1.108***	-7.578***
Dummy	[1.53]	[-12.94]	[-2.61]
RBC*Post 9-11	-0.011*	0.250***	3.066***
Dummy	[-1.73]	[15.15]	[5.66]
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
$\chi 2$	7217.24	27314.51	15208.26
Adjusted-R^2	0.293	0.622	0.484
Kleibergen-Paap LM Stat	214.27***	213.89***	13.86***
Wald F Stat	54.19***	54.73***	10.20***
Hansen J Test	5.48	4.32	5.04
Number of Obs.:		16296	

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and *, respectively. Investment risk is measured as percentage of invested assets in common stock, preferred stock and mortgage-backed securities; Underwriting risk is natural logarithm of standard deviation of insurers' combined ratio over the three-year period; Leverage is net premiums written divided by policyholders' surplus; Reinsurance usage is reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Firm size is natural log of total admitted asset; RBC ratio is total adjusted capital divided by company action level RBC; Rating is a dummy variable equals to one if the insurer is rated above B+; Catastrophe Risk Exposure is premiums written from homeowners line in Gulf area and coastal states and earthquake line divided by total premiums written; Stock Dummy equals to one if firm is a stock insurer; Group dummy equals to one if the insurers is an affiliated company and zero otherwise; HHI is Herfindahl index of net premiums written by business lines; GHHI is Herfindahl index of net premiums written by states; Premium growth is change in net premium written; Volatility of S&P 500 is the annual volatility rate of S&P 500 index; Post 9-11 Dummy is a dummy variable equals to one for years after the 9-11 terror attack: year 2002 - 2013. Instrument relevance is tested via a Kleibergen-Paap rk LM test and Wald test in the first-stage regression. The Hansen J test evaluates the validity of the instruments.

Table 1.6: 3SLS Regression Results: Relationship Between Insurers' Investment Risk, Underwriting Risk, and Leverage with Post Financial Crisis Dummy, 1998 - 2013

Dependent Variable	Underwriting $Risk_t$ Coefficient [T-Stat]	Investment $Risk_t$ Coefficient [T-Stat]	$Leverage_t$ Coefficient [T-Stat]
Underwriting $Risk_t$		-0.007	-0.281***
		[-1.46]	[-3.50]
Investment $Risk_t$	-0.507		-0.045***
	[-1.35]		[-2.98]
$Leverage_t$	-0.178***	-0.063***	
	[-11.16]	[-19.63]	
$Reinsurance_{t-1}$	0.222***	-0.065***	0.127***
	[7.24]	[-7.40]	[3.28]
Firm $Size_{t-1}$	0.007	0.033***	0.034***
	[0.92]	[20.42]	[3.66]
Firm Age_{t-1}	-0.042***	0.024***	-0.036***
	[-3.68]	[7.73]	[-2.56]
Stock $Dummy_{t-1}$	-0.058**	-0.038***	0.043
	[-2.48]	[-5.77]	[1.51]
Group $Dummy_{t-1}$	0.002	-0.032***	-0.031
	[0.08]	[-5.40]	[-1.22]
$Rating_{t-1}$	-0.246***	-0.006	-0.146***
	[-11.54]	[-0.92]	[-5.51]
HHI_{t-1}	0.270***	-0.022**	-0.173***
	[8.01]	[-2.22]	[-4.27]
$GHHI_{t-1}$	0.013	0.028***	0.015
	[1.53]	[4.05]	[0.51]
RBC $Ratio_{t-1}$	-0.024***	-0.013***	-0.024***
	[-6.15]	[-14.13]	[-5.66]
Cat $Risk_{t-1}$	0.064***		
	[2.34]		
Premium $Growth_{t-1}$			0.039***
			[6.81]
S&P 500 $Volatility_t$		-4.12***	
		[-93.12]	
Underwriting $Risk_{t-1}$	0.452***		
	[64.25]		
Investment $Risk_{t-1}$		0.165***	
		[22.21]	
$Leverage_{t-1}$			0.626***
			[51.80]

Table 1.6: Continued

Dependent Variable	Underwriting Risk$_t$ Coefficient [T-Stat]	Investment Risk$_t$ Coefficient [T-Stat]	Leverage$_t$ Coefficient [T-Stat]
UR*Post FC		-0.039***	-0.209***
Dummy		[-3.81]	[-5.22]
IR*Post FC	-0.131		-1.299***
Dummy	[-0.48]		[-4.42]
Lev*Post FC	-0.021***	-0.013	
Dummy	[-0.65]	[-1.56]	
Reinsurance*Post	0.033	0.023	-0.098
FC Dummy$_{t-1}$	[0.28]	[0.67]	[-0.68]
Size*Post FC	0.018	-0.018**	0.004
Dummy$_{t-1}$	[0.69]	[-2.49]	[0.15]
Age* Post FC	0.063	-0.007	0.044
Dummy	[1.34]	[-0.51]	[0.77]
Stock*Post FC	0.089	0.005	0.004
Dummy	[0.97]	[0.19]	[0.04]
Group* Post FC	-0.092	0.035	-0.047
Dummy	[-1.10]	[1.42]	[-0.46]
Rating*Post FC	0.061	-0.002	0.097
Dummy	[0.67]	[-0.08]	[0.88]
HHI*Post FC	0.307**	0.044	0.916
Dummy	[2.39]	[1.14]	[0.98]
GHHI*Post FC	-0.076	-0.008	0.063
Dummy	[-0.79]	[-0.28]	[0.54]
RBC*Post FC	0.007	-0.003	-0.022*
Dummy	[0.62]	[-1.08]	[-1.73]
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
$\chi 2$	6951.12	23807.53	15533.89
Adjusted-R^2	0.287	0.589	0.490
Kleibergen-Paap LM Stat	204.62***	203.37***	12.01***
Wald F Stat	59.39***	57.20***	11.29***
Hansen J Test	5.49	4.28	6.43
Number of Obs.:		16296	

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and *, respectively. Investment risk is measured as percentage of invested assets in common stock, preferred stock and mortgage-backed securities; Underwriting risk is measured natural logarithm of standard deviation of insurers' combined ratio over the three-year period; Leverage is net premiums written divided by policyholders' surplus; Reinsurance usage is measured as reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Firm size is measured as natural log of total admitted asset; Firm age is measured as the natural logarithm of insurers' operational year; RBC ratio is measured as total adjusted capital divided by company action level RBC; Rating is a dummy variable equals to one if the insurer is rated above B+; Catastrophe Risk Exposure is premiums written from homeowners line in Gulf area and coastal states and earthquake line divided by total premiums written; Stock Dummy equals to one if firm is a stock insurer; Group dummy equals to one if the insurers is an affiliated company and zero otherwise; HHI is Herfindahl index of net premiums written by business lines; GHHI is Herfindahl index of net premiums written by states; Premium growth is change in net premium written from year t-1 to year t; Volatility of S&P 500 Index is the annual volatility rate of S&P 500 index; Post FC Dummy is a dummy variable equals to one if the year is after the occurrence of 2008-2009 financial crisis: year 2010 – 2013. Instrument relevance is tested via a Kleibergen-Paap rk LM test and Wald test in the first-stage regression. The Hansen J test evaluates the validity of the instruments.

1.6.3. Robustness Check

In the robustness check, I use alternative measures for underwriting risk and investment risk variables. First, for underwriting risk, I use the proportion of net premium written in the risky lines, which includes commercial auto liability, allied lines, earthquake, surety, theft, inland marine, fire, international, boiler and machinery, reinsurance, and medical malpractice occurrence. My definition of the alternative underwriting risk is based on Cheng and Weiss (2013)'s discussion in the view of RBC risk factor loadings. The overall results are quite consistent with the main results that insurers tend to tradeoff between the leverage ratio and underwriting risk and investment risk, but there is no clear evidence showing that underwriting risk and investment risk also have a trade-off relationship during the sample period.

Second, an alternative way to measure investment risk is to use the proportion of invested assets in common stock, preferred stock, mortgage-backed securities and low-rated bonds.[21] This includes a broader measure of insurers' risky asset. Again, the results are similar to the main results. Therefore, applying an alternative measure does not change the main conclusions of this paper.

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[21] Low-rated bonds (class 4 to class 6 bond) measures exposure to non-investment grade bonds as a percentage of surplus. Generally, non-investment grade bonds carry higher default and liquidity risks. The designation of Class 3 through 6 bonds as non-investment grade utilizes the NAIC bond quality classifications that coincide with different bond ratings assigned by major credit rating agencies.

1.7. Conclusions

This study presents an empirical analysis of the interactions between U.S. P/C insurers' investment risk, underwriting risk, and leverage risk using an appropriate methodology based on a conceptual framework grounded in insurance theory. Simultaneous equation model is used to express the relationship between insurers' leverage ratio and two types of risks: underwriting risk and investment risk. Overall, the results support the trade-off hypothesis, which indicates that insurers trade off one risk against the other. Specifically, I find that leverage is negatively related to both insurers' investment risk and underwriting risk. This is a piece of evidence showing that insurers make a joint decision towards their overall risk-taking: insurers with a higher underwriting risk or investment risk will choose to operate at relatively lower leverage to avoid excessive financial risk. However, the results also suggest that there are no direct association between insurers' underwriting risk and investment risk, even after the 9-11 terror attack.

This is the first empirical study systematically examining the relationship between U.S. P/C insurers' investment risk, underwriting risk, and leverage risk simultaneously using the data in recent years. Instead of modeling the relationship between these decision variables in pairs, I estimate it with a 3SLS method and use a simultaneous framework incorporating the partial adjustment effects. Some prior studies use the 3SLS to examine the relationship between capital and risk, but this extensive empirical work also discusses the relationship between leverage and firm risks while also considering the impact of group affiliation, firm size, firm age, and organizational form, etc. Additionally, I conduct subsample analyses to address the impact of 9-11 terror attack and financial crisis on insurers' risk-taking behavior. And this study has revealed P/C insurers' different adjustment speeds towards the targeted level of risks and leverage. In this way, this study provides some new insights into insurers' risk-taking behavior.

The results show that insurers are making joint decisions by adjusting their leverage ratio based on the underwriting risk and investment risk level. However, insurers might still have underestimated the relationships between underwriting risk and investment risk. This study has some important policy implications, since the risk-taking behavior of U.S. P/C insurers affects the firms' financial fragility and economic growth. Figuring out how these three different types of risks are related would be helpful for regulators to better scrutinize insurers' total risk and insolvency.

CHAPTER 2

IMPACT OF CREDIT RISK ON INSURERS' REINSURANCE DEMAND -- EVIDENCE FROM U.S. PROPERTY-CASUALTY INSURANCE INDUSTRY

2.1. Introduction

Reinsurance plays a fundamental economic role in the insurance industry. Reinsurers are equipped with a superior capacity to diversify and transfer risks nationwide and globally, reduce insurers' insolvency propensity, and deal with the uncertainties or shocks caused by catastrophic losses. Through ceding risks to reinsurers, a primary insurer is benefited in several ways. According to Webb et al. (2002), there are six functions that reinsurers provide to insurance companies: stabilization of loss experience, increase in capacity, surplus relief, catastrophe protection, underwriting assistance and withdrawal from business territory or class.

Given the importance of reinsurance, considerable research has been done in this field. Some traditional studies focus on dealing with the information asymmetries in the insurer-reinsurer relationships (Garven, Hilliard, and Grace, 2014). Others explore into the costs and benefits of reinsurance (Cummins et al., 2008). Another strand of studies analyzes the demand for reinsurance by primary insurers (Cole and McCullough, 2006; Tan and Weng, 2012). According to their findings, the motivations for reinsurance demand include investment incentives, bankruptcy cost, risk-bearing incentives, and the availability of real services.

Despite the abundant studies on reinsurance-related topics, little has been done to examine how insurers' reinsurance demand is affected by their credit risk. The main objective of this research is to analyze the relationship between insurers' reinsurance demand and firms' credit risk. According to A.M. Best, a Best's Credit Rating (BCR) is a forward-looking, independent, and objective opinion regarding an insurer's relative creditworthiness. The opinion represents a comprehensive analysis consisting of a quantitative and qualitative evaluation of balance sheet strength, operating performance, and business profile or the specific nature and details of a security.[22] To measure credit risk, I rely on Gavern, Hilliard, and Grace (2014) and use insurers' rating grade as a proxy for credit risk. In addition, I also study the impact of rating movement, especially downgrades, on insurers' reinsurance demand.

This study relates insurers' reinsurance demand and credit rating. The rating agencies provide policyholders with information on the credit-worthiness of the insurers. U.S. P/C insurers are rated by various rating agencies, including A.M. Best, Standard and Poor's, Moody's and Fitch rating. Amongst these rating agencies, A.M. Best is a U.S.-based professional agency that exclusively focuses on the insurance industry, and its rating system is regarded as a benchmark in the industry. Financial rating is important to an insurer, as many corporate insurance purchasers have minimum ratings requirements, and personal-lines consumers are price sensitive with respect to ratings (Berger, Cummins, and Tennyson, 1992). Prior literature also suggests that maintaining a high rating is beneficial. For instance, Epermanis and Harrington (2006) document that firms will experience a decrease in premiums written following rating downgrades.

Theoretically, insurers' credit ratings can affect their reinsurance purchases. As mentioned by Sommer (1996), policyholders pay higher premium to be insured by less risky insurers, which provides an incentive for insurers to reduce default risk by purchasing

[22] See A.M. Best Guide to Understanding Best's Credit Ratings (2016), page 3-4.

reinsurance. Reinsurance can reduce firms' expected cost of bankruptcy, and insurers can benefit from the real services of the reinsurers who has relative advantages over ceding insurers in provision of these services (Mayers and Smith, 1982). Primary insurers transfer part of their underwriting risks to the counterparty reinsurers to obtain surplus relief, hedge the risk of catastrophic losses, stabilize underwriting performance, and expand capacity to undertake new businesses (Cole et al., 2011). By doing so, insurers can diversify their risk profile or mitigate loss volatility, ultimately improving their financial reports. Since some of the accounting measures in financial reports that are affected by reinsurance arrangements also largely overlap with the factors affecting the A.M. Best rating, the utilization of reinsurance may be motivated by rating related reasons.

This paper expands the existing literature by linking reinsurance demand and insurers' credit risk and downgrade risk. Prior studies have related reinsurance demand to many firm-specific characteristics. In this study, I will mainly explore whether and to what extent insurers' reinsurance demand is affected by credit rating status and downgrade risk.

The remainder of this paper is organized as follows: section 2 briefly reviews the relevant literature on reinsurance. Section 3 develops hypotheses. Section 4 presents the data and describes variables. Section 5 outlines the methodology. Finally, sections 6 and 7 continue the analysis of empirical results and conclusion of this paper.

2.2. Literature Review

2.2.1. Determinant of Reinsurance Demand

There is ample research on the determinant factors for reinsurance demand. Mayers and Smith (1990) argue that the purchase of reinsurance by an insurance company is comparable to the purchase of insurance by firms in other industries. They find that the ownership structure, firm size, geographic concentration, and line-of-business concentration factors all have significant impacts on the demand for reinsurance. Garven and Lamm-Tennant (2003) present a thorough summarization of the theoretical motivations for reinsurance demand. According to their empirical findings, factors such as firm size, leverage, equity risk, and length of the tail have a significant impact on the demand for reinsurance.

In a similar manner, Cole and McCullough (2006) examine how the state of the reinsurance industry affects reinsurance demand by exploring the overall demand for reinsurance and the utilization of foreign reinsurance by U.S. P/C insurers. Consistent with prior literature, they find such demand is mainly driven by firm size, group affiliation, and organizational form. Garven, Hilliard, and Grace (2014) expand the literature by specifically examining the impact of insurer-reinsurer relationship tenure on reducing information asymmetry in reinsurance transactions. They find that the demand for reinsurance, ceding insurer’s profitability, and A.M. Best rating grade all increase with the tenure of the insurer-reinsurer relationship.

Some studies focus on how bankruptcy affects reinsurance demand. For example, Sloan, Hoerger, and Hassan (1990) find that the probability of bankruptcy affects a firm’s reinsurance decision. The purchase of reinsurance shifts some portion of the insurer's risk to the reinsurer, thus reducing the probability and expected cost of bankruptcy. This finding also provides some theoretical foundation for my study since I also study how bankruptcy-related factors affect insurers’ reinsurance demand. But I adopt a different proxy for credit risk. Mayers and Smith (1990) use the A.M. Best rating as a proxy for default risk and analyze how it affects reinsurance transactions. Their results imply that highly-rated insurers purchase less reinsurance. But this study only uses a limited number of insurers, and A.M. Best used a different rating scale at that time.[23] My current study relates to this study in theory and methodology, but I will use a larger sample and apply a more recent A.M. Best rating system.

2.2.2. Reinsurance and Firm Performance

Following the late 2000s financial crisis, there are increasing attentions focused on the stability of the insurance industry. Some researchers have investigated the counterparty relationship between insurers and reinsurers, and their interconnectedness. Other studies examine how reinsurance affects firms' performance.

Cummins et al. (2008) demonstrate that optimal use of reinsurance can improve shareholder value by substituting for equity, which thereby reduces the cost of capital and increases return from underwriting activities. Cummins and Weiss (2011) investigate the reinsurance counterparty relationship for both property-liability and life insurers in the U.S., by providing both aggregate level and firm level reinsurance information. They conclude that the concentration of ceded reinsurance premiums, as well as reinsurance recoverable, is relatively high for U.S. P/C insurers, which indicates that many primary insurers would be seriously at risk if several large reinsurers were to fail. Cummins, Feng, and Weiss (2012) analyze the counterparty relationship between insurers and reinsurers. They find that firm performance is positively related to reinsurance utilization, especially with foreign reinsurers, but adversely related to concentration in reinsurance counterparties.

Some recent literature on reinsurance uses a micro-level network approach to study how reinsurance network relationships affect firms' performance. For instance, Lin, Yu, and Peterson (2014) test the impact of network centrality (the contracted numbers of

[23] This study includes only a sample of 330 non-group firms, among which 85 firms do not have a valid A.M. Best rating. Also, the A.M. Best rating ranged from A+ to C at the time of this analysis.

reinsurers), and network cohesion (business linkage among the set of reinsurers used) on the reinsurance decision and firm performance. Using a similar methodology, Chen et al. (2014) analyze how reinsurance network position affects insurers' performance. They document a U-shaped relationship between an insurer's network position and its combined ratio, and profitability.

Studies that focus on the impact of reinsurers' rating movements on insurers' performance or reinsurance arrangement are very limited. Epermanis and Harrington (2006) analyze the relationship between an insurer's premium growth and changes in financial strength ratings of U.S. P/C insurers. They find significant premium declines in the year of and the year following rating downgrades, with insurers losing an A- rating suffering the most. They conclude that premium change surrounding rating changes are consistent with risk-sensitive demand.

Park and Xie (2014) review the impact of reinsurers' credit risk on primary insurers' financial strength and stock market performance. They find that primary insurers are more likely to be downgraded when their contracting reinsurers are downgraded. Also, primary insurers' stock price reacts negatively to reinsurers' downgrades. Bodoff (2013) documents that primary insurers manage credit risk by taking into consideration the creditworthiness of reinsurer counterparties. Another relevant study by Park, Rui, and Xie (2015) investigates the relationship between reinsurance demand and the credit risk change of reinsurers, and results show that reinsurance demand is sensitive to the reinsurers' rating movements. Other papers studying rating changes mainly focus on the impact of financial rating downgrades on insurance companies' stock price and most of them find that insurer's stock prices are observed to decrease following downgrades (Halek and Eckles, 2010;

Singh and Power, 1992).

Therefore, despite extensive studies on the reinsurance topic, there are relatively limited studies of the relationship between insurers' credit risk and their reinsurance demand. This study intends to fill this gap to some extent by investigating how sensitive the reinsurance demand is to the credit risk of primary insurers, and testing how ceding insurers' reinsurance strategy changes if they are downgraded.

2.3. Hypothesis Development

2.3.1. Credit Rating and Reinsurance Demand

This section discusses the development of hypotheses that are tested in the subsequent sections of this essay. The hypothesis development is grounded on two basic assumptions. First, reinsurers provide homogeneous service to insurers.[24] Second, the buyers are risk-averse, care about insurers' risk and are willing to pay for a higher price for a policy that has lower risk (Cummins and Danzon, 1997; Weiss and Chung, 2004).

Based upon these two assumptions, I hypothesize that insurers' reinsurance demand will be affected by the insurers' rating. As discussed earlier, A.M. Best's financial strength rating reflects the agency's opinion on the firms' ability to meet their obligations to pay policyholders and remain solvent. An early work of Denenberg (1967) shows the importance of the A. M. Best rating as an effective tool to detect the likelihood of insolvency of P/C insurers. In addition to solvency prediction, the rating also conveys insurers' financial strength. Doherty and Phillips (2002) argue that insurers attempt to market their financial strength ratings as a signal of the firm's financial strength, which is important to policyholders and investors. Similarly, Parekh (2006) suggests that insurers

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[24] Future study will relax this assumption and analyze the quality of reinsurers as well.

with ratings above some specified threshold are more popular than other insurers. Alissa et al. (2013) note that investors are particularly aware of the "investment grade" ratings, providing an incentive for firms to manage earnings around a specific rating. To conclude, maintaining strong financial ratings are beneficiary to attract risk-sensitive customers.

Also, existing theory has shown that reinsurance is effective in maintaining or improving insurers' rating grades, possibly through capital and surplus relief. Rating agencies rely heavily on proprietary capital models which overlap with the formulas that produce insurer RBC ratios (Pottier and Sommer, 1997). According to Mankai and Belgacem (2015), reinsurance is closely related to capital and risk, and is therefore a major consideration for insurers' risk management. Prior literature argues that reinsurance helps reduce insolvency risk. Mayers and Smith (1990) contend that the default risk of the insurer affects the demand for reinsurance through investment incentives and expected bankruptcy costs, which implies that riskier firms have incentives to purchase more reinsurance. They find evidence that high-rated insurers on average have a lower demand for reinsurance. Adams (1996) documents that one way to reduce volatility and insolvency risk is to use reinsurance, particularly when the capital level moves closer to solvency constraints.

Since reinsurance serves as an efficient tool for the ceding insurers to control the risk exposure, improve capital adequacy, and meet a rating agency's certain criteria, insurers with a poor financial rating are expected to be more eager to obtain benefits to capital management and surplus relief through purchasing reinsurance. Therefore, I hypothesize that low-rated insurers are expected to demand more reinsurance. This develops into Hypothesis 1:

> ***Hypothesis 1****:* Insurers' reinsurance demand is sensitive to credit rating status. Insurers with a lower credit rating have a higher demand for reinsurance due to

bankruptcy concerns, other things being equal.

2.3.2. The Impact of Downgrading on Reinsurance Demand

Insurers' credit rating involves regular movements from time to time, where an upgrade or downgrade occurs as firms' performance or capital adequacy changes over time. Downgrades happen when the agency feels that the prospects for the insurer have weakened or deteriorated from the original recommendation, usually due to a material and fundamental change in the company's operations, reputation, and industry outlook. There is an increasingly downhill rating trend before or around impairments.

Insurance companies' downgrade signals negative information to policyholders, investors, regulators, and counterparty reinsurers. Pottier and Sommer (1998) find that downgrades were important predictors for insolvency, suggesting that rating transitions reflect perceived changes in insurers' financial strength. Similarly, Halek and Eckles (2010) examine market reactions to financial strength rating changes. They find a significant negative stock market reaction to the rating changes. Therefore, empirical evidence indicates that downgraded insurers are more likely to suffer from a decline in premium growth or deterioration in stock market performance.

The late 2000s global financial crises, as well as the credit crunch that followed, has put credit risk management under a stricter regulatory spotlight. To ensure safety, regulators began to demand more transparency and increase their scrutiny over insurers' business and risk profile, especially for downgraded insurers or insurers with a rating below a certain threshold. Thus, downgraded insurers are likely to have a stronger incentive to improve their solvency and rating status, possibly by engaging in reinsurance transactions.

According to the market discipline theory (Epermanis and Harrington, 2006), policyholders' insurance demand changes following insurance companies' financial rating changes, and insurance premium growth is significantly and negatively related to their rating downgrades. Park, Rui, and Xie (2015) re-examine the market discipline hypothesis by analyzing the impact of their reinsurers' downgrade risk on insurers' reinsurance demand. Therefore, it is important to see whether the market offers adequate discipline for ceding insurers to manage their credit risk and downgrade risk. If the market discipline theory holds, insurers' reinsurance demand is also expected to be sensitive to their own rating downgrade.

Based on the above discussions, I develop Hypothesis 2, which predicts that downgraded insurers have incentives to enhance their rating to avoid stricter regulatory scrutiny, possibly through the help of reinsurance.

> ***Hypothesis 2:*** Insurers' demand for reinsurance is sensitive to their rating movement. Downgraded insurers have a higher demand for reinsurance than other insurers that are not downgraded, other things being equal.

2.3.3. Internal vs. External Reinsurance Demand

Some ceding insurers can engage in reinsurance transactions with both affiliated and unaffiliated reinsurers.[25] They can either choose to cede to affiliated companies within the same group where the cost is lower, or cede to unaffiliated reinsurers for the benefits of risk diversification. Powell and Sommer (2007) has shown that the internal and external reinsurance are not perfect substitutes for affiliated insurers, and the purchase of internal and external reinsurance are motivated by different reasons. While both internal and external reinsurance are affected by the expected costs of bankruptcy and investment incentives, external reinsurance is also driven by catastrophe risk mitigation.

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[25] Only group-affiliated insurers have both access to affiliated internal reinsurance and external unaffiliated reinsurers. Single stand-alone insurers only can cede to unaffiliated insurers.

Affiliated reinsurance transactions take place within groups of companies under common ownership. Information asymmetries between ceding insurers and their affiliated reinsurers are lower than between insurers and unaffiliated reinsurers. Powell and Sommer (2007) confirm this and show that reinsurance transactions within a group lower information and monitoring cost compared to external reinsurers. Cole et al. (2011) maintain that reinsurers have incentives to monitor their counterparty insurers' underwriting risk. Affiliated reinsurers have better knowledge of primary insurers' underwriting profile and risk exposure; and ceding insurers' information about their counterparty reinsurer is also more accurate when doing business with affiliated reinsurers. Such information availability and transparency between group-affiliated members would naturally affect insurers' reinsurance decisions. Moreover, agency theory implies that the misalignment of the incentives between two agents allows one to pursue strategies different from those preferred by the other. Accordingly, agency problems between group-affiliated insurers are less prominent than between unaffiliated insurers and reinsurers. In addition, the transaction costs for group-affiliated reinsurers are lower than external reinsurers, which could be one of the motivations to use internal reinsurance (Cole et al., 2011; Powell and Sommer, 2007).

In addition, Powell and Sommer (2007) find that reinsurance from internal sources are more cost-effective than from external markets, showing the importance of internal reinsurance transactions with affiliated insurers.[26] And unaffiliated reinsurance often requires longer negotiations over the terms and price of the contract (Doherty and Smetter, 2005). Cole and McCullough (2006) and Mayers and Smith (1990) document a positive

[26] According to Powell and Sommer (1997), internal reinsurance is considered cheaper because of less noisiness created by asymmetric information.

and significant relationship between the use of reinsurance and group membership. Cummins and Weiss (2011) argue that non-affiliated reinsurance poses more counterparty risk than affiliated reinsurance. Therefore, while external reinsurance provides expertise in certain areas, internal reinsurance has lower cost due to the reduced asymmetric information and monitoring cost, and thus is more desirable to the downgraded insurers. To examine how downgrade risk affects group-affiliated insurers' internal reinsurance demand, I develop the following hypothesis:

> ***Hypothesis 3:*** Downgraded insurers will demand more reinsurance from the group-affiliated reinsurers than others that are not downgraded, everything else being equal.

2.4. Data and Sample Selection

The data is mainly obtained from the National Association of Insurance Commissioners (NAIC) database and *Best's Key Rating Guides*, in various years. I merge the two datasets by insurance company NAIC company code. Data on insurers' firm level characteristics is mainly taken from the NAIC annual reports. Reinsurance transaction data is taken from the NAIC Annual Statement -- Schedule F. Insurers' financial strength rating information is collected from A.M. *Best's Key Rating Guide*.

This is a firm-level analysis. I apply the following sample selection criteria to the initial data and sample. First, the firm must be active, and file its NAIC annual statement individually. Second, the firm must have positive values for total assets, liabilities, surplus, and premiums written. Third, I delete firms that have a reinsurance ratio (premiums ceded to reinsurer to total premiums written), internal reinsurance ratio or external reinsurance ratio below zero or above one.[27] In addition, I also exclude the firms with a reinsurance ratio above 75% of total written premiums, since this current study only focus on primary insurers rather than professional reinsurers.[28] Also, the firm must have a recorded rating in the *Best's Key Rating Guide*. Finally, I Winsorize the data at the 1% and 99% level to remove outliers.

The sample period is from 2000 to 2014, 15 years in total. The final sample includes 15,443 firm-year observations. The firms in the sample account for more than 80% of industry assets. Finally, this is an unbalanced panel.

2.5. Methodology

2.5.1. Model

To test Hypothesis 1, I estimate the following model, where reinsurance demand is the dependent variable, and rating grade and firm characteristics are independent variables.

$$ReinsDemand_{it} = \alpha_0 + \alpha_1 Rating_{i,t-1} + \boldsymbol{\alpha_2 X_{i,t-1}} + v_i + u_t + \varepsilon_{it} \quad (1)$$

where ReinsDemand = the quantity of reinsurance used by insurers, measured as the ratio of reinsurance premiums ceded to the sum of direct premiums written and reinsurance assumed;

Rating = numerical rating grade converted from A.M. *Best's Key Rating Guide*, where "1 as the highest and "13" as the lowest (consistent with Garven, Hilliard, and Grace, 2014);

X = a vector of control variables affecting firms' reinsurance demand, which includes:

Firm size = natural logarithm of total admitted asset;

Leverage = net premiums written divided by policyholders' surplus;

Group Affiliation Dummy = value of one if the insurer is group affiliated and zero otherwise;

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[27] In the internal reinsurance analysis regression, in addition to the sample selection criteria described above, I also exclude insurer which has an internal reinsurance ratio equal to zero. In other words, this sample includes group-affiliated insurers only for internal reinsurance regression.

[28] This definition is cited from A.M. Best and was also used by Cole and McCullough (2007).

Stock Dummy = value of one if the insurer is a stock company and zero otherwise;

Catastrophe Risk Exposure = premiums written from homeowners line in gulf area and coastal states, and earthquake line divided by total direct premiums written;

Long-tail Risk = proportion of premium written in long-tail business lines;

HHI = Herfindahl index of net premiums written by business line;

GHHI = Herfindahl index of net premiums written by state;

ROA = net income divided by total assets;

v_t = year-fixed effects;

u_i = firm-fixed effects;

ε_{it}= random error term.

I first consider an Ordinary Least Squares (OLS) model to examine the relationship between firms' credit risk and reinsurance demand. However, an endogeneity test (Hausman Test) indicates the existence of a potential problem in that firms' reinsurance utilization also affects their credit rating. That is, insurers using more reinsurance might have a higher rating because of the benefits embedded in reinsurance transactions. Considering the endogeneity issues, I use 2SLS regression to estimate it. Hypothesis 1 will be supported if the coefficient on the rating variable is positive and significant.

Regarding the choice of instruments, I identify and select them according to the existing literature. I find that the two-period lagged rating variable and one-period lagged BCAR are valid instrument candidates. BCAR measures an insurer's adjusted surplus relative to the required capital necessary to support its operating and investment risks.[29]

[29] BCAR is Best's capital adequacy ratio, which examines an insurer's leverage, underwriting activities, and financial performance and uses this information to test various scenarios to see how each would impact the insurer's balance sheet. BCAR is calculated as adjusted surplus divided by net required capital. More

Companies deemed to have "adequate" balance sheet strength normally would generate a BCAR score of over 100% and will usually carry a Secure Best's Rating. As claimed by A.M. Best, BCAR is the most important factor in issuing a rating (A.M. Best, 2009). To check the relevance and the validity of the instrumental variables, I perform the Kleibergen-Paap rk LM test for under-identification, Kleibergen-Paap rk Wald F test for a weak instrument check, and the Hansen J test for overidentification check.

To test Hypothesis 2, I estimate the following model:

$$ReinsDemand_{it} = \alpha_0 + \alpha_1 Downgrade_{i,t-1} + \boldsymbol{\alpha_2}\mathbf{X_{i,t-1}} + v_i + u_t + \varepsilon_{it} \quad (2)$$

where ReinsDemand = the quantity of reinsurance used by insurers, measured as the ratio of reinsurance premiums ceded to the sum of direct premiums written and reinsurance assumed;

Downgrade = 1 if the insurer has been downgraded by A.M. Best during the previous year;

X = a vector of control variables affecting firms' reinsurance demand, which includes:

Firm size = natural logarithm of total admitted asset;

Leverage = net premiums written divided by policyholders' surplus;

Return on Asset = net income divided by total assets;

Group Affiliation Dummy = value of one if the insurer is group affiliated and zero otherwise;

Stock Dummy = value of one if the insurer is a stock company and zero for mutual;

Catastrophe Risk Exposure = premiums written from homeowners line in Gulf area and coastal states, and earthquake line divided by total direct premiums written;

Long-tail Risk = proportion of premium written in long-tail business lines;

HHI = Herfindahl index of net premiums written by business line;

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information on BCAR is available in A.M. Best 2017 report, *Understanding BCAR for U.S. Property/Casualty Insurers*.

GHHI = Herfindahl index of net premiums written by state;

v_t = year-fixed effects;

u_i = firm-fixed effects;

ε_{it}= random error term.

Hypothesis 2 would be supported if the coefficient on the downgrade variable is positive and significant. The utilization of reinsurance may also affect the firms' capital ratio and the likelihood of being downgraded. In this case, OLS estimation will be biased. Considering this endogeneity issue, I use 2SLS regression with instrumental variable to estimate equation (4). In the first stage, I use probit regression instead of OLS because the dependent variable is a categorical variable. The instrumental variable I use is an economic growth measure. To be specific, I use annual growth in the GDP rate as the instrument, since economic activities are related to firms' rating movement, but unrelated to insurers' reinsurance demand.[30]

In addition, I use lagged values for control variables in the equation since it is the values at the beginning of the period that are most likely to impact the reinsurance decision during the period. Robust standard errors are presented in the reports to correct for heteroscedasticity. Also, the Breusch-Pagan Lagrange Multiplier test indicates that unit effects are present in this dataset, so that either a fixed-effects or a random-effects model should be used to provide a more efficient estimate than a pooled cross-sectional model. A fixed-effects model is preferred according to the Hausman test. Therefore, I add both firm-

[30] Best Annual Impairment Report (2015) has reported that in years of lower economy activity, there is a higher rate of downgrade or impairment propensity. As recorded, the upgrade/downgrade ratio is relatively low from 2004 to 2007 and then increased during 2008-2009 period as the real growth in GDP declined to the lowest historical level of the study period of -2.8% in 2009. While the downgrade ratio in 2009 hits the highest 3.71% in 2009.

fixed and year-fixed effects. This helps to control for both the macroeconomic conditions and insurance industry-specific conditions that affect the ratings of primary insurers. I also assess the degree of multicollinearity among the independent variables using the variance inflation factor (VIF) method. The results show all VIF values for the independent variables are below 10, indicating that multicollinearity is not a concern.

To test Hypothesis 3, I use the internal reinsurance utilization ratio and external reinsurance utilization ratio as the dependent variables to re-estimate equations (1) to (2). In the reinsurance ratio analysis, I include only group-affiliated insurers since the single stand-alone insurers do not have access to group-affiliated reinsurers and do not have the choice to cede business to group-affiliated reinsurers. Therefore, for internal reinsurance analysis, the single unaffiliated insurers are excluded from the sample and the group dummy variable is dropped.

2.5.2. Definition of Variables

Prior studies have documented a few methodologies to define reinsurance demand. In this study, I use reinsurance premium ceded divided by direct premiums written plus reinsurance premiums assumed as a measure for reinsurance demand (Cole and McCullough, 2006; Garven and Lamm-Tennant, 2003; Mayers and Smith, 1990). The detailed definitions for all variables are presented in Table 2.1.

The main explanatory variable is Rating and Downgrade. The rating variable refers to an insurers' credit rating quality, and it is defined as a group of ordered numbers by converting a firm's A.M. Best rating into a number. Garven, Hilliard, and Grace (2014) define firms' rating as a categorical variable so that if the insurer falls within the various A-rating categories (A++, A+, A, and A−), then it is assigned scores of 1, 2, 3, and 4, respectively. If the insurer falls within the various B rating categories (B++, B+, B, and

B−), then it is assigned scores of 5, 6, 7, and 8, respectively; if the insurer falls within the various C rating categories (C++, C+, C, and C−), then it is assigned scores of 9, 10, 11, and 12, respectively; if the insurer falls within the D, E, or F rating categories, then it is assigned a score of 13. Consistent with this method, I assign 13 ordered numbers to 13 discrete rating categories (from the highest, A++ to the lowest, D), with "1" as the highest and "13" as the lowest. Downgrade is a dummy variable assigned the value one of if the insurer is downgraded by A.M. Best during the previous year.

Other control variables include firm size, return on assets, leverage ratio, long-tail risk exposure, catastrophe risk exposure, organizational form dummy, group affiliation dummy, line-of-business concentration, and geographical concentration.[31]

First, firm size is measured as the natural logarithm of the firm's total net admitted assets. Prior studies predict that firm size has a negative impact on the demand for reinsurance, because smaller insurers purchase more reinsurance to reduce their probability of bankruptcy. According to Cummins, Feng, and Weiss (2012), large insurers with significant financial strength depend less on reinsurance in expanding their underwriting capacity both because larger firms have a higher degree of internal risk diversification than smaller firms, and because they have higher capitalization relative to the size of the risks insured. Therefore, larger insurers are expected to use less reinsurance.

Second, prior studies show that insurers' profitability should be associated with their reinsurance demand. To control for this impact, I add a return on asset (ROA) variable, measured as net investment gain divided by total assets. Cole and McCullough (2006) use ROA as a proxy for profitability to test the underinvestment problem and bankruptcy

[31] I also considered some other variables but many of these variables are related with each other, causing multicollinearity problem. I keep only significant variables and remove similar ones.

avoidance as potential motivations for the purchase of reinsurance. They find a negative and significant relationship between ROA and the use of reinsurance. Mayer and Smith (1990) and Powell and Sommer (2007) also find similar results. Because more profitable insurers are expected to have more cash resources to cover the assumed underwriting risks than relatively less profitable insurers, it is expected that insurers that earn more profits are better able to tolerate larger losses or financial pressures and thus demand less reinsurance.

Third, I add leverage variable which is defined as the net premiums written divided by policyholders' surplus. It is expected that insurers with higher leverage are expected to demand more reinsurance because of investment incentives. According to Myers (1977), some firms may have the incentive to reject positive net present value (NPV) projects because of the conflicts of interest that exist between shareholders and debt holders. Similarly, large unexpected losses may cause the equity-holders of an insurance company to reject a positive NPV project since the benefits would primarily go to the policyholders. By purchasing reinsurance an insurer can transfer the risk of large unexpected losses to reinsurers, and reduce the expected cost of foregoing valuable projects. In this way, insurers with higher leverage are expected to demand more reinsurance because of investment incentives. Consistent with this argument, Mayers and Smith (1990) hypothesize that the use of reinsurance can potentially reduce underinvestment by transferring some of the uncertainty resulting from the potential for large losses to the reinsurer. Cole and McCullough (2006), and Garven and Lamm-Tennant (2003) also predict a positive relationship between the leverage ratio and demand for reinsurance. Therefore, I expect that insurers with a higher leverage tend to utilize more reinsurance.

Furthermore, following the literature (Fier, McCullough, and Carson, 2013), I define long-tail risk as the business written in lines that include farmowners multiple peril, homeowners multiple peril, commercial multiple peril, ocean marine, medical malpractice, international, reinsurance, workers' compensation, other liability, products liability, aircraft, boiler and machinery, and automobile liability.[32] Writing in long-tail business lines may create significant risk for U.S. P/C insurers, because the total loss amounts are not known for many years following policy issue. Firms that write more business in long-tail lines are considered to have higher underwriting risk than short-tail business, because of unpredictable loss payment and a longer time lag between premium receipt and claim payments. Therefore, I expect that there will be a positive relationship between the long-tail risk and reinsurance demand.

In addition to long-tail risk, I also add a catastrophe risk exposure variable as a proxy for underwriting portfolio risk. Following the method used in Powell and Sommer (2007), I define it as the percentage of an insurer's premiums written in the earthquake line nationwide and in the homeowners line in the Gulf area and east coast states.[33] Insurers that write more business in catastrophe-prone areas are more likely to suffer from a catastrophe shock and have higher underwriting risk. Prior studies have shown that insurers that write riskier lines of business, such as insurance for property catastrophes, or long-tail lines, such as other liability or product liability, are likely to be more reliant on reinsurance.[34] Therefore, a positive relationship is expected to be found between reinsurance demand and insurers' catastrophe risk exposure.

[32] Long-tail business lines exclude surety, fidelity, fire, allied lines, island marine, financial guaranty, earthquake, credit accident and health, group accident and health, burglary and theft, auto physical damage, warranty, and credit.
[33] The Gulf areas and east coast states include Florida, South Carolina, Texas, Alabama, and Missouri.
[34] See Cummins, Feng, and Weiss (2012).

Then, I add two dummy variables. The first dummy variable describes insurers' organizational form. The major types of organizational forms for U.S. P/C insurers are stock and mutual, so this sample includes stock insurers and "mutual" insurers.[35] And "mutual" includes both mutual and reciprocal.[36] A Stock Dummy is assigned a value of one for stock insurers and zero otherwise. Mayers and Smith (1990) suggest that the organizational form could influence insurers' risk-taking behavior and alter the demand for reinsurance. They argue that a mutual firm is likely to have greater difficulty accessing sources of new capital in the event of a large loss and therefore purchases more reinsurance. Wang et al. (2008) find some evidence that demutualized insurers decrease their need for reinsurance after conversion, suggesting that mutual insurers have a higher demand for reinsurance. Harrington and Niehaus (2002) also find that mutual insurers tend to hold more capital than stock insurers and are more likely to manage risk through reinsurance. So, I expect a negative relationship between stock dummy and reinsurance demand.

Group affiliation dummy is assigned a value of one if insurers belong to a group of insurers under common ownership, and zero otherwise. Group members may be considered more financially strong if differences are perceived for insurers that are members of a group. Affiliated insurers in general are less exposed to capital constraints because of the possible funding help from other associated firms within the group and therefore may afford to bear more risks (Cummins and Sommer, 1996). But it is also possible that group-affiliated insurers have more access to cede business to group-affiliated reinsurers.

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[35] There are also other organizational forms and ownership structures existing in the insurance industry, including Lloyds and risk retention groups (RRGs). I exclude these types because they are relatively rare and uninfluential in the U.S. P/C market. According to the NAIC records, Lloyds only accounts for less than 1 percent of total P/C premiums, and RRGs' market share is even lower.

[36] Mutual and reciprocal are grouped together because mutual and reciprocal have similar owner–manager agency problems (Cheng, Cummins, and Weiss, 2017).

Finally, to control for the effects of diversification, I add two Herfindahl index variables: HHI and GHHI.[37] Both Herfindahl indexes are based on net premium written by lines of business and states, respectively.[38] Firms with a lower Herfindahl index demonstrate a more diversified premium composition, either in business lines written or in geographic areas involved. Prior studies have mentioned that the demand for reinsurance could be driven by product mix (Wang et al., 2008). In fact, reinsurers not only provide protection for unexpected large losses to insurers but also offer real services associated with specialized knowledge and economies of scale. If insurers issue policies in multiple lines of business or diverse states, they will have a greater motivation to purchase reinsurance because of such reasons. So, from a real services hypothesis, a more business- or geographically-concentrated insurer may demand less reinsurance.

On the other hand, a reinsurance contract offers a mechanism to increase the diversification of risk for insurers. According to the risk diversification theory, insurers with a highly-concentrated business composition in a given line or geographic area may have a higher incentive to purchase more reinsurance, probably because they have a higher demand to diversify a particular type of risk they undertake. By contrast, if insurers issue policies in multiple lines of business or diverse geographic areas, they may have a lower incentive to purchase reinsurance. Consequently, a higher business- or geographically-concentrated insurer may demand more reinsurance. The sign on business concentration and geographic concentration variables are ambiguous due to such conflicting explanations.

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[37] These two Herfindahl Indexes are widely used as control variables in the literature. See Mayers and Smith (1988, 1994), and Pottier and Sommer (1997).

[38] They are calculated as: $HHI = \sum_{i=1}^{N} s_i^2$ and $GHHI = \sum_{i=1}^{N} s_j^2$, where s_i = the proportion of net premiums written in line i divided by total net premium; and s_j = the proportion of net premiums written in state j divided by total net premium.

Table 2.1: Definitions of Variables

Variables	Definition
<u>Reinsurance Variables</u>	
Reinsurance Ratio	Reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed
Internal Reinsurance Ratio	Reinsurance premium ceded to affiliated reinsurers divided by direct premium written plus reinsurance premiums assumed
External Reinsurance Ratio	Reinsurance premium ceded to unaffiliated reinsurers divided by direct premium written plus reinsurance premiums assumed
<u>Credit Risk Variables</u>	
Rating	Rating grade issued by A.M. Best rating and converted to ordered categorical or cardinal value, where "1" as the highest and "13" as the lowest
Downgrade	A dummy variable equals to value one if the insurer is downgraded by A.M. Best during the previous year
<u>Control Variables</u>	
Firm Size	Natural logarithm of total admitted asset
Leverage	Net premium written divided by policyholders' surplus
ROA	Return on assets, net income divided by total assets
Catastrophe Risk Exposure	Premiums written from homeowners line in Gulf area and coastal states and earthquake line divided by total premiums written
Long-tail Risk	Proportion of premium written in long-tail business lines including farm-owners, multiple peril, homeowners multiple peril, commercial multiple peril, ocean marine, medical malpractice, international, reinsurance, workers' compensation, other liability, products liability, aircraft, boiler and machinery, and automobile liability
HHI	Herfindahl index of premiums written by business lines
GHHI	Herfindahl index of premiums written by states
Stock Dummy	A dummy variable equals to one if the insurer is a stock company and zero otherwise
Group Dummy	A dummy variable equals to one if the insurers is single unaffiliated company and zero otherwise
BCAR	Best's Capital Adequacy Ratio
GDP Growth	An inflation-adjusted measure that reflects the value of all goods and services produced by an economy in a given year, expressed in base-year prices

This table presents annual statistics for variables used in this study. The sample period is from 2000 to 2014. The sample consists of 15,443 year-firm observations for the analysis.

2.6. Empirical Results

2.6.1. Descriptive Statistics

Table 2.2 displays the summary statistics. The mean value of A.M. Best's rating in the sample is 6.67, corresponding to a rating grade that falls between B+ and B. The average utilization of reinsurance is 0.374, where the internal reinsurance utilization is 0.244 and the external reinsurance utilization is 0.13. The sum of external reinsurance utilization is composed of two parts: overall utilization of reinsurance from single stand-alone insurers, and the external part of reinsurance utilization from the group-affiliated insurers. The summary statistics for other variables is comparable to prior literature.

Table 2.2: Descriptive Statistics, 2000-2014

Variables	Mean	Median	STD	Min	Max
Reinsurance Ratio	0.374	0.339	0.290	0.000	0.750
Internal Reins Ratio	0.244	0.060	0.290	0.000	0.750
External Reins Ratio	0.130	0.066	0.157	0.000	0.536
Rating	6.166	6.000	4.431	1.000	13.000
Downgrade	0.099	0.000	0.298	0.000	1.000
Firm Size	18.550	18.462	1.661	14.849	23.048
Net Leverage	2.614	2.500	2.415	0.500	5.600
ROA	0.019	0.232	0.061	-0.245	0.239
Stock Dummy	0.742	1.000	0.437	0.000	1.000
Group Dummy	0.751	1.000	0.432	0.000	1.000
Long-Tail Risk	0.579	0.638	0.297	0.000	1.000
Cat Risk Exposure	0.016	0.014	0.276	0.000	1.000
HHI	0.440	0.357	0.285	0.115	1.000
GHHI	0.533	0.471	0.377	0.056	1.000
BCAR	258.84	114.256	227.00	123.90	550.30
GDP Growth	2.092	2.428	1.678	-2.776	4.685
Number of Obs.:			15443		

This table presents annual statistics for variables used in this study. The sample period is from 2000 to 2014. The sample consists of 15,443 year-firm observations for the analysis.

2.6.2. Analysis of Results

Table 2.3 and Table 2.4 present results for 2SLS estimation of equation (1) on how the rating affects insurers' reinsurance demand. Table 2.3 reports results for overall reinsurance demand using full sample and Table 2.4 displays results for internal reinsurance analysis and external reinsurance analysis. Hypothesis 1 is supported because the coefficient on the insurers' rating variable is 0.033, positive and significant, showing that insurers with a lower rating on average buy more reinsurance.[39] To be specific, when insurers' rating decrease by one level, their demand for reinsurance increase by 3.3%. This is consistent my expectation that low-rated firms have higher bankruptcy risk and are more concerned about their financial quality, and they may address such concerns through engaging in reinsurance transactions.

Also, according to Table 2.3, the control variables that emerge as significant include firm size, leverage, HHI, GHHI, ROA, long-tail risk, catastrophe risk exposure, stock and group dummy. For example, firm size is negative and significant, which is consistent with prior literature that smaller firms demand more reinsurance. Long-tail risk and catastrophe risk exposure variable are both positive and significant, indicating that the catastrophe risk exposure and length of tail both have a positive impact on reinsurance demand. Taken together, these results further support that reinsurance demand is sensitive to firm's bankruptcy risk and underwriting risk. Leverage is positive and highly significant, supporting the investment incentives hypothesis that highly leveraged insurers are expected to utilize more reinsurance due to the greater risk of insolvency. HHI and GHHI index are both negative and significant, which is consistent with the established argument that

[39] Rating variable is defined as rating grade issued by A.M. Best rating and converted to ordered categorical or cardinal value, where "1" is the highest and "13" is the lowest (A++ = 1, A+ = 2…, D = 13).

reinsurance demand is often driven by product and geographic mix. The stock dummy variable is positive and significant, indicating that stock insurers demand more reinsurance. This is opposite to Mayers and Smith (1990), but consistent with Cole and McCullough (2006). In addition, Garven and Lamm-Tennant (2003) did not find any significant relationship between organizational form and reinsurance demand. The differences in results may be caused by the time period studied, and firms included. The group affiliation dummy is also positive and significant, which is consistent with most prior findings that group-affiliated insurers purchase more reinsurance (Mayers and Smith, 1990; Cole and McCullough, 2006).

In Table 2.4, I observe that the internal reinsurance demand is also positively related to insurers' rating using a subsample where only group-affiliated insurers are included. The coefficient is 0.029, showing that the demand for reinsurance from affiliated reinsurers decreases by 2.9% if insurers' rating moves up by one level, on average. Hypothesis 3 is therefore supported. But the coefficient for $rating_{t-1}$ in the external reinsurance equation is not significant. Since Powell and Sommer (2007) shown that the internal reinsurance utilization is associated with cost-based incentives such as reducing information asymmetry, it is probably also due to this reason that low-rated group-affiliated insurers prefer to cede to internal affiliated reinsurers to diversify the risks.

In addition, the instrumental variables for rating variable, one-period lagged BCAR ratio and the two-period lagged rating variable, are both highly significant and positive in all the regressions. This is also consistent with my expectation. The results for instrumental variables validity check are presented in Table 2.3 and Table 2.4. In the first stage, both Kleibergen-Paap rk Wald test and the Kleibergen-Paap rk LM test have a significant p-value, rejecting the null hypothesis that the instruments are jointly insignificant or weak. In the second-stage regression, I report Hansen J test for overidentification.[40] Since the Hansen J statistics is insignificant, the overidentification restriction is thereby satisfied. Both test results confirm the validity of the instrumental variables.

Table 2.3: 2SLS Regression Results for Insurers' Reinsurance Demand and Credit Rating, 2000-2014

Dependent Variable:	**First Stage** Rating Grade Coefficient/[T-Stat]	**Second Stage** Overall Reinsurance Coefficient/[T-Stat]
$Rating_{t-1}$		0.033** [2.07]
Firm $Size_{t-1}$	0.0002 [0.01]	-0.032*** [-9.77]
Net $Leverage_{t-1}$	-0.018 [-0.59]	0.019*** [3.87]
ROA_{t-1}	-3.125*** [-4.28]	0.268** [2.15]
Stock $Dummy_{t-1}$	0.069 [1.33]	0.088*** [7.13]
Group $Dummy_{t-1}$	0.012 [0.21]	0.086*** [8.40]
Long-Tail $Risk_{t-1}$	0.174*** [2.70]	0.073*** [6.27]
Cat $Risk_{t-1}$	-0.135* [-1.81]	0.031* [1.87]
HHI_{t-1}	0.011 [0.15]	-0.029*** [-12.39]
$GHHI_{t-1}$	0.004 [0.08]	-0.188*** [-13.52]
$BCAR_{t-1}$	-0.003*** [-12.44]	
$Rating_{t-2}$	0.293*** [19.02]	
Adjusted-R^2	0.631	0.167
Year FE	Yes	Yes
Firm FE	Yes	Yes

[40] The Kleibergen-Paap rk LM test statistics and Wald F test statistics are significant at the 1% level. The Hansen's J test statistics are insignificant at the 5% level, suggesting that the instruments are both relevant and exogenous.

Table 2.3: Continued

Dependent Variable:	**First Stage** Rating Grade Coefficient/[T-Stat]	**Second Stage** Overall Reinsurance Coefficient/[T-Stat]
K-P rk LM Statistic	24.65***	
Wald F Statistic	12.59***	
Hansen J Statistic	0.30	
Number of Obs.	15443	

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and * respectively.
Reinsurance ratio is measured as reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Rating is rating grade issued by A.M. Best rating and converted to ordered categorical or cardinal value, where "1" as the highest and "13" as the lowest; Firm size is measured as natural log of total admitted asset; Net leverage is the net premium written divided by policyholder's surplus; Long-tail risk variable is measured as the proportion of premium written in long-tail business lines; Catastrophe Risk Exposure is premiums written from homeowners line in Gulf area and coastal states and earthquake line divided by total premiums written; ROA is return on assets, net income divided by total assets; Stock Dummy equals to one if firm is a stock insurer; Group dummy equals to one if insurer is an affiliated company and zero otherwise; HHI is Herfindahl index of net premiums written by business lines; GHHI is Herfindahl index of net premiums written by states; BCAR is Best's Capital Adequacy Ratio.
Instrument relevance is tested via a Kleibergen-Paap rk LM test and Wald test in the first-stage regression. Instrument validity is tested using Hansen's J test for overidentification.

Table 2.4: 2SLS Regression Results for Internal and External Reinsurance Demand and Credit Rating, 2000-2014

Dependent Variable:	**Internal First Stage** Coefficient [T-Stat]	**Internal Second Stage** Coefficient [T-Stat]	**External First Stage** Coefficient [T-Stat]	**External Second Stage** Coefficient [T-Stat]
$Rating_{t-1}$		0.029*		0.005
		[1.83]		[0.611]
$Firm\ Size_{t-1}$	-0.022	-0.035***	0.0002	-0.005**
	[-1.39]	[-7.50]	[0.01]	[-2.49]
$Net\ Leverage_{t-1}$	-0.012	0.021***	-0.018	-0.003
	[-0.35]	[3.78]	[-0.59]	[-1.24]
ROA_{t-1}	-3.66***	0.320**	-3.125***	-0.018
	[-4.49]	[2.18]	[-4.28]	[-0.26]
$Stock\ Dummy_{t-1}$	0.033	0.141***	0.069	-0.011
	[0.55]	[7.33]	[1.33]	[-1.49]
$Group\ Dummy_{t-1}$			0.012	-0.076***
			[0.21]	[-11.85]
$Long\text{-}Tail\ Risk_{t-1}$	0.137*	0.072***	0.174***	0.014**
	[1.86]	[4.71]	[2.70]	[2.13]

Table 2.4: Continued

Dependent Variable:	<u>Internal First Stage</u> Coefficient [T-Stat]	<u>Internal Second Stage</u> Coefficient [T-Stat]	<u>External First Stage</u> Coefficient [T-Stat]	<u>External Second Stage</u> Coefficient [T-Stat]
Cat Risk$_{t-1}$	-0.154	-0.052**	-0.135*	0.084***
	[-1.47]	[-2.12]	[-1.81]	[7.99]
HHI$_{t-1}$	-0.074	-0.277***	0.011	0.028***
	[-0.93]	[-11.83]	[0.15]	[2.93]
GHHI$_{t-1}$	0.006	-0.206	0.004	-0.018**
	[0.10]	[-10.64]	[0.08]	[-2.36]
BCAR$_{t-1}$	-0.003***		-0.003***	
	[-10.92]		[-12.44]	
Rating $_{t-2}$	0.325***		0.293***	
	[18.72]		[19.02]	
Adjusted-R^2	0.664	0.187	0.631	0.129
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
K-P rk LM Stat	27.39***		24.65***	
Wald Statistic	13.87***		12.59***	
Hansen J Stat	4.534		5.490	
Number of Obs.	11504		15443	

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and * respectively. Reinsurance ratio is measured as reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Rating is rating grade issued by A.M. Best rating and converted to ordered categorical or cardinal value, where “1” as the highest and “13” as the lowest; Firm size is measured as natural log of total admitted asset; Net leverage is the net premium written divided by policyholder’s surplus; Long-tail risk variable is measured as the proportion of premium written in long-tail business lines; Catastrophe Risk Exposure is premiums written from homeowners line in Gulf area and coastal states and earthquake line divided by total premiums written; ROA is return on assets, net income divided by total assets; Stock Dummy equals to one if firm is a stock insurer; Group dummy equals to one if insurer is an affiliated company and zero otherwise; HHI is Herfindahl index of premiums written by business lines; GHHI is Herfindahl index of premiums written by states; BCAR is Best’s Capital Adequacy Ratio.
Instrument relevance is tested via a Kleibergen-Paap rk LM test and Wald test in the first-stage regression. Instrument validity is tested using Hansen’s J test for overidentification.

Table 2.5 and Table 2.6 report 2SLS IV regression results for equation (2) which analyzes how downgrades affect insurers’ reinsurance demand. When using overall reinsurance as the dependent variable, I find the downgrade dummy is significant and positive as expected in Table 2.5. The coefficient is 0.144, which implies that the reinsurance utilization among downgraded insurers is higher than among insurers that are not downgraded during the past year, on average.

In Table 2.6, where I break down the reinsurance transactions into an affiliated internal part versus an unaffiliated part, the trend shows distinct patterns in terms of downgrade dummy's coefficients. Internal affiliated reinsurance is positively related to the downgrade dummy, while external unaffiliated reinsurance demand is negatively related to the downgrade dummy. This is partly consistent with the expectations in Hypothesis 3 that downgraded insurers have a higher reinsurance demand from the group-affiliated reinsurers than others, while their demand for external unaffiliated reinsurers is lower than other insurers. The coefficients on internal and external reinsurance utilization is 0.595 and -0.251, respectively. The opposite coefficients on internal and external reinsurance is probably because downgraded insurers care more about the transparency between counterparties. And they prefer group-affiliated reinsurers probably out of their lower cost and higher efficiency.

Results regarding most control variables show a similar pattern compared to equation (1). Firm size is negative and significant. Group dummy is positive, which means that group-affiliated insurers have a higher demand for reinsurance. Catastrophe risk exposure and long-tail risk variables are both positive and significant, which is consistent with the intuition that extreme risk and long-tail risk exposure may drive up reinsurance demand. Leverage is positive and ROA is negative, which supports that insurers with higher bankruptcy risk have a higher demand for reinsurance. The instrumental variable, annual growth in GDP, is significantly and negatively related to downgrade dummy in the first stage estimation using probit regression. This is consistent with the hypothesis that in years with lower economic growth, downgrading increases among insurers. The validity of instrument is confirmed using a Kleibergen-Paap rk LM test and a Wald test.

Table 2.5: 2SLS Regression Results for Overall Reinsurance Demand and Downgrade Risk, 2000-2014

Dependent Variable:	**First Stage** Downgrade Coefficient/[T-Stat]	**Second Stage** Overall Reinsurance Coefficient/[T-Stat]
Downgrade$_{t-1}$		0.144** [20.16]
Firm Size$_{t-1}$	-0.168*** [-20.14]	-0.303** [-9.57]
Net Leverage$_{t-1}$	0.187*** [22.92]	0.41*** [8.22]
ROA$_{t-1}$	-0.436** [-2.41]	-0.494* [-1.81]
Stock Dummy$_{t-1}$	0.025 [0.93]	0.046 [0.76]
Group Dummy$_{t-1}$	-0.375*** [-13.00]	0.845*** [7.78]
Long-Tail Risk$_{t-1}$	-0.034 [-0.92]	0.062*** [4.98]
Cat Risk$_{t-1}$	0.119*** [2.99]	0.129** [2.69]
HHI$_{t-1}$	0.380*** [9.03]	-0.487*** [4.62]
GHHI$_{t-1}$	1.151*** [4.52]	-0.324*** [-3.90]
GDP Growth$_{t-1}$	-0.023*** [-3.70]	
Adjusted-R^2	0.106	0.156
Year FE	Yes	Yes
Firm FE	Yes	Yes
K-P rk LM Statistics	24.67***	
Wald Test Statistics	12.39***	
Number of Obs.	15443	

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and * respectively. Reinsurance ratio is measured as reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Downgrade is a dummy variable equals to value one if the insurer is downgraded by A.M. Best during the previous year; Firm size is measured as natural log of total admitted asset; Net leverage is the net premium written divided by policyholder's surplus; Long-tail risk variable is measured as the proportion of premium written in long-tail business lines; Catastrophe Risk Exposure is premiums written from homeowners line in gulf area and coastal states and earthquake line divided by total premiums written; ROA is return on assets, net income divided by total assets; Stock Dummy equals to one if firm is a stock insurer; Group dummy equals to one if insurer is an affiliated company and zero otherwise; HHI is Herfindahl index of net premiums written by business lines; GHHI is Herfindahl index of net premiums written by states; GDP growth is an inflation-adjusted measure that reflects the value of all goods and services produced by an economy in a given year, expressed in base-year prices. The first stage is regressed using the probit model. Instrument relevance is tested via a Kleibergen-Paap rk LM test and Wald test in the first-stage regression.

Table 2.6: 2SLS Regression Results for Internal and External Reinsurance Demand and Downgrade Risk, 2000-2014

Dependent Variable:	**Internal First Stage** Coefficient [T-Stat]	**Internal Second Stage** Coefficient [T-Stat]	**External First Stage** Coefficient [T-Stat]	**External Second Stage** Coefficient [T-Stat]
Downgrade$_{t-1}$		0.595** [2.49]		-0.251*** [-9.02]
Firm Size$_{t-1}$	-0.143*** [-15.48]	0.002 [0.19]	-0.168*** [-20.14]	-0.060*** [-9.00]
Net Leverage$_{t-1}$	0.150*** [15.91]	0.053*** [4.40]	0.187*** [22.92]	0.010*** [2.61]
ROA$_{t-1}$	-0.174*** [-2.68]	-0.067** [-1.12]	-0.436** [-2.41]	-0.097* [-1.68]
Stock Dummy$_{t-1}$	-0.144 [-1.36]	0.127*** [8.18]	0.025 [0.93]	-0.029** [-2.26]
Group Dummy$_{t-1}$			-0.375*** [-13.00]	-0.253*** [-11.05]
Long-Tail Risk$_{t-1}$	-0.140*** [-4.07]	0.089*** [5.22]	-0.034 [-0.92]	-0.023 [-0.82]
Cat Risk$_{t-1}$	0.142*** [3.10]	0.094*** [3.98]	0.119*** [2.99]	0.108*** [6.67]
HHI$_{t-1}$	0.512*** [10.29]	-0.365*** [-9.12]	0.380*** [9.03]	0.160*** [7.20]
GHHI$_{t-1}$	0.161*** [4.19]	-0.241*** [-8.34]	1.151*** [4.52]	0.076*** [4.36]
GDP Growth$_{t-1}$	-0.021*** [-2.87]		-0.023*** [-3.70]	
Adjusted-R^2	0.056	0.564	0.106	0.136
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
K-P rk LM Stat	24.50***		24.67***	
Wald Stat	24.32***		12.39***	
Number of Obs.	11504		15443	

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and * respectively.

Reinsurance ratio is measured as reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Downgrade is a dummy variable equals to value one if the insurer is downgraded by A.M. Best during the previous year; Firm size is measured as natural log of total admitted asset; Net leverage is the net premium written divided by policyholder's surplus; Long-tail risk variable is measured as the proportion of premium written in long-tail business lines; Catastrophe Risk Exposure is premiums written from homeowners line in gulf area and coastal states and earthquake line divided by total premiums written; ROA is net income divided by total assets; Stock Dummy equals to one if firm is a stock insurer; Group dummy equals to one if insurer is an affiliated company and zero otherwise; HHI is Herfindahl index of net premiums written by business lines; GHHI is Herfindahl index of net premiums written by states; GDP growth is an inflation-adjusted measure that reflects the value of all goods and services produced by an economy in a given year, expressed in base-year prices. The first stage is regressed using the probit model. Instrument relevance is tested via a Kleibergen-Paap rk LM test and Wald test in the first-stage regression.

2.6.3. Robustness Check

Several robustness tests have been conducted. First, I consider an alternative definition of rating variable. I divide insurers into two groups according to their rating grade: high-rated insurers and low-rated insurers. The A.M. Best ratings are broadly grouped into two categories, "secure" or "vulnerable." Ratings between A++ and B+ are considered "secure," whereas all ratings below B+ are considered "vulnerable".[41] Then I replace the ordered rating grade variable with a dummy variable, called "high-rating," which is assigned the value one if the insurer is within the "secure" group and repeat the regressions. The results are largely consistent with the main results.

Furthermore, as mentioned earlier, since the single stand-alone insurers do not have the choice to cede to group-affiliated reinsurers, they are excluded in the internal reinsurance regression reported in Table 2.4 and Table 2.6. As a robustness check, I also conduct a truncated regression to study the internal reinsurance ratio for the full sample to examine how downgrade risk and reinsurance demand are related. Truncated regression is appropriate in this case because in my sample, there are about 27% of insurers that are

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[41] The "secure" category includes ratings of A++, A+, A, A–, B++, and B+, while the "vulnerable" category includes ratings of B, B–, C++, C+, C, C–, D, E, F, and ratings of S are not observed in the dataset.

single unaffiliated stand-alone insurers that do not have any access to group-affiliated reinsurers. As a result, these insurers have a "zero" internal reinsurance utilization because they don't have group-affiliated members to cede business to. Therefore, a truncated model would be appropriate. The results for the truncated regressions are presented in Table 2.7. The results are consistent with the main results and further confirms that downgraded insurers have a higher demand for reinsurance than the those that are not downgraded.

Table 2.7: Truncated Regression Results for Internal Reinsurance Demand and Downgrade Risk, 2000-2014

Dependent Variable	**Internal Reinsurance Demand**	
	Coefficient	[T-Stat]
Downgrade_{t-1}	0.281**	1.99
Firm Size_{t-1}	-0.013**	-1.88
$\text{Net Leverage}_{t-1}$	0.102***	13.87
ROA_{t-1}	0.160***	3.57
Stock Dummy_{t-1}	0.095***	19.81
Group Dummy_{t-1}	0.278***	12.05
$\text{Long-Tail Risk}_{t-1}$	0.102***	13.87
Cat Risk_{t-1}	0.024**	2.45
HHI_{t-1}	-0.283***	-12.44
GHHI_{t-1}	-0.167***	-14.60
Intercept	0.361**	2.29
Wald Test	8813.91***	
Sigma	0.266***	
Year FE	Yes	
Firm FE	Yes	
Number of Obs:	15443	

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and * respectively. Reinsurance ratio is measured as reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Downgrade is Firm size is measured as natural log of total admitted asset; Net leverage is the net premium written divided by policyholder's surplus; Long-tail risk variable is measured as the proportion of premium written in long-tail business lines; Catastrophe Risk Exposure is premiums written from homeowners line in gulf area and coastal states and earthquake line divided by total premiums written; ROA is return on assets, net income divided by total assets; Stock Dummy equals to one if firm is a stock insurer; Group dummy equals to one if insurer is an affiliated company and zero otherwise; HHI is Herfindahl index of net premiums written by business lines; GHHI is Herfindahl index of net premiums written by states. Sigma measures the estimated standard error of the regression.

Lastly, as an additional robustness check, I run another regression where both the downgrade dummy and rating grade variables are included as main explanatory variables in the model. The results for the overall reinsurance demand, internal reinsurance demand, and external reinsurance demand regressions are presented in Table 2.8. Based on this table, I find that the estimations results are still largely consistent with prior conclusion.

Table 2.8: Regression Results for Insurers' Reinsurance Demand and Credit Rating & Downgrade Risk, 2000-2014

Dependent Variable	**Overall Reins** Coefficient [T-Stat]	**Internal Reins** Coefficient [T-Stat]	**External Reins** Coefficient [T-Stat]
$Rating_{t-1}$	0.001* [1.85]	0.003** [2.37]	0.001 [0.13]
$Downgrade_{t-1}$	0.035*** [4.28]	0.06*** [5.53]	-0.025*** [-5.82]
Firm $Size_{t-1}$	-0.029*** [-6.73]	-0.034*** [-5.88]	-0.006** [-2.35]
Net $Leverage_{t-1}$	0.016*** [5.04]	0.021*** [5.78]	0.002 [1.25]
ROA_{t-1}	0.017 [0.43]	0.020 [0.73]	0.006 [0.26]
Stock $Dummy_{t-1}$	0.095*** [5.85]	0.124*** [5.50]	-0.024** [-2.60]
Group $Dummy_{t-1}$	0.095*** [7.49]		-0.064*** [-8.47]
Long-Tail $Risk_{t-1}$	0.053*** [3.89]	0.061*** [3.48]	0.001 [0.03]
Cat $Risk_{t-1}$	0.069*** [3.04]	0.052 [0.53]	0.095*** [6.45]
HHI_{t-1}	-0.220*** [-9.60]	-0.268*** [-9.39]	0.022* [1.73]
$GHHI_{t-1}$	-0.184*** [-9.92]	-0.174*** [-7.20]	-0.026** [-2.41]
Adjusted-R^2	0.175	0.164	0.133
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Number of Obs.	15443	11504	15443

Note: Statistical significance at the 1, 5, and 10 percent levels are denoted by ***, **, and * respectively. Reinsurance ratio is measured as reinsurance premium ceded divided by direct premium written plus reinsurance premiums assumed; Rating is rating grade issued by A.M. Best rating and converted to ordered categorical or cardinal value, where "1" as the highest and "13" as the lowest; Firm size is measured as natural log of total admitted asset; Net leverage is the net premium written divided by policyholder's surplus; Long-tail risk variable is measured as the proportion of premium written in long-tail business lines; Catastrophe Risk Exposure is premiums written from homeowners line in Gulf area and coastal states and earthquake line divided by total premiums written; ROA is return on assets, net income divided by total assets; Stock Dummy equals to one if firm is a stock insurer; Group dummy equals to one if insurer is an affiliated company and zero otherwise; HHI is Herfindahl index of net premiums written by business lines; GHHI is Herfindahl index of net premiums written by states.

2.7. Conclusions

U.S. P/C insurers cede a substantial share of premiums to reinsurers. In exchange for premiums, reinsurers assume part of the risk from primary insurers. Understanding the relationship between risk and reinsurance is an essential step in evaluating the interconnectedness of the insurance industry. The traditional motivations for reinsurance include investment incentives, the probability of bankruptcy, tax effects, and the availability of real services. Prior work shows that such demand is closely related to firm-specific characteristics, including firm size, leverage, organizational form, group affiliation, line-of-business concentration, geographic concentration, and capital adequacy, etc. Besides these, there is little direct and thorough empirical studies on how firms' rating affects their reinsurance demand, which is another potential motivation.

The main objective is to examine the relationship between insurers' reinsurance demand and credit risk using the U.S. P/C insurance industry as the focus. To be specific, I study how firms' credit rating and downgrade risk affect their reinsurance demand. With data from 2000 to 2014, I find that low-rated insurers have a higher demand for reinsurance on average, which supports the bankruptcy risk hypothesis. Another important finding is that the downgraded insurers on average have a higher reinsurance demand than other insurers that are not downgraded, especially from the internal group-affiliated reinsurers.

However, their reliance on external unaffiliated reinsurers decreases after downgrade.

Prior studies have documented many motivations to explain insurers' reinsurance demand. But this is the first study empirically investigating how reinsurance demand is affected by firms' rating grade and downgrade risk. Existing literature provides some theoretical background to analyze the relationship between insurers' credit risk and reinsurance demand, yet did not provide any direct empirical evidence on how these two factors are related. This study fills this gap by using the recent data and a large sample of both stock and mutual insurers to thoroughly explore the impact of rating grade and downgrade risk on insurers' reinsurance demand. The results, robust to various model specifications, have shown that the credit risk has a significant impact on insurers' reinsurance demand. The implications of this study are important because existing literature has not fully indicated the impact of credit rating or rating movement on insurers' reinsurance demand. And the findings should help us better understand the motivation of insurers' reinsurance buying, and help regulatory authorities better supervise an insurer's rating and solvency status.

Future studies could consider the following ways. First, this study mainly considers downgrade risk as a major source of credit risk. In future analysis, it would be interesting to explore how default risk and other forms of credit risk affects insurers' reinsurance demand. Second, moral hazard and adverse selection issues might also affect the relationship between credit risk and reinsurance arrangements, because insurers have more information on their underwriting risk, and they may retain the "good risks" and cede the "bad risks" to reinsurers. Third, the creditworthiness of reinsurers also needs to be addressed in future analysis as well. Park and Xie (2014) mention that the likelihood of a primary insurer's downgrade increases with its reinsurance default risk exposure from downgraded counterparty reinsurers. In this study, I assume that a reinsurer's downgrade does not affect insurers' reinsurance decisions. But future analyses on the insurer-reinsurer relationship incorporating such reinsurer counterparty credit risk would be insightful.

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