國立政治大學風險管理與保險學系

博士學位論文

內部資本市場的三篇論文:以美國產險業為例

Three Essays on Internal Capital Markets: Evidence from the U.S. Non-Life Insurance Industry

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Abstract

This dissertation consists of three essays and focuses on intra-group reinsurance arrangements as the main internal capital markets activities in the U.S. non-life insurance industry from the period of 1999 to 2016. In essay 1, by employing the regression model of Cragg (1971) to analyze the determinants of internal reinsurance provision and receipt, we document the following results. First, internal reinsurance provision is positively related to external reinsurance, investment risk, and profitability, suggesting that they are the capacity sources to support the provision internal reinsurance. In contrast, these variables negatively affect internal reinsurance receipt. Second, we discover the inverse-U patterns regarding the effects of external reinsurance and investment risk on internal reinsurance provision, which may indicate that these internal reinsurance providers tend to curtail internal reinsurance provision to avoid posing excessive counterparty risk on the recipients of internal reinsurance. Moreover, we also find such non-linear effects of underwriting risk variables on internal reinsurance receipt, which indicate that the recipients tend to avoid transferring excessive underwriting risk to the providers.

In essay 2, we analyze the relations among intra-group reinsurance, capital, and risk, and document the following results. First, the insurers whose intra-group reinsurance participation status are converted to providers are associated with the decrease in capital

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ratio. Such result s may be driven by the substitution effect of an increase in the income streams from internal reinsurance transactions on capital financing. Second, we find a positive effect of capital ratio on internal reinsurance provision, which suggests that the provision of internal reinsurance is supported by capital. On the contrary, internal reinsurance receipt and capital are negatively interrelated, suggesting that they are substitutes. Moreover, we find a positive relation between internal reinsurance receipt and investment risk, which may imply that internal reinsurance could be utilized for allocating risk among investment and underwriting activities.

In essay 3, we analyze how insurers adjust their capital structure and document the following results. First, the deviation from target leverage positively affects the funds received via internal capital transfer for both internal reinsurance providers and recipients. Such relation does not exist for the insurers without intra-group reinsurance participation. Our results may indicate that the insurers with the economic connections created by intra-group reinsurance are more likely to receive supports when they are undercapitalized. In addition, some results indicate that the negative effect of target leverage deviation on premiums growth is weaker for recipients, which may be caused by the offsetting effect of the capacity supplement via internal reinsurance.

Key words: internal capital markets, intra-group reinsurance, risk-bearing capacity, capital, risk-taking, capital structure, capital adjustment channels

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Chapter 1: The Determinants of Internal Capital Provision and Receipt: Evidence from the Intra-Group Reinsurance Activities of the U.S. Non-Life Insurance Industry

1. Introduction

In finance and insurance literature, there are growing studies on internal capital markets. Drawing from these studies, internal capital markets transactions could be used for fulfilling several purposes, such as mitigating affiliates' financial constraint and enhancing affiliates' solvency. To the best of our knowledge, most of these studies mainly focus on the perspective of internal capital recipients. Specifically, these studies generally investigate what factors influence capital allocation and allocation efficiency of internal capital within business group and conglomerate (e.g. Gertner, Scharfstein and Stein, 1994; Stein, 1997), and the financial consequences of internal capital allocation on recipients (e.g. Gopalan, Nanda, and Seru, 2007; Powell, Sommer, and Eckles, 2008; Almeida, Kim and Kim, 2015). Despite these studies have provided many insights, the works on internal capital providers appear to be scant in literature. In finance literature, several studies have implied that the financial strength of internal capital providers could influence the amount of internal capital received by affiliates and ultimately affect affiliates' performance (e.g. Boutin, Cestone, Fumagalli, Pica, and Serrano-Velarde, 2013; Kim, 2016). Despite the importance of internal capital providers

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suggested by these studies, the factors influencing internal capital provision are largely underexplored in literature.

Since prior studies pay considerably less attention to the supply side of internal capital markets, we attempt to explore and compare the determinants of internal capital provision and receipt by analyzing intra-group reinsurance activities in the U.S non-life insurance industry. According to previous studies, intra-group reinsurance could be regarded as the most common type of internal capital markets transaction due to the prevalence and volume (e.g. Powell and Sommer, 2007; Fier, McCullough, and Carson, 2013). Under an intra-group reinsurance arrangement, the assuming insurers in intra-group reinsurance transactions are regarded as "providers" since they provide capacity for other affiliates. In contrast, the ceding insurers are considered as "recipients" because they acquire capacity from other affiliates. In the following contents, we refer the assuming and ceding insurers as providers and recipients respectively.

Our study focuses on how financing activities, profitability, and portfolio risk affect the participation and volume decisions of internal reinsurance provision and receipt. As previous studies suggest, insurers have incentives to limit insolvency risk due to the increased regulatory costs and the decrease in insurance demand associated with excessive insolvency risk (e.g. Cummins and Sommer, 1996; Cummins and Danzon, 1997; Baranoff and Sager, 2002, 2003). For internal reinsurance providers,

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they assume the risk from other affiliates and reduce their own capacity after intra-group reinsurance arrangements. To ensure the supply of internal reinsurance without taking excessive insolvency risk, internal reinsurance provision should be backed by sufficient risk-bearing capacity. Therefore, we expect that internal reinsurance provision is positively related to the capital raised and profitability and negatively related to investment and underwriting risk exposure.

On the contrary, we expect that internal reinsurance receipt is negatively affected by the capacity replenished via financing activities as these recipients could have sufficient funds to support their business operations. Regarding the relation between investment risk and internal reinsurance receipt, we expect a positive relationship between these two variables even though internal reinsurance is not used for managing investment risk. The insurers with higher investment risk may use more internal reinsurance to reduce the risk from underwriting activities and limit overall insolvency risk. On the other hand, we expect a positive association between underwriting risk and internal reinsurance receipt as reinsurance is primarily used for managing underwriting risk.

To investigate both participation and volume decisions of internal reinsurance provision and receipt, we employ the model of Cragg (1971) in our empirical analysis. Consistent with our expectation, we find that both external reinsurance use and

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investment profitability exert positive effects on internal reinsurance provision, suggesting that these two variables could be the sources of capacity for providers to assume risk from other affiliates. Contrary to our expectation, our results show that internal reinsurance provision participation is positively associated with investment risk. The possible explanation for such result is that insurers with more risky investment portfolios have higher expected investment returns to support internal reinsurance provision. On the other hand, we find a negative relation between internal reinsurance provision participation and underwriting risk, which is consistent with our expectation. Turning to internal reinsurance recipients, we find that internal reinsurance receipt is negatively related to external reinsurance usage, investment and underwriting profitability. These results may indicate that the capital replenishment from these sources reduces the demand for the supports provided by other affiliates. Consistent with our expectation, we also find that both underwriting risk and hurricane exposure are positively associated with internal reinsurance receipt.

In our analysis, we further explore the non-linearity regarding the effects of the following variables on intra-group reinsurance activities: external reinsurance, investment risk, underwriting risk, and hurricane exposure. For providers, although the capacity acquired from external reinsurance could be a source of capacity for internal reinsurance provision, excessive use of external reinsurance could make providers

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exposed to significant reinsurance counterparty risk from non-affiliated reinsurers. To limit the counterparty risk posed on recipients, the providers which overuse external reinsurance may need to reduce or even discontinue the provision of internal reinsurance. Likewise, insurers with excessive investment risk have a greater probability of incurring large investment loss. These providers may need to reduce or even cease the provision of internal reinsurance so that they can limit the reinsurance counterparty risk on recipients. For recipients, we expect the existence of inverse-U patterns in the effects of underwriting risk and hurricane exposure on internal reinsurance receipt. The recipients with large values in these variables have more chance to incur large loss and put heavy strain on providers' financial positions. Thus, we anticipate that the positive effects of underwriting risk and hurricane exposure on internal reinsurance receipt will begin to decrease once the values of these variables reach to certain thresholds.

Consistent with our expectation, we find inverse-U patterns in the effects of external reinsurance and investment risk on the provision of internal reinsurance. For recipients, we also find such pattern in the effects of underwriting risk and hurricane exposure on internal reinsurance receipt. Based on these results, both providers and recipients tend to limit the risk posed on their counterparties.

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Our contributions are summarized as follows. First, our study discovers and compares the determinants of internal capital provision and receipt, and thus provides more comprehensive understanding of how internal capital markets work. In finance literature, Gopalan et al. (2007) analyze the characteristics of the providers and recipients in internal capital markets, and the sources by which providers finance internal capital provision, such as external financing and internally generated cash. Nevertheless, their work tends to emphasize more on the negative spillover effects of affiliates' insolvencies on the rest of group. In our work, we extensively focus on the determinants of internal capital providers and recipients. In addition to internally generated funds and external financing activities, we further incorporate both investment and underwriting risk in our analysis as these types of business portfolio risk could be related to insurers' risk-bearing capacity and the decisions regarding internal capital provision and receipt. Thus, we can provide more comprehensive analysis regarding the factors influencing internal capital provision and receipt. In insurance literature, previous studies mainly focus on the determinants of reinsurance usage rather than reinsurance provision (e.g. Mayers and Smith, 1990; Cole and McCullough, 2006; Powell and Sommer, 2007). Our work could be the first study on insurers' decisions to assume reinsurance premiums from affiliates.

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Second, we further discover the non-linear effects of external reinsurance, investment risk, and underwriting risk variables on internal reinsurance provision and receipt, which could indicate that the intra-group reinsurance participants tend to avoid putting substantial risk on their counterparties. These results could be crucial for group-wide solvency as the intra-group reinsurance transactions participants tend to limit the risk borne by their counterparties. Such arrangements could reduce the likelihood of the negative spillover effects associated with the insolvencies of intra-group reinsurance participants. As Gopalan et al. (2007) suggest, the linkages among group members generated by internal capital markets activities could be the potential conduits of negative spillover effects over the rest of group. In insurance industry, intra-group reinsurance arrangements are also the potential channels of negative spillover effects. When internal reinsurance providers become insolvency, the value of recipients' reinsurance receivable could substantially decrease. In addition, the recipients may not be able to receive additional capacity from group members. On the other hand, internal reinsurance providers could pay attention to recipients' underwriting risk as the underwriting results of recipients could be relevant to the reimbursements made by providers, and the ultimate financial positions of providers. Due to these potential spillover effects, it is important to understand and examine the effects of the aforementioned variables on internal reinsurance provision and receipt in more detailed

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manners. Furthermore, like intra-group reinsurance, other types of internal capital markets transactions, such as intra-group loans, and guarantees, could also involve risk allocation among group members and counterparty risk. Therefore, our results could further provide implications for other types of internal capital markets activities.

The remainder of this work is organized as follows. In section 2, we review internal capital markets and insurance literature, and then propose our research hypotheses. The data and methodology used in empirical analysis will be explained in section 3. In section 4, we present and explain our empirical results. Finally, we conclude our study and propose several future research directions in section 5.

2. Literature Review and Hypotheses Development

2.1 Several strands of studies on internal capital markets

Drawing from previous studies on internal capital markets, we classify these studies into the following strands. The first strand of works focuses on the efficiency of internal capital allocation. Gertner, et al. (1994) and Stein (1997) indicate that headquarters of multidivisional firms have the control right over their divisions and the access to divisions' information. These two conditions enable headquarters to monitor these divisions and redeploy the resources efficiently among divisions. Nevertheless, Rajan, Servaes, and Zingales (2000) argue that the discrepancies in resources and growth opportunities among divisions within a conglomerate could cause inefficient resources

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allocation. Scharfstein and Stein (2000) introduce two layers of agents, CEO and divisional managers. They contend that two layers of agency problem could cause the inefficiency of capital allocations. To synthesize these studies, the theoretical models and arguments on the efficiency of internal capital markets are divergent in literature.

Another strand of works investigates the roles of internal capital markets in business groups and the financial consequences of internal capital allocation. Many of these works indicate that internal capital markets could be utilized for mitigating subsidiaries' financial constraint and facilitating investment. For example, Desai, Foley and Hines (2004) find that affiliates located in countries with weaker creditor rights and less developed credit markets tend to borrow more from their parents. Some empirical studies further find the evidence supporting the role of internal capital markets in facilitating subsidiaries' investment (e.g. Buchuk, Larrain, Munoz, and Urzúa, 2014; Almeida, Kim, and Kim, 2015). In addition, internal capital markets could be used for solvency management. Gopalan, Nanda, and Seru (2007) suggest that business groups tend to support financially weak members to avoid the negative spillover effects of affiliate's insolvency on the rest of the group. In insurance literature, several empirical works also find the supports for the roles played by internal capital markets. Powell, Sommer, and Eckles (2008) find that the receipt of internal capital leads to higher premiums growth. Fier et al. (2013) find the linkage between intra-group reinsurance

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and the deviation from the target capital structure. Niehaus (2018) find that the insurers with performance dip and lower risk-based capital (RBC) ratios tend to receive more internal capital from other group members.

Compared with the studies mentioned above, the third strand of works pays relatively more attention to the supply side of internal capital markets. Many of these studies analyze how parent companies' strength is related to subsidiaries' financial or product market performance. For instance, De Haas and Van Lelyveld (2010) find the evidence that the multinational bank subsidiaries which are affiliated with financially strong parents experience faster loan growth. Boutin et al. (2013) and Kim (2016) find that the cash resources hoarded by business group play a vital role in affiliates' product market performance. In addition, several studies further indicate that affiliates could suffer when their parents are hit by adverse shocks. For instance, De Haas and Van Lelyveld (2014) find the evidence that multinational bank subsidiaries considerably reduced loan growth when the financial crisis from 2008 to 2009 hit their parents.

To synthesize the works above, the majority of the studies on internal capital markets focus on the perspective of internal capital recipients. Some works find the relation between parents' financial resources and subsidiaries' performance and indicate the importance of internal capital providers. Nevertheless, the factors which affect the decision on internal capital provision still considerably underexplored in literature.

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2.2 Hypotheses Development

Because intra-group reinsurance arrangements involve capital and risk allocation among affiliates, we expect that the internal reinsurance arrangements should be relevant to the factors which influence insurers' risk-bearing capacity. In this section, we purpose our research hypotheses on how financing activities, profitability, and business portfolio risk affect internal reinsurance provision and receipt decisions.

2.2.1 External Reinsurance Usage and Capital Issuance

In this work, we argue that the provision of internal reinsurance should be supported by sufficient risk-bearing capacity. In banking and insurance literature, several studies on the relation between capital and risk suggest that insurers tend to limit overall riskiness to avoid the costs associated with excessive insolvency risk (e.g. Shrieves and Dahl, 1992; Cummins and Sommer, 1996; Rime, 2001; Baranoff and Sager, 2002, 2003). Such costs include regulatory and bankruptcy costs. In addition, excessive insolvency risk could negatively influence insurance demand and price (e.g. Sommer, 1996; Cummins and Danzon, 1997). In addition to the negative consequence of excessive insolvency risk, limiting reinsurance counterparty risk could be another reason for providers to have adequate risk-bearing capacity prior to the provision of internal reinsurance. As Gopalan et al. (2007) suggest, internal capital markets activities could be potential conduits of negative spillover effects. Under intra-group reinsurance

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transactions, the insolvencies of internal reinsurance providers could cause large depletion in the reinsurance recoverable of the recipients. In insurance literature, several studies on systematic risk of insurance sector mention that the interconnectedness created by reinsurance arrangements could be a potential channel of systematic risk (e.g. Cummins and Weiss, 2014; Park and Xie, 2014). To mitigate the concerns regarding the contagion effects caused by intra-group reinsurance arrangements, insurance group may tend to designate the insurers with adequate capacity as the providers of internal reinsurance.

Based on the rationales above, we expect that the provision of internal reinsurance should be backed by sufficient risk-bearing capacity. Both external reinsurance and capital issuance could be important sources for insurers to replenish risk-bearing capacity. The insurers with greater external reinsurance usage and capital issuance could be able to provide internal reinsurance for other group members. Thus, we propose the following hypotheses:

Hypothesis 1a: the amount of external reinsurance positively affects the participation and volume of internal reinsurance provision.

Hypothesis 1b: the amount of capital issuance positively affects the participation and volume of internal reinsurance provision.

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Unlike the capital issuance, insurers' reinsurance recoverable is subject to default risk when reinsurers become insolvent. The insurers with substantial external reinsurance usage could be exposed to non-trivial reinsurance counterparty risk from non-affiliated reinsurers. Such counterparty risk could be potentially transmitted to other affiliates via intra-group reinsurance transactions. To avoid such contagion effect, the providers with considerable large amount of external reinsurance usage may need to reduce the amount of internal reinsurance provision. Thus, we expect the existence of an inverse-U pattern in the effect of external reinsurance use on internal reinsurance provision. When external reinsurance use reaches a certain threshold, the positive effect of external reinsurance on internal reinsurance provision may begin to decrease. The corresponding hypothesis is proposed as follows.

Hypothesis 2: the effect of external reinsurance on internal reinsurance provision exhibits the inverse-U pattern. After reaching a threshold, the positive effect of external reinsurance on internal reinsurance provision will become decreasing.

Contrary to internal reinsurance provision, the receipt of internal reinsurance coverage could be associated with less external reinsurance and capital issuance as these sources of capital replenishment could substitute the demand for internal reinsurance coverage. Therefore, we expect that both external reinsurance and capital issuance exert negative effects on internal reinsurance receipt. The hypotheses are proposed as follows:

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Hypothesis 3a: the amount of external reinsurance negatively affect the participation and volume of internal reinsurance receipt.

Hypothesis 3b: the amount of capital issuance negatively affect the participation and volume of internal reinsurance receipt.

2.2.2 Investment and Underwriting Profitability

The income flows generated from profitability could also be the sources of capacity replenishment. In our study, we consider the effects of investment and underwriting profitability on internal reinsurance provision. Although both investment and underwriting profitability are the potential sources of capacity replenishment, they may influence internal reinsurance provision in different manners. In insurance industry, investment activities could be less related to internal reinsurance arrangements as reinsurance transactions mainly involve the allocation of underwriting capacity. Thus, it is reasonable to anticipate that insurance groups do not allocate capacity to the insurers with better investment profitability. Instead, the insurers with superior investment profitability generate more cash flows to replenish capacity and thus could be able to provide internal reinsurance for other affiliates. Thus, we expect a positive association between investment profitability and internal reinsurance provision. In contrast, the insurers with lower investment profitability may not have sufficient capacity to back their underwriting activities and thus need the supports from other

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affiliates. Therefore, we anticipate that investment profitability is negatively related to internal reinsurance receipt. The hypotheses are stated as follows.

***Hypothesis 4a*:** investment profitability positively affects internal reinsurance provision.

***Hypothesis 4b*:** investment profitability negatively affects internal reinsurance receipt.

Conversely, however, insurance groups may choose to allocate capacity to those affiliates with superior underwriting profitability since these affiliates are more likely to use their capacity to earn higher underwriting income. Powell et al. (2008) find a positive relationship between underwriting profitability and internal reinsurance usage, which indicated that the insurance groups were efficiently allocating capacity to their better performing affiliates. Clearly, therefore, underwriting performance should be negatively (positively) related to internal reinsurance provision (receipt). The corresponding hypotheses are stated as follows:

Hypothesis 5a: Underwriting profitability negatively affects internal reinsurance provision.

Hypothesis 5b: Underwriting profitability positively affects internal reinsurance receipt.

Nevertheless, those insurers with superior underwriting performance may be well suited to the provision of internal reinsurance to other affiliates since they can generate greater cash flows through their underwriting activities. This argument therefore implies the complete opposite to that above, which is that underwriting profitability

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positively (negatively) affects internal reinsurance provision (receipt). In this study, we also state the following hypotheses which are opposite to hypothesis 5a and 5b:

Hypothesis 6a: Underwriting profitability positively affects internal reinsurance provision.

Hypothesis 6b: Underwriting profitability negatively affects internal reinsurance receipt.

2.2.3 Investment and Underwriting Risk

In addition to the sources of capital replenishment, we further analyze the effects of investment and underwriting risk on internal reinsurance provision. We expect that the insurers with higher levels of risk-taking in investment and underwriting activities need to conserve more capacity and thus not be able to assume additional risk from other affiliates. Thus, we anticipate that both types of risk exert negative effects on the provision of internal reinsurance. The corresponding hypotheses are proposed as follows:

Hypothesis 7a: investment risk negatively affects internal reinsurance provision.

Hypothesis 7b: underwriting risk negatively affects internal reinsurance provision.

In contrast, these two types of risk could be positively related to internal reinsurance receipt. Although internal reinsurance is not used for managing investment risk, insurers with higher risk-taking in investment activities may use more internal

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reinsurance to reduce overall insolvency risk. According to coordinated risk management hypothesis developed by Schrand and Unal (1998), firms can engage in risk management to allocate overall risk among different risk categories. The risk reduction in an activity could enable firms to take more risk in another activity. In insurance literature, Che and Liebenberg (2017) find a positive relation between line of business diversification and risk-taking in investment activities, indicating that the reduction in underwriting risk enables insurers to take more risk in investment activities. Conversely, the insurers with higher investment risk may also have the motivation to reduce the risk from underwriting activities. Thus, we expect a positive relation between investment risk and internal reinsurance receipt. On the other hand, underwriting risk is more directly related to reinsurance usage. Insurers with higher underwriting risk could be motivated to use more internal reinsurance. Therefore, we anticipate that the risk-taking in underwriting activities leads to more internal reinsurance receipt. Based on the rationales above, we propose the following hypotheses:

Hypothesis 8a: investment risk positively affects internal reinsurance receipt.

Hypothesis 8b: underwriting risk positively affects internal reinsurance receipt.

In our study, we further investigate possible non-linear pattern in the effect of underwriting risk on internal reinsurance receipt. Under intra-group reinsurance arrangements, providers' financial position and underwriting results could be

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influenced by recipients' underwriting risk. The recipients with excessive risk-taking in underwriting activities could have higher probability of incurring large underwriting loss and thus can put heavy stress on providers' financial positions. To avoid posing considerable strain on providers, these recipients may be less inclined to use internal reinsurance. Therefore, we anticipate there is an inverse-U shape in the effect of underwriting risk on internal reinsurance receipt. We propose the hypothesis as follows:

Hypothesis 9: the effect of underwriting risk on internal reinsurance receipt exhibits an inverse-U pattern. After reaching a threshold, the positive effect of underwriting risk on internal reinsurance receipt will become decreasing.

We summarize the research hypotheses as table 1-1.

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Table 1- 1 Summary of research hypotheses

Variable	Internal reinsurance provision	Internal reinsurance receipt
External reinsurance	*Hypothesis 1a:* external reinsurance positively affects the participation and volume of internal reinsurance provision (+).	*Hypothesis 3a*: external reinsurance negatively affects the participation and volume of internal reinsurance receipt (-).
Capital holding	*Hypothesis 1b:* capital issuance positively affects the participation and volume of internal reinsurance provision (+).	*Hypothesis 3b:* capital issuance negatively affects the participation and volume of internal reinsurance receipt (-).
Non-linear effect of external reinsurance	*Hypothesis 2*: the effect of external reinsurance on internal reinsurance provision exhibits an inverse-U pattern.	
Investment profitability	*Hypothesis 4a*: investment profitability positively affects internal reinsurance provision (+).	*Hypothesis 4b*: investment profitability negatively affects internal reinsurance receipt (-).
Underwriting profitability	*Hypothesis 5a:* underwriting profitability negatively affects internal reinsurance provision (-).	*Hypothesis 5b:* underwriting profitability positively affects internal reinsurance receipt (+).
	Hypothesis 6a: underwriting profitability negatively affects internal reinsurance provision (+).	*Hypothesis 6b:* underwriting profitability negatively affects internal reinsurance receipt (-).
Investment risk	*Hypothesis 7a:* investment risk negatively affects internal reinsurance provision (-).	*Hypothesis 8a*: investment risk positively affects internal reinsurance receipt (+).
Underwriting risk	*Hypothesis 7b:* underwriting risk negatively affects internal reinsurance provision (-).	*Hypothesis 8b*: underwriting risk positively affects internal reinsurance receipt (+).
Non-linear effect of underwriting risk		*Hypothesis 9:* the effect of underwriting risk on internal reinsurance receipt exhibits an inverse-U pattern.

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3. Data, Methodology, and Variables

3.1 Data

In our study. We collect the data on the U.S. non-life insurers for the sample period from 1999 to 2016 from National Association of Insurance Commissioners (NAIC) database. The sample selection procedures are described as follows. First, only group-affiliated insurers are included in our analysis since standalone insurers essentially do not have access to internal reinsurance transactions. Then we only include the active group-affiliated insurers without regulatory process since the insurers under other conditions, such as liquidation, receivership, merger and acquisition, may not be able to maintain normal operating activities and make business decisions. Third, we only include the insurers with positive values in gross premiums written and surplus, and non-negative values in net premiums written. After these preliminary selection procedures, we exclude the observations with extraordinary values in the variables included in our study, such as the observations with the Herfindahl index in terms of geographic and line of business concentration that lie outside the range from 0 to 1. In addition, we follow Powell and Sommer (2007) and exclude the insurers whose external reinsurance premiums is greater than 75% of total premiums written. This step excludes professional reinsurers from our sample. Finally, we lag all explanatory variables for 1 period to mitigate potential endogeneity problem. Then After these steps, our sample

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size is 25,817firm/year observations. To mitigate the effects of extreme values on our empirical results, we winsorize our sample by replacing the observations that below 0.5^{th} percentile and 99.5^{th} percentile with 0.5^{th} percentile and 99.5^{th} percentile respectively.

3.2 Regression Model

In our empirical analysis, we investigate both participation and volume of internal reinsurance provision and receipt. Following the studies which analyze both participation and volume decisions regarding derivatives use (Cummins, Phillips, and Smith, 2001) and diversification (Berry-Stolzle, Liebenberg, Ruhland, and Sommer, 2012), we employ the model of Cragg (1971) in our empirical analysis. We consider Cragg's two-part regression as an appropriate model for our analysis because it allows the potential determinants influence participation and volume decisions in different ways. Our regressions are constructed as follows:

$$\text{Internal reinsurance provision}_{i,t} = \delta X_{i,t-1} + \text{Year dummies} + \varepsilon_{i,t} \quad (1)$$

$$\text{Internal reinsurance receipt}_{i,t} = \delta X_{i,t-1} + \text{Year dummies} + \varepsilon_{i,t} \quad (2)$$

In regressions (1) and (2), internal reinsurance provision and receipt are the dependent variables. In our work, there are two forms of internal reinsurance decisions: participation and volume. In the first part of Cragg's model, we analyze the determinants of participation decisions. In the second part, we investigate the volume

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decisions given that the insurers are providers or recipients. The subscripts i and t represent insurer i and year t respectively. $X_{i,t-1}$ represents the vector of all explanatory variables in year t-1. The error term is denoted by $\varepsilon_{i,t}$. To control the time effects, we include year dummies in our regressions.

3.3 Variables

3.3.1 Intra-Group Reinsurance Variables

The participation decision on internal reinsurance is measured as follows. If an insurer is a provider (recipient), the value of internal reinsurance provision (receipt) participation will be 1, and 0 otherwise. The volume of internal reinsurance provision (receipt) is calculated as the ratio of the net amount of internal reinsurance assumed (ceded) to gross premiums written.

3.3.2 Main Explanatory Variables

External Reinsurance

We define external reinsurance use as the difference between external reinsurance ceded and external reinsurance assumed, scaled by gross premiums written.

Capital Issuance

In the study of Berry-Stolzle, Nini, and Wende (2014), the amount of new paid-in capital is measured as the summation of capital change paid-in and surplus adjustment paid-in, minus the increase in treasury stock. The new issuance of surplus note is the

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amount of change in surplus notes. In our work, we calculate the measurement of capital issuance as follows. First, we aggregate the amount of new paid-in capital and surplus notes to measure the volume of capital issuance. In insurance industry, surplus notes are bond-like instruments which are subordinated to the claims of policyholders and creditors. Therefore, surplus notes can be considered as a type of capital. These are the main reasons for as to calculate the amount of capital issuance in such manner. Second, we exclude the change in treasury stock. As treasury stock is the stock purchased back by insurer, the decrease in the volume of treasury stock may not be considered as "capital issuance". Furthermore, the change in treasury stock could be caused by some special purposes other than replenishing capital position, such as improving stock prices. Based on these reasons, the change in treasury stock is excluded in the amount of capital issuance in our study. Finally, we scale the amount of capital issuance by insurer's previous surplus.[1]

Investment Profitability

Investment profitability is defined as the ratio of investment income to surplus.

Underwriting loss

[1] Niehaus (2018) further provides a supplementary explanation on capital issuance measurement adopted by Berry-Stolzle et al. (2014), which states that this measurement may include the internal capital transfer within the same group. Thus, our proxy for capital issuance nay not be a clear measurement of external capital financing. However, we are unable to identify whether the items regarding the capital changes on balance sheet are influenced by internal or external financing activities due to the data limitations. Thus, we do not attempt to adjust our proxy for capital issuance by excluding the capital change due to internal capital transfer.

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We calculate an insurer's underwriting loss based on direct premiums written rather than net premiums written. The main rationale for us to calculate underwriting loss in such manner is that net premium written based measurement is contaminated by the effects of reinsurance arrangements. In our study, underwriting loss is calculated as insurance loss from direct business divided by the total amount of direct premiums written, which is an inverse measure of underwriting profitability.[2]

Investment Risk

Referring to the works of Cheng and Weiss (2013), Lin, Lai, and Powers (2014), we use RBC risk-weighted investment risk measure, which is calculated as the summation of each invested asset multiplied by its corresponding risk factor, divided by total invested assets.

Underwriting Risk.

Similar with investment risk measure, we also include RBC risk-weighted underwriting risk measure, which is calculated as the summation of direct premiums written in each line of business multiplied by the corresponding risk factor, divided by total direct premiums written. In previous studies regarding the relation between capital and risk use net premiums written as the basis of variable calculation (e.g. Cheng and

[2] In the database, the data on earned premiums is based on net premiums written. We are unable to retrieve the data on earned premiums for direct premiums written. Thus, we use the amount of direct premiums written as denominator in the calculation of underwriting loss.

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Weiss, 2013). In our work, however, we attempt to remove the effects of reinsurance arrangements on underwriting risk variable so that we could be able to test the relationship between the degrees of underwriting risk prior to reinsurance arrangements and internal reinsurance decisions. Moreover, we also consider the underwriting risk in terms of geographic areas. Thus, we include hurricane exposure as an explanatory variable Following Cheng and Weiss (2012), this measurement is calculated as direct premiums written in hurricane-prone areas divided by total direct premiums written.[3]

3.3.3 Other control variables

In addition to the abovementioned variables, we also include several control variables in our empirical analysis. First of all, we include two variables to proxy the degree of underwriting portfolio concentration: geographic concentration and line of business concentration. The extent of insurance business concentration could be related to insurers' risk and thus influence insurers' internal reinsurance internal and external reinsurance. Some studies suggest that insurers could realize income smoothing through diversification and thus be able to take more risk. For instance, Che and Liebenberg (2017) find that diversified insurers are able to take more risk in investment activities due to coinsurance effect of diversification. This may imply that diversification leads

[3] According to Cheng and Weiss (2012), hurricane prone states include Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina, and North Carolina.

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to more (less) internal reinsurance provision (receipt). Nevertheless, another argument contends that insurers may concentrate on less volatile insurance business, which implies that more concentrated insurers have lower risk. Due to the divergent arguments above, we do not make prediction on the effects of diversification on internal reinsurance provision and receipt. Referring to previous studies in insurance literature (e.g. Cole and McCullough, 2006; Berry-Stolzle, Liebenberg, Ruhland, and Sommer, 2012), geographic and line of business concentration are measured as Herfindahl index of direct premiums written by geographic areas and line of business respectively.

The other control variables are briefly explained as follows. To measure the level of insurance leverage prior to any reinsurance arrangement, we include direct premiums written ratio in our work. Following Cole and McCullough (2006), Garven and Lamm-Tennant (2003), this variable is measured to the ratio of direct premiums written to surplus. Following prior works in insurance literature, we included firm size as a control variable, which is measured as the natural logarithm of total admissible assets. To control the effect of regulatory jurisdiction, we include a dummy variable which equals to one if the insurer is licensed in New York State. According to Cummins and Sommer (1996), the insurers licensed in New York State are subject to more stringent regulatory environment. Since intra-group reinsurance arrangements involve risk allocation and could be relevant to insures' solvency, we expect this variable exerts significant effects

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on internal reinsurance provision and receipt. Finally, we include an indicator variable to control the effect of insurer's organization form. Following Cummins and Sommer (1996), the value of this indicator variable equals to one for stock insurer and zero otherwise. The definitions of the variables in our work are summarized as Table 1-2.

Table 1- 2 Variable definitions

Variables	Definitions
Panel A: Dependent variables	
Internal reinsurance provider indicator	Variable taking the value of 1 if the amount of internal reinsurance assumed exceed the amount of internal reinsurance ceded.
Internal reinsurance recipient indicator	Variable taking the value of 1 if the amount of internal reinsurance ceded exceed the amount of internal reinsurance assumed.
Internal reinsurance provision volume	If the value of internal reinsurance provider indicator takes 1, this variable is measured as the ratio of net amount of internal reinsurance assumed to gross premiums written; otherwise 0.
Internal reinsurance receipt volume	If the value of internal reinsurance provider indicator takes 1, this variable is measured as the ratio of net amount of internal reinsurance ceded to gross premiums written; otherwise 0.
Panel B:Explanatory variables	
External reinsurance usage	The difference between external reinsurance ceded and external reinsurance assumed, divided by gross premiums written.
Capital issuance	The amount of capital issuance divided by surplus kin previous year.
Investment profitability	The ratio of investment income to surplus.
Underwriting loss	The loss incurred from direct business divided by direct premiums written.
Investment risk	The summation of the amount of each type of invested asset multiplied by the corresponding risk factor, divided by total invested assets.
Underwriting risk	The summation of the amount of direct premiums written in each line of business multiplied by the corresponding risk factor, divided by total direct premiums written.
Hurricane exposure	The ratio of direct premiums written in hurricane-prone areas to total direct premiums written.
Geographic concentration	Herfindahl index of direct premiums written by states.
Line of business concentration	Herfindahl index of direct premiums written by lines of business.
Direct premiums written ratio	The ratio of direct premiums written to surplus.
Firm size	Natural logarithm of insurer's annual total assets.
New York indicator	Variable taking the value of 1 if the insurer is licensed in New York state; otherwise 0.
Organization form	Variable taking the value of 1for stock insurer; otherwise 0.

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4. Empirical Results

4.1 Data Description

Figure 1-1 displays the average amount of direct premiums written, internal and external reinsurance, and net premiums written by group-affiliated insurers in our sample. In Figure 1-1, the amount of internal reinsurance premiums far exceeded that of external ones, suggesting that intra-group reinsurance transactions are prevailing in the U.S non-life insurance industry. In addition, internal reinsurance assumed and ceded demonstrated very similar trends with direct and net premiums written. These phenomena may indicate that intra-group reinsurance activities play a crucial role in insurers' underwriting business growth. The numbers of internal reinsurance providers, recipients, and the insurers without intra-group reinsurance engagement during our sample period are displayed in Table 1-3. The internal reinsurance providers and recipients are further classified into the following subgroups: pure internal reinsurance providers, other internal reinsurance providers, other internal reinsurance recipients, and pure reinsurance recipients. In Table 1-3, pure internal reinsurance providers and recipients are the extreme cases of intra-group reinsurance participation. For pure providers, the only source of underwriting revenue is internal reinsurance premiums assumed. These insurers have zero values in direct premiums written. On the contrary,

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pure recipients cede all the premiums written to other affiliates and thus have zero net premiums written.

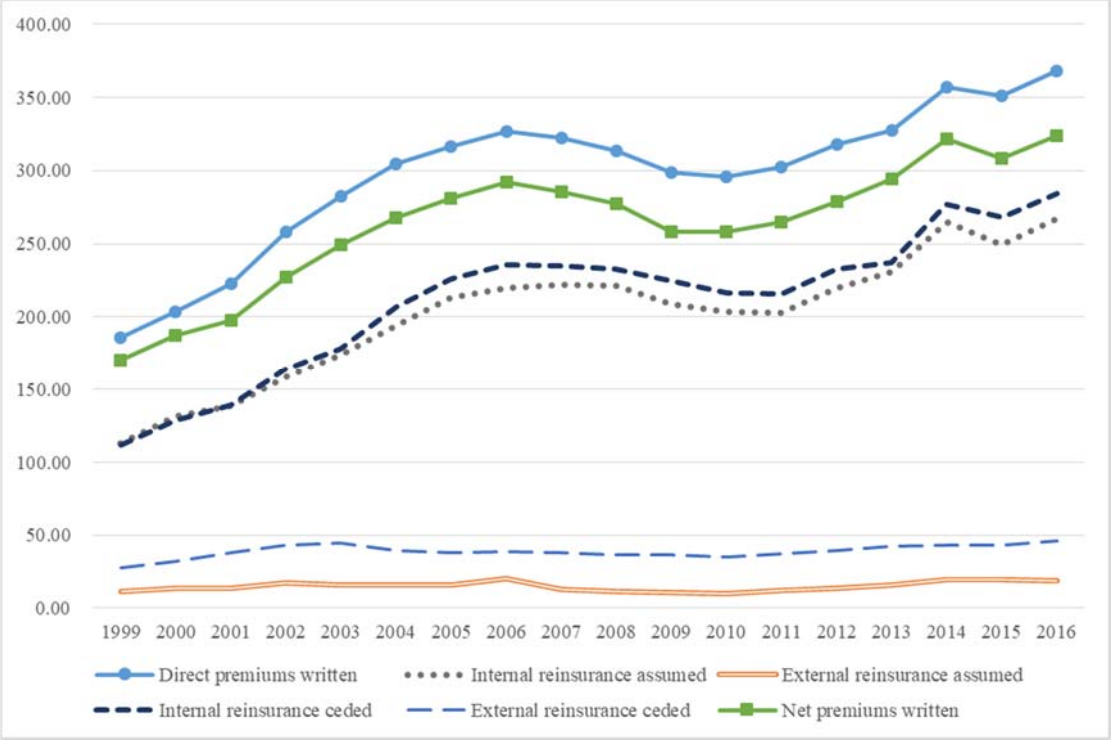

Figure 1-1 The average amount of direct premiums written, internal and external reinsurance premiums, and net premiums written of the U.S. non-life insurance industry (1999 to 2016)

Notes:
(1) Unit: million dollars.
(2) The statistics are calculated as the aggregate amount of premiums of the group-affiliated insurers included in our sample, divided by the number of insurers in each year.

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Table 1- 3 Number of internal reinsurance participants during sample period

Year	A. Providers				B. Recipients				C. Non-Participant		Total
	a. Pure provider		b. Other provider		a. Other recipient		b. Pure recipient				
	Obs	%	Obs	%	Obs	%	Obs	%	Obs	%	
1999	20	1.36	453	30.73	599	40.64	158	10.72	244	16.55	1,474
2000	20	1.43	427	30.59	594	42.55	153	10.96	202	14.47	1,396
2001	19	1.31	404	27.80	640	44.05	161	11.08	229	15.76	1,453
2002	19	1.32	394	27.38	634	44.06	175	12.16	217	15.08	1,439
2003	18	1.25	409	28.44	637	44.30	160	11.13	214	14.88	1,438
2004	17	1.21	406	28.86	631	44.85	171	12.15	182	12.94	1,407
2005	21	1.52	391	28.21	612	44.16	180	12.99	182	13.13	1,386
2006	26	1.89	395	28.69	616	44.73	177	12.85	163	11.84	1,377
2007	22	1.58	377	27.03	660	47.31	181	12.97	155	11.11	1,395
2008	23	1.67	378	27.49	643	46.76	181	13.16	150	10.91	1,375
2009	16	1.11	393	27.27	680	47.19	186	12.91	166	11.52	1,441
2010	16	1.10	411	28.17	679	46.54	181	12.41	172	11.79	1,459
2011	23	1.56	402	27.24	696	47.15	203	13.75	152	10.30	1,476
2012	29	1.98	385	26.32	683	46.68	208	14.22	158	10.80	1,463
2013	26	1.78	387	26.51	658	45.07	224	15.34	165	11.30	1,460
2014	26	1.92	340	25.17	609	45.08	214	15.84	162	11.99	1,351
2015	23	1.52	368	24.32	678	44.81	267	17.65	177	11.70	1,513
2016	30	1.98	356	23.51	685	45.24	266	17.57	177	11.69	1,514
Total	394	1.53	7,076	27.41	11,634	45.06	3,446	13.35	3,267	12.65	25,817

Notes:

1. The explanation of each intra-group reinsurance participation status is summarized as follows. (1) Provider: insurers are classified as providers when the volume of internal reinsurance premiums assumed exceeds that of internal reinsurance premiums ceded. This type of intra-group reinsurance participant could be divided into two subgroups: (a) pure providers: the amount of internal reinsurance premiums assumed is the only source of underwriting income for these insurers. (b) Other providers: these insurers have positive values in both direct premiums written and internal reinsurance assumed. (2) Recipients: insurers are classified as recipients when the volume of internal reinsurance premiums ceded exceeds that of internal reinsurance premiums assumed. This type of intra-group reinsurance participant could be divided into two subgroups: (a) pure recipients: these insurers transfer all premiums written to other affiliates. (b) Other recipient: these insurers have positive values in both net premiums written and internal reinsurance ceded. (3) Non-participants: these insurers do not engage in intra-group reinsurance transactions.
2. Obs: number of observations; %: the proportion of the observations in each subgroup to total observations presented in the last column.

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Based on Table 1-3, internal reinsurance providers and recipients account for 29% and 58% of the total number of group-affiliated insurers respectively, indicating that the majority of group-affiliated insurers participated in intra-group reinsurance transactions. It is worth noting that the number of pure internal reinsurance recipients accounts for 12.65% of the number of insurers in our sample. In addition, the number of internal reinsurance providers displays a decreasing trend during the sample period. This situation may indicate that the underwriting risk becomes more concentrated in fewer providers within insurance groups.

Table 1-4 further compares internal reinsurance providers and recipients. On average, providers are considerably larger then recipients in terms of total admissible assets. Furthermore, table 4 also reveals the differences between providers and recipients in terms of premiums composition. For providers, direct premiums written accounts for less than 50% of gross premiums written. It is worth noting that the proportion of internal reinsurance provision to gross premiums written exhibited an upward trend during our sample period. Taken this with the decreasing trend of the number of internal reinsurance providers represented in Table 1-3 together, we interpret these trends as the phenomenon of underwriting risk concentration within insurance groups. Thus, the financial adequacy of internal reinsurance providers become more crucial for group-wide solvency. Turning to internal reinsurance recipients, the direct

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premiums written accounts for over 70% of gross premiums written, which is much higher than providers. In addition, the ratio of net internal reinsurance ceded to gross premiums written exhibited increasing trend during the sample period. These figures may indicate that the capital relief from intra-group reinsurance transaction is an important source of underwriting capacity. In short, the aforementioned figure and tables suggest the existence of active intra-group reinsurance markets and the importance of intra-group reinsurance activities on business growth and solvency of insurance groups.

4.2 Descriptive statistics and univariate analysis

The descriptive statistics demonstrated in Table 1-5 reveal that the amount of internal reinsurance provision (receipt) accounts for 34% (60%) of gross premiums written by internal reinsurance providers (recipients). The correlation coefficients represented in Table 1-6 indicate that the participation of internal reinsurance provision is positively associated with investment profitability, investment risk, and underwriting risk, whereas it is negatively related to hurricane exposure. On the other hand, internal reinsurance receipt indicator is negatively related to external reinsurance use, investment profitability, investment risk, whereas it is positively related to hurricane exposure. Likewise, internal reinsurance provision and receipt volume variables are related to the main explanatory variables in similar manners.

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Table 1- 4 The comparison of providers and recipients: total admissible assets and the composition of premiums written (1999 to 2016)

Year	Panel A: Providers								Panel B: Recipients							
	Column (1) Assets	Column (2) GPW	Column (3) DPW		Column (4) ICM Rein Provision		Column (5) Ext Rein Use		Column(1) Assets	Column(2) GPW	Column (3) DPW		Column (4) ICM Rein Receipt		Column (5) Ext Rein Use	
			Vol	%	Vol	%	Vol	%			Vol	%	Vol	%	Vol	%
1999	1,212.77	559.41	272.23	48.66	149.85	26.79	27.09	4.84	237.27	232.78	172.41	74.06	91.51	39.31	12.68	5.45
2000	1,283.40	645.32	303.90	47.09	171.01	26.50	35.64	5.52	230.84	244.95	180.03	73.50	98.23	40.10	9.29	3.79
2001	1,385.26	759.47	364.63	48.01	202.62	26.68	60.38	7.95	251.61	258.08	191.42	74.17	108.60	42.08	9.30	3.60
2002	1,546.96	933.57	432.57	46.34	233.40	25.00	66.11	7.08	238.74	268.25	212.45	79.20	129.03	48.10	8.25	3.08
2003	1,690.04	979.91	445.65	45.48	252.84	25.80	65.52	6.69	279.91	301.42	246.32	81.72	143.10	47.47	13.81	4.58
2004	1,845.49	1,035.85	455.33	43.96	262.26	25.32	42.51	4.10	314.13	333.44	273.99	82.17	161.29	48.37	14.96	4.49
2005	2,063.52	1,112.71	468.75	42.13	288.79	25.95	41.11	3.69	345.43	352.39	287.81	81.67	172.65	48.99	14.14	4.01
2006	2,367.14	1,108.95	458.32	41.33	291.11	26.25	31.68	2.86	390.72	376.15	306.46	81.47	182.21	48.44	12.44	3.31
2007	2,483.21	1,150.96	470.07	40.84	328.72	28.56	50.88	4.42	367.75	361.05	295.12	81.74	176.58	48.91	13.65	3.78
2008	2,138.71	1,102.91	451.17	40.91	316.87	28.73	55.14	5.00	367.34	362.37	290.80	80.25	173.27	47.82	13.21	3.64
2009	2,196.25	1,050.15	424.12	40.39	307.52	29.28	59.14	5.63	390.30	350.96	282.24	80.42	170.56	48.60	10.97	3.13
2010	2,059.60	929.93	382.60	41.14	291.70	31.37	51.08	5.49	442.71	385.38	295.89	76.78	166.31	43.15	13.64	3.54
2011	2,071.78	961.03	392.66	40.86	308.87	32.14	53.57	5.57	437.06	379.58	295.94	77.97	167.15	44.04	11.02	2.90
2012	2,263.30	1,064.55	431.91	40.57	336.32	31.59	55.85	5.25	454.81	391.60	304.05	77.64	177.34	45.29	11.63	2.97
2013	2,458.19	1,118.61	450.32	40.26	368.63	32.95	63.44	5.67	446.69	405.67	311.21	76.71	183.27	45.18	8.47	2.09
2014	2,997.01	1,289.11	490.82	38.07	437.95	33.97	53.65	4.16	505.65	459.90	348.28	75.73	214.70	46.68	8.16	1.77
2015	2,932.29	1,302.19	471.54	36.21	443.05	34.02	59.15	4.54	484.97	434.68	348.91	80.27	213.91	49.21	9.06	2.08
2016	3,281.29	1,403.03	497.50	35.46	495.13	35.29	72.32	5.15	501.78	454.03	366.97	80.82	229.15	50.47	9.72	2.14

Notes:
1. Unit: million dollars
2. Assets: total admissible assets; GPW: gross premiums written, DPW: direct premiums written; ICM Rein Provision: the net amount of internal reinsurance provision, which is calculated as the difference between internal reinsurance assumed and internal reinsurance ceded; ICM Rein Receipt: the net amount of internal reinsurance receipt, which is calculated as the difference between internal reinsurance ceded and internal reinsurance assumed; Ext Rein Use: External reinsurance use, which is defined as the difference between external reinsurance ceded and external reinsurance assumed.
3. In column (3), (4), and (5), the left side displays the volume of direct premiums written, internal reinsurance provision (receipt), and net external reinsurance use. The right side shows the percentage of direct premiums written, internal reinsurance provision (receipt), and net external reinsurance use to gross premiums written.

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Table 1- 5 Descriptive statistics

Variable	Mean	Median	St. dev.	Minimum	Maximum
Internal reinsurance provision indicator	0.2893	0.0000	0.4535	0.0000	1.0000
Internal reinsurance receipt indicator	0.5841	1.0000	0.4929	0.0000	1.0000
Internal reinsurance provision volume	0.3431	0.2382	0.3118	0.0000	1.0000
Internal reinsurance receipt volume	0.5994	0.6689	0.3754	0.0000	1.0000
External reinsurance usage	0.0771	0.0079	0.1768	-0.4606	0.9122
Capital issuance	0.0481	0.0000	0.2292	-0.2593	2.1338
Investment profitability	0.0813	0.0659	0.0647	-0.0588	0.4244
Underwriting loss	0.5771	0.5495	0.5466	-2.0742	5.3294
Investment risk	0.0187	0.0067	0.0236	0.0000	0.1204
Underwriting risk	0.9579	0.9521	0.0896	0.7980	1.6099
Hurricane exposure	0.2816	0.1515	0.3506	0.0000	1.0000
Geographic concentration	0.5089	0.4116	0.3818	0.0390	1.0000
Line of business concentration	0.6294	0.5739	0.2912	0.1570	1.0000
Direct premiums written ratio	3.1112	1.3568	6.4032	0.0000	59.0853
Firm size	18.4565	18.3468	1.8710	14.5689	23.9627
New York State	0.0496	0.0000	0.2172	0.0000	1.0000
Organization Form	0.8248	1.0000	0.3802	0.0000	1.0000

Note: the calculation of the descriptive statistics of internal reinsurance provision and receipt volume is based on the subsamples of internal reinsurance providers and recipients respectively. The numbers of observations in providers and recipients subsample are 7,470 and 15,180 firm/year observations respectively. The descriptive statistics on other remaining variables are calculated by using total sample, which is consist of 25,817 firm/year observations.

Table 1- 6 Correlation Coefficients

Variable	IRPI		IRRI		IRPV		IRRV		EXTRE		CAP		INVPROF	
IRRI	-0.7562	***	1.0000											
IRPV	0.6801	***	-0.5143	***	1.0000									
IRRV	-0.5425	***	-0.7114	***	-0.3690	***	1.0000							
EXTRE	-0.0087		-0.1558	***	-0.0633	***	-0.2384	***	1.0000					
CAP	-0.0155	*	-0.0080		-0.0010		-0.0236	***	0.0482	***	1.0000			
INVPROF	0.2046	***	-0.1956	***	0.1277	***	-0.3103	***	-0.0171	***	-0.0618	***	1.0000	
UNDLOSS	0.0087		0.0059		0.0220	***	0.0237	***	-0.0119		0.0185	***	0.0820	***
INVRISK	0.2173	***	-0.2065	***	0.0869	***	-0.2868	***	0.0373	***	-0.0312	***	0.0001	
UNDRISK	0.0245	***	-0.0084		0.0136	**	-0.0114		0.0083		0.0078		0.0777	***
HUREXP	-0.1190	***	0.0757	***	-0.0692	***	0.1294	***	0.1228	***	0.0391	***	-0.1236	***
GEOCON	-0.0779	***	-0.0675	***	-0.0030		0.0328	***	0.0414	***	0.0181	***	-0.1699	
LOBCON	-0.0950	***	-0.0420	***	-0.0251	***	0.0240	***	-0.0073		0.0498	***	-0.1476	***
DPWRATIO	-0.3381	***	0.3532	***	-0.4520	***	0.3749	***	0.0750	***	0.0055		-0.0023	***
FS	0.3763	***	-0.2463	***	0.2017	***	-0.4206	***	-0.0489	***	-0.0149	**	0.3198	***
NYSTATE	0.0060		0.0039		-0.0085		-0.0073		0.0009		0.0049		0.0521	
OF	-0.0973	***	0.1062	***	0.0395	***	0.0747	***	-0.0268	***	0.0437	***	0.0639	***

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Table 1-6 Correlation Coefficients (continued)

Variable	UNDLOSS		INVRISK		UNDRISK		HUREXP		EXTRE		CAP		INVPROF	
INVRISK	-0.0206	***	1.0000											
UNDRISK	-0.0127	**	-0.0255	***	1.0000									
HUREXP	-0.0090		-0.0957	***	-0.0637	***	1.0000							
GEOCON	-0.0059		-0.1294	***	-0.0575	***	0.1550	***	1.0000					
LOBCON	0.0074		-0.1376	***	0.0806	***	0.1123	***	0.3136	***	1.0000			
DPWRATIO	-0.0015		-0.2366	***	-0.0798	***	0.1254	***	-0.0521	***	-0.0941	***	1.0000	
FS	0.0131	**	0.3547	***	0.0617	***	-0.1896	***	-0.4470	***	-0.2873	***	-0.1404	***
NYSTATE	0.0077		-0.0500	***	0.0171	***	-0.1025	***	-0.0445	***	-0.0744	***	-0.0139	**
OF	-0.0066		-0.2375	***	-0.0159	***	-0.0947	***	-0.1748	***	0.0542	***	-0.0048	

Variable	FS		NYSTATE	OF
NYSTATE	0.0584	***	1.0000	
OF	-0.0345	***	0.0040	1.0000

Notes:
1. IRPI: internal reinsurance provision indicator; IRRI: internal reinsurance receipt indicator; IRPV: internal reinsurance provision volume; IRRV: internal reinsurance receipt volume; EXTRE: external reinsurance use; CAP: capital issuance; INVPROF: investment profitability; UNDLOSS: underwriting loss; INVRISK: investment risk; UNDRISK: underwriting risk; HUREXP: hurricane exposure; GEOCON: geographic concentration; LOBCON: line of business concentration; DPWRATIO: direct premiums written ratio; FS: firm size; NYSTATE: New York State indicator; OF: Organization form.
2.*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

In short, the statistics presented in Table 1-5 and 1-6 suggest that internal reinsurance providers generally have superior investment profitability, hold more risky invested assets, and have less direct premiums written in hurricane-prone areas. On the other hand, recipients generally have less external reinsurance use, lower investment profitability and risk, higher hurricane exposure.

In Table 1-7, we further compare the main subgroups in our sample: providers, recipients, and non-participants. Based on the results showed in Table 1-7, the insurers which do not participate in intra-group reinsurance transactions generally have greater external reinsurance use and capital issuance. Furthermore, these insurers tend to have more direct premiums written in hurricane prone areas and more concentrated

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underwriting portfolio in comparison with internal reinsurance providers and recipients. Greater external reinsurance usage and hurricane exposure are consistent with the argument of Powell and Sommer (2007), which states that the insurance groups compartmentalize catastrophe exposure by using external reinsurance instead of internal reinsurance. Turning to other results, internal reinsurance providers have the highest investment profitability and investment risk. In addition, they have the least hurricane exposure and the most diversified underwriting portfolio in terms of geographic areas and lines of business among the three subgroups in Table 1-7. On the other hand, internal reinsurance recipients have the lowest level of investment profitability and risk, and the highest level of direct premiums written.

In Table 1-8, we further divide internal reinsurance providers and recipients into the following subgroups and make comparisons: pure providers, other providers, other recipients, and pure recipients. In comparison with other providers, pure providers have considerably smaller firm size, lower investment risk, and less external reinsurance usage. Based on these results, pure providers may specialize in pooling the risk from other affiliates. Thus, they do not have large firm size and use less external reinsurance as supplemental capacity. Nevertheless, the number of pure providers only accounts for quite small fraction of our entire sample. The majority of providers still have positive values in both direct premiums written and internal reinsurance assumed.

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Table 1- 7 Univariate analysis: the comparison of internal reinsurance providers, recipients, and non- participants

Variable	(1) Providers (N=7,470)		(2) Recipients (N=15,080)		(3) Non-Participants (N=3,267)		T-test		
	Mean	St dev	Mean	St dev	Mean	St dev	(1) vs (2)	(1) vs (3)	(2) vs (3)
External reinsurance usage	0.0747	0.1669	0.0539	0.1480	0.1899	0.2588	9.1459 ***	-23.4120 ***	-29.0402 ***
Capital issuance	0.0425	0.2153	0.0465	0.2268	0.0680	0.2673	-1.3044	-4.8066 ***	-4.2608 ***
Investment profitability	0.1021	0.0682	0.0706	0.0595	0.0832	0.0682	33.9685 ***	13.2325 ***	-9.7321 ***
Underwriting loss	0.5848	0.5900	0.5798	0.5009	0.5485	0.6440	0.6163	2.7259 ***	2.6081 ***
Investment risk	0.0267	0.0252	0.0146	0.0221	0.0193	0.0216	35.4279 ***	15.55367 ***	-11.2968 ***
Underwriting risk	0.9615	0.0939	0.9573	0.0849	0.9532	0.1004	3.1694 ***	3.9677 ***	2.1660 **
Hurricane exposure	0.2137	0.2930	0.3034	0.3543	0.3247	0.4194	-19.7002 ***	-13.6353 ***	-2.6964 ***
Geographic concentration	0.4605	0.3656	0.4877	0.3826	0.7092	0.3490	-5.0571 ***	-33.0508 ***	-32.3018 ***
Line of business concentration	0.5844	0.2891	0.6194	0.2884	0.7711	0.2645	-8.3463 ***	-32.2524 ***	-29.2230 ***
Direct premiums written ratio	0.9149	1.0291	4.3925	7.8339	1.8469	3.4901	-53.4901 ***	-14.9581 ***	28.8172 ***
Firm size	19.5599	1.8440	18.0678	1.7054	17.7282	1.5666	58.6140 ***	52.7352 ***	11.0515 ***
New York State	0.0517	0.2214	0.0503	0.2186	0.0416	0.1998	0.4301	2.3182 **	2.2188 **
Organization Form	0.7668	0.4229	0.8588	0.3482	0.8001	0.4000	-16.2714 ***	-3.9025 ***	7.7741 ***

Note: *** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

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Table 1- 8 Univariate difference across intra-group reinsurance participation status

Variable	Providers (N=7,470)				Recipients (N=15,080)				t-test					
	(1) Pure Providers (N=394)		(2) Other Providers (N=7,076)		(3) Other Recipients (N=11,634)		(4) Pure Recipients (N=3,446)							
	Mean	St dev	Mean	St dev	Mean	St dev	Mean	St dev	(1) vs (2)	(1) vs (3)	(1) vs (4)	(2) vs (3)	(2) vs (4)	(3) vs (4)
External reinsurance usage	0.0219	0.1181	0.0776	0.1688	0.0698	0.1624	0.0000	0.0552	-8.8762 ***	-7.8118 ***	3.6461 ***	3.1054 ***	35.0603 ***	39.3800 ***
Capital issuance	0.0524	0.2807	0.0419	0.2110	0.0529	0.2378	0.0249	0.1832	0.7257	-0.0409	1.8974 *	-3.2954 ***	4.2584 ***	7.3429 ***
Investment profitability	0.0817	0.0695	0.1032	0.0679	0.0798	0.0622	0.0399	0.0347	-5.9914 ***	0.5456	11.7697	23.6555 ***	63.2694 ***	48.2690 ***
Underwriting loss			0.5847	0.5737	0.5694	0.4397	0.6146	0.6658				1.8993 *	-2.2527 **	-3.7470 ***
Investment risk	0.0112	0.0194	0.0276	0.0252	0.0168	0.0231	0.0073	0.0161	-16.1070 ***	-5.6111 ***	3.7993 ***	29.4290 ***	49.9267 ***	27.1432 ***
Underwriting risk			0.9617	0.0938	0.9588	0.0887	0.9523	0.0704				2.0559 ***	5.7277 ***	4.5141 ***
Hurricane exposure			0.2139	0.2929	0.2694	0.3221	0.4182	0.4265				-12.0039 ***	-25.2879 ***	-18.9361 ***
Geographic concentration			0.4592	0.3651	0.4424	0.3697	0.6408	0.3857				3.0144 ***	-22.9618 ***	-26.7624 ***
Line of business concentration			0.5833	0.2887	0.6089	0.2882	0.6548	0.2865				-5.8255 ***	-11.9275 ***	-8.2526 ***
Direct premiums written ratio			0.9171	1.0294	3.5810	6.1966	7.1288	11.3643				-45.2970 ***	-32.0211 ***	-17.5683 ***
Firm size	17.9219	1.6433	19.6511	1.8116	18.4772	1.6238	16.6857	1.1616	-20.2146 ***	-6.5990 ***	14.5232 ***	44.6769 ***	101.3932 ***	72.0507 ***
New York State	0.0761	0.2656	0.0503	0.2186	0.0596	0.2367	0.0192	0.1371	1.8953 *	1.2226	4.1962 ***	-2.7213 ***	8.9183 ***	12.6118 ***
Organization Form	0.9670	0.1789	0.7557	0.4297	0.8811	0.3237	0.7835	0.4119	20.4051 ***	9.0431 ***	16.0669 ***	-21.1778 ***	-3.2103 ***	12.7900 ***

Notes:

1. *** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

2. Pure providers: the insurers which only assume premiums from affiliates; other providers: these insurers have positive values in both direct premiums written and internal reinsurance assumed; pure recipients: these insurers transfer all premiums written to other affiliates; other recipient: these insurers have positive values in both net premiums written and internal reinsurance ceded.

3.. Most pure providers do not have positive values in direct premiums written based variables in previous year, only with very few exceptions. Thus, the univariate analysis for these variables is not available for pure providers.

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Another extreme case is pure recipients. Based on the results in Table 1-8, pure recipients have the lowest values in external reinsurance usage and capital issuance among the four types of intra-group reinsurance participants. Furthermore, they have the highest hurricane risk exposure and the most concentrated underwriting portfolio. Based on these characteristics, pure recipients could have greater demand for reinsurance coverage, yet they may have more limited access to external financing and reinsurance. Thus, they may rely on the capital relief provided by other affiliates via intra-group reinsurance transactions.

4.3 Multivariate analysis

The empirical results of multivariate regressions are represented in Table 1-9. The results of internal reinsurance provision and receipt decisions are showed in column (1) to (2) and (3) to (4) respectively. First of all, the coefficient of external reinsurance use is positive and significant in internal reinsurance provision participation regression, indicating that the insurers with more external reinsurance usage are more likely to be providers. Nevertheless, external reinsurance exerts negative effect on internal reinsurance provision as shown in column (2).

To reconcile these two seemingly contradicting results, we make the following explanations. The insurers with more external reinsurance usage have more additional risk-bearing capacity and thus be able to be the providers in intra-group reinsurance.

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Table 1- 9 Multivariate regression analysis

Variables	Internal Reinsurance Provision				Internal Reinsurance Receipt			
	(1) Participation		(2) Volume		(3) Participation		(4) Volume	
	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
Constant	-5.5431 ***	0.1764	-0.7744 ***	0.1209	3.6562 ***	0.1690	2.7054 ***	0.0662
External reinsurance usage	0.6264 ***	0.0591	-0.0965 *	0.0561	-1.8046 ***	0.0586	-1.0161 ***	0.0357
Capital issuance	0.0258	0.0473	-0.0212	0.0392	-0.1085 **	0.0456	-0.0435 ***	0.0157
Investment profitability	3.1819 ***	0.1804	0.6611 ***	0.1174	-4.4146 ***	0.1981	-2.1044 **	0.1081
Underwriting loss	-0.0413 ***	0.0216	0.0370 ***	0.0118	0.0897 ***	0.0234	0.0530 ***	0.0078
Investment risk	1.4261 ***	0.4665	-1.7278 ***	0.3365	-3.4972 ***	0.4878	-2.1995 ***	0.2191
Underwriting risk	-0.6927 ***	0.1198	0.1613 *	0.0840	1.2137 ***	0.1188	0.2950 ***	0.0457
Hurricane exposure	-0.2094 ***	0.0315	0.1136 ***	0.0222	0.1726 ***	0.0279	0.0661 ***	0.0089
Geographic concentration	0.2593 ***	0.0299	0.1767 ***	0.0210	-0.6213 ***	0.0279	-0.1358 ***	0.0096
Line of business concentration	-0.0673 *	0.0366	-0.0961 ***	0.0260	-0.5203 ***	0.0338	-0.0571 ***	0.0108
Direct premiums written ratio	-0.3299 ***	0.0094	-0.1529 ***	0.0066	0.3567 ***	0.0102	0.0752 ***	0.0030
Firm size	0.2939 ***	0.0068	0.0088 *	0.0050	-0.2055 ***	0.0065	-0.1304 ***	0.0028
New York State	-0.2011 ***	0.0438	-0.1487 ***	0.0367	0.1470 ***	0.0418	0.0387 ***	0.0134
Organization Form	-0.3187 ***	0.0265	0.2604 ***	0.0218	0.3458 ***	0.0249	0.1002 ***	0.0096
Year dummies	Yes		Yes		Yes		Yes	
Wald test	4,876.56***				4,700.78***			
Pseudo Likelihood Ratio	-8,255.9343				-13,328.389			

Note: *** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

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To reconcile these two seemingly contradicting results, we make the following explanations. The insurers with more external reinsurance usage have more additional risk-bearing capacity and thus be able to be the providers in intra-group reinsurance. Nevertheless, large external reinsurance use is also associated with higher counterparty risk from non-affiliated reinsurers. This factor may restrain providers from assuming more internal reinsurance. On the other hand, capital issuance does not have significant effects on both participation and volume of internal reinsurance provision. Based on these results above, hypothesis 1a is only supported in participation decision. Conversely, capital issuance is not found to have any significant effects on either internal reinsurance provision participation or volume. Thus, our empirical results do not provide support for Hypothesis 1b.

Turning to the results shown in column (3) and (4), we find that both external reinsurance and capital issuance exert negative effects on participation and volume of internal reinsurance, suggesting that the capital replenishments from financing activities exhibit substitute effects on internal reinsurance receipt. Both hypothesis 3a and 3b are supported.

As regards investment profitability, we find that insurers with higher investment profitability are more likely to be providers and associated with greater amount of internal reinsurance provision. On the contrary, investment profitability is negatively

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related to both the participation and volume of internal reinsurance receipt. These results suggests that the income flows generated from investment g activities are the sources of the capacity for the provision of internal reinsurance coverage to other affiliates. In contrast, the insurer with lower investment profitability may not be able to generate sufficient cash flows and thus need more supports from other group members. Both Hypothesis 4a and 4b receive support in our work.

Turning to underwriting profitability, underwriting loss is negatively related to internal reinsurance provision participation, which suggests that the insurers with superior underwriting profitability are more likely to be providers. However, the effects of the underwriting loss on the volume of internal reinsurance provision are both found to be significantly positive. A possible explanation for the effects of the underwriting loss on internal reinsurance provision participation and volume is that those providers with greater underwriting loss may wish to smooth their underwriting income by assuming more internal reinsurance premiums. As for recipients, we find that both the participation and volume of internal reinsurance receipt have associations with a greater underwriting loss. These results are consistent with the notion that those insurers with lower incomes generated from underwriting activities require the support of the other affiliates. Based on the results regarding the relation between underwriting profitability and internal reinsurance receipt, hypothesis 6b is fully supported.

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The effects of business portfolio risk variables on the provision of internal reinsurance are mixed in column (1) and (2). Contrary to our initial expectation, insurers with higher investment risk taking are more likely to be providers in intra-group reinsurance. A possible explanation is that insurers which take more investment risk have higher expected investment profitability and thus be able to provide coverage for other affiliates. In contrast, investment risk is negatively related to the volume of internal reinsurance provision, which is consistent with our expectation that insurers with excessive investment risk do not have additional risk-bearing capacity to provide internal reinsurance coverage. Taken these results together, investment risk could be a source of capital replenishment as it is associated with higher expected investment incomes in the future. Nevertheless, the insurers which take excessive investment risk have higher probability of incurring large investment loss and thus may reduce the volume of internal reinsurance provision. Due to the divergent results regarding the effects of investment risk on participation and volume decisions of internal reinsurance provision, we do not conclude that hypothesis 7a is supported.

With respect to underwriting activities, we find that both underwriting risk and hurricane exposure variables exert negative effects on internal reinsurance provision participation, which are consistent with our expectation. But these variables have positive effects on the volume of internal reinsurance provision. The possible reason

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for positive effects of underwriting risk and hurricane exposure variables is that the providers with greater underwriting risk exposure may use intra-group reinsurance transactions to realize the diversification effects since the insurance loss from internal reinsurance premiums assumed may not be perfectly correlated with that from other insurance business. Based on the aforementioned results, we do not find consistent evidence supporting hypothesis 7b.

Turning to recipients, investment risk is negatively related to both participation and volume of internal reinsurance receipt. Therefore, hypothesis 8a does not receive support. On the other hand, underwriting risk and hurricane exposure variables have positive effects on internal reinsurance receipt participation and volume. These results are consistent with our anticipation that internal reinsurance is primarily used for managing underwing risk. Hypothesis 8b is supported in our work.

With respect to the remaining control variables, geographic concentration positively affect internal reinsurance provision, whereas line of business concentration exerts negative effect. The possible explanation for the positive relationship between geographic concentration and internal reinsurance provision is that more geographically concentrated insurers want to diversify their underwriting portfolio by assuming premiums from other affiliates. On the other hand, the negative association between line of business concentration and internal reinsurance provision could be attributed to

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the reduced underwriting risk. Once the risk from underwriting risk is reduced, insurers could have more capacity to assume risk from other affiliates. For recipients, both geographic and line of business concentration variables are negatively related to internal reinsurance receipt, indicating that insurers with more diversified underwriting portfolio tend to receive internal reinsurance coverage provided by other affiliates.

Turning to other control variables, firm size and direct premiums written ratio affect internal reinsurance provision and receipt in consistent ways. The provision (receipt) of internal reinsurance is associated with larger (smaller) firm size and lower (higher) direct premiums written ratio. In addition, both regulatory jurisdiction and organization form are significantly related to internal reinsurance arrangements. The insurers licensed in New York State tend to be recipients rather than providers in intra-group reinsurance arrangements. This result may indicate that insurers which face more stringent regulatory environments have greater demand for the supports from other affiliates to meet requirements. Finally, we find that stock insurers are less likely to be providers in intra-group reinsurance transactions. But stock indicator variable is positively related to the volume of internal reinsurance provision. On the other hand, stock indicator is positively related to both participation and volume of internal reinsurance receipt. The positive signs in both internal reinsurance receipt participation and volume regressions may be consistent with managerial discretion hypothesis by

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Mayers and Smith (1981) and Lamm-Tennant and Starks (1993), which states that stock insurers have more discretion in risky and complex activities since the agency problem between owners and managers is more likely to be controlled in stock organization form. Thus, stock insurers are more likely to receive additional capacity from other affiliates and exercise their discretion to expand the amount of premiums written. The positive sign of stock indicator in internal reinsurance provision volume may suggest that stock insurers have greater access to financing sources and thus be able to provide more internal reinsurance.

4.4 Non-Linear Effects of External Reinsurance, Investment Risk, and Underwriting Risk on Internal Reinsurance Decisions

To test hypothesis 2 and 9, we investigate the non-linearity effect of external reinsurance on internal reinsurance provision, and those of underwriting risk and hurricane exposure on internal reinsurance receipt. Moreover, the aforementioned results in Table 1-9 reveal that investment risk influence internal reinsurance provision participation and volume decisions in different manners. These results may imply that the insurers with higher investment risk could generate higher investment income to replenish their capacity to assume risk from other affiliates. Therefore, investment risk could be positively related to internal reinsurance provision. However, excessive investment risk could make insurers exposed to higher probability of incurring large

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loss via investment activities. To avoid posing substantial reinsurance counterparty risk on other affiliates, these insurers may need to reduce the amount of internal reinsurance provision. These arguments could imply an inverse-U shape regarding the effect of investment risk on internal reinsurance provision. Thus, we also analyze the non-linearity effect of investment risk in this section.

The results are shown in Table 1-10. With respect to internal reinsurance provision decisions, the coefficients on both external reinsurance and investment risk variables are positive, whereas the square terms of these two variables are negative. In participation decision, the inflection points at which the positive effects of external reinsurance and investment risk reaches the maximum point are 0.7608 and 0.0474 respectively. When the value of investment risk reaches 0.0949, the effect of investment risk turns negative. Turning to the volume decision, we find that the inflection points at which the positive effect of external reinsurance and investment risk start to decrease are 0.1161 and 0.0305 respectively.

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Table 1- 10 The non-linearity in the effects of external reinsurance, investment risk, underwriting risk, and hurricane exposure on internal reinsurance decisions

Variables	Internal Reinsurance Provision				Internal Reinsurance Receipt			
	(1) Participation		(2) Volume		(3) Participation		(4) Volume	
	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
Constant	-5.4050 ***	0.1771	-0.6708 ***	0.1144	1.4037 **	0.5490	1.7118 ***	0.2208
External reinsurance usage	0.8762 ***	0.1013	0.3371 ***	0.0826	-1.8108 ***	0.0589	-1.0133 ***	0.0356
External reinsurance square term	-0.5752 ***	0.1792	-1.4518 ***	0.1838				
Capital issuance	0.0511	0.0470	0.0024	0.0371	-0.1155 **	0.0456	-0.0461 ***	0.0156
Investment profitability	3.0166 ***	0.1800	0.5579 ***	0.1129	-4.3943 ***	0.1982	-2.0851 **	0.1077
Underwriting loss	-0.0393 *	0.0220	0.0341 ***	0.0113	0.0875 ***	0.0235	0.0522 ***	0.0077
Investment risk	20.6864 ***	1.1878	3.2968 ***	0.7834	-3.5349 ***	0.4906	-2.2018 ***	0.2182
Investment risk square term	-217.8842***	12.9988	-53.9832 ***	8.4393				
Underwriting risk	-0.7316 ***	0.1212	0.0879	0.0852	5.1640 ***	0.9452	2.0164 ***	0.3859
Underwriting risk square term					-1.7545 ***	0.4114	-0.7657 ***	0.1718
Hurricane exposure	-0.1814 ***	0.0317	0.1192 ***	0.0211	1.0256 ***	0.1559	0.3537 ***	0.0497
Hurricane exposure square term					-0.9113 ***	0.1646	-0.3070 ***	0.0522
Geographic concentration	0.2517 ***	0.0302	0.1658 ***	0.0199	-0.4562 ***	0.0400	-0.0753 ***	0.0143
Line of business concentration	-0.0142	0.0371	-0.0562 **	0.0247	-0.5102 ***	0.0339	-0.0528 ***	0.0108
Direct premiums written ratio	-0.3406 ***	0.0095	-0.1582 ***	0.0072	0.3580 ***	0.0102	0.0755 ***	0.0030
Firm size	0.2737 ***	0.0069	0.0049	0.0047	-0.2082 ***	0.0065	-0.1304 ***	0.0028
New York State	-0.1909 ***	0.0444	-0.1480 ***	0.0351	0.1407 ***	0.0419	0.0360 ***	0.0134
Organization Form	-0.2399 ***	0.0268	0.2794 ***	0.0207	0.3195 ***	0.0252	0.0906 ***	0.0097
Year dummies	Yes		Yes		Yes		Yes	
Wald test	5,299.84***				4,693.01***			
Pseudo Likelihood Ratio	-7,979.6366				-13,270.1820			

Note: *** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

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Moreover, the effects of external reinsurance and investment risk on the volume of internal reinsurance provision becomes negative after the values of external reinsurance and investment risk use reach 0.2322 and 0.0611 respectively. These results suggest the existence of inverse-U shape regarding the effects on externa reinsurance and investment risk. Hypothesis 2 is supported.

With respect to internal reinsurance receipt, we also find the non-linearity effects of underwriting risk and hurricane exposure. Specifically, the coefficients on both underwriting risk and hurricane exposure are positive, whereas the coefficients on the square terms of these variables are negative. The positive effects of underwriting risk and hurricane exposure on the participation of internal reinsurance receipt are maximized when the values of these variables are 1.4716 and 0.5627 respectively. Turing to volume decision, the inflection points at which underwriting risk and hurricane exposure are maximized are 1.3167 and 0.5761 respectively. In comparison with the maximum values displayed in Table 1-5, we find that the inflection points of underwriting risk variable are fairly close to the maximum value of underwriting risk, which is 1.6099. This result indicates that the positive effect of underwriting risk begins to decrease only when this variable reaches considerably large value. In short, the aforementioned results suggest the existence of inverse-U effects of underwriting risk variables. Hypothesis 9 is supported in our work.

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4.5 Robustness Checks

The potential endogeneity among internal reinsurance arrangements, financing activities, and portfolio risk could be a concern as these decisions could be jointly made by insurers. Although we have lagged explanatory variables for 1 year in our regression analysis, such endogeneity concern still exists. Therefore, we employ instrumental variables approach to cope with the endogeneity issue. The steps of this analysis are explained as follows. Firstly, we identify the instrumental variables for the following four variables: external reinsurance usage, capital issuance, investment risk, and underwriting risk. According to Almeida and Campello (2010), the lagged values of endogenous variables could contain relatively limited information regarding the error terms of structural equations. Moreover, these lagged values could be highly relevant to endogenous variables. Thus, we treat them as the candidates for instrumental variables. In addition to the lagged values of these variables, we also include the following two additional instrumental variables: insurer's returns on assets (ROA) volatility over previous 5 years, and unrealized capital gains in previous year. As ROA volatility could reflect insurer's riskiness based on past experience, we anticipate that it could be relevant to financing and portfolio risk decisions. The unrealized capital gains could be related to insurer's cash flows in near future, and thus influence insurer's financing and risk decisions.

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In the next step, we perform over-identification tests to confirm the validity of the aforementioned instrumental variables. Our results confirm the validity of the instruments.[4]Then we regress external reinsurance usage, capital issuance, investment risk, and underwriting risk on these instrumental variables and the remaining explanatory variables to estimate the fitted values of these potential endogenous variables. In the final step, we replace actual values with the fitted values in multivariate regression analysis. The results are shown in Table 1-11. Generally, our main results demonstrated in Table 1-9 and 1-10 still hold only with few exceptions after considering these potential endogeneity issues.

[4] In this step, we perform Sargan test. The null hypothesis of the test is that instrumental variables are exogenous. If the results of the tests are not statistically significant, we can conclude that the instrumental variables are valid. The results are summarized as follows. When dependent variable is the participation (volume) of internal reinsurance provision, the p-values of Sargan chi-square statistics are 0.5506 (0.7375) and 0.5510 (0.7379). When dependent variable is the participation (volume) of internal reinsurance receipt, p-values of Sargan ukchi-square statistics are 0.6544 (0.9003) and 0.6548 (0.9005). In addition, we also perform Basemann test as an alternative over-identification test and yield very similar results.

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Table 1- 11 Multivariate regression with consideration of potential endogeneity of the main explanatory variables

Variables	Internal Reinsurance Provision				Internal Reinsurance Receipt			
	(1) Participation		(2) Volume		(3) Participation		(4) Volume	
	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
Constant	-5.2785 ***	0.2250	-0.5425 ***	0.1408	1.0990 *	0.6382	1.7979 ***	0.2403
External reinsurance usage	1.0816 ***	0.1613	0.3070 **	0.1211	-2.0702 ***	0.1472	-0.9578 ***	0.0828
External reinsurance square term	-0.9149 ***	0.2688	-2.0386 ***	0.2599				
Capital issuance	-0.6923	1.6829	0.8730	1.1039	1.4542	2.2196	-0.6576	1.3410
Investment profitability	3.4228 ***	0.4123	0.3727	0.2634	-4.7431 ***	0.5274	-2.0603 ***	0.3118
Underwriting loss	-0.0335	0.0494	0.0158	0.0296	0.0673	0.0622	0.0772 **	0.0352
Investment risk	21.8411 ***	1.5738	3.1554 ***	1.0354	-2.4411 ***	0.7457	-2.3539 ***	0.2848
Investment risk square term	-250.5874 ***	17.8324	-61.8112 ***	11.7918				
Underwriting risk	-0.8350 ***	0.1496	-0.0804	0.0919	5.4184 ***	1.0875	2.1588 ***	0.3970
Underwriting risk square term					-1.7946 ***	0.4699	-0.8031 ***	0.1695
Hurricane exposure	-0.1546 ***	0.0520	0.0931 ***	0.0329	0.9557 ***	0.1744	0.3813 ***	0.0622
Hurricane exposure square term					-0.8720 ***	0.1753	-0.3162 ***	0.0562
Geographic concentration	0.2592 ***	0.0467	0.1897 ***	0.0304	-0.4268 ***	0.0615	-0.0912 ***	0.0306
Line of business concentration	0.0073	0.0665	-0.0755 *	0.0428	-0.5516 ***	0.0800	-0.0286	0.0444
Direct premiums written ratio	-0.3731 ***	0.0158	-0.1740 ***	0.0110	0.3968 ***	0.0188	0.0939 ***	0.0097
Firm size	0.2638 ***	0.0129	0.0151 *	0.0086	-0.1994 ***	0.0158	-0.1382 ***	0.0087
New York State	-0.1426 **	0.0538	-0.1651 ***	0.0403	0.1275 **	0.0560	0.0519 **	0.0248
Organization Form	-0.2284 ***	0.0467	0.2284 ***	0.0322	0.3131 ***	0.0559	0.0936 ***	0.0301
Year dummies	Yes		Yes		Yes		Yes	
Wald test	4,694.10***				4,157.96***			
Pseudo Likelihood Ratio	-7,001.7484				-11,785.8900			

Notes:

1.*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

2. The values of external reinsurance, capital issuance, investment risk, and underwriting risk are the fitted values obtained by estimating reduced form regressions. These variables are regressed on other control variables and the following instrumental variables: the lagged 2 year values of external reinsurance, capital issuance, investment risk, and underwriting risk, the volatility of ROA over the past 5 years, and unrealized capital gain.

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Another possible concern in our work is that our results may be affected by the special features of certain types of insurers. In our sample, pure providers do not have direct premiums written and only assume the reinsurance premiums from other affiliates. On the contrary, pure recipients are essentially the "fronting companies" as they cede all the premiums to other group members and only earn the reinsurance commission. To test whether our main results are influenced by the distinct features of these insurers, we exclude both pure providers and recipients, and then rerun regressions. The results are shown in Appendix A. [5]Based on the coefficients estimated, our results are generally unchanged, suggesting that the effects of the determinants on internal reinsurance provision and receipt are robust to the special characteristics of pure providers and recipients.

In addition, we also rerun our regressions by using the unwinsorized sample to test whether our results are sensitive to the extreme values in the sample. The results of using the original data are demonstrated in Appendix A.[6] We find that the magnitude of the coefficient on investment risk in internal reinsurance provision participation decision is considerably smaller than those shown in previous tables. Such result could be driven by the extreme values in our sample. Nevertheless, this coefficient is still

[5] Please refer to Table A-1 in Appendix A.
[6] Please refer to Table A-2 in Appendix A.

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positive and significant, which is consistent with our expectation and the results in previous sections. Besides, the main results are generally unaffected after using the unwinsorized sample. In short, our results are generally robust to the influence of the outliers in our data.

5. Conclusion

By analyzing the sample of the U.S non-life insurers from 1999 to 2016, we provide direct evidence on the determinants of internal reinsurance provision and receipt. We find that the provision of internal reinsurance provision is positively related to external reinsurance, investment profitability and investment risk, suggesting that these factors are potential sources of the capacity to assume more internal reinsurance premiums. On the contrary, internal reinsurance receipt is generally associated with less capital issuance and external reinsurance, lower profitability, and greater underwriting risk. In our empirical analysis, we further discover several inverse-U patterns. Specifically, both external reinsurance and investment risk exert positive effects on internal reinsurance provision. After reaching certain thresholds, the positive effects start to decline. These results suggest that insurers with considerably large values in these two variables may curtail internal reinsurance provision to avoid posing substantial counterparty risk on other affiliates. With respect to recipients, we also find similar patterns regarding the effects of underwriting risk variables on internal

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reinsurance receipt. Based on these results, recipients may avoid transferring excessive underwriting risk to other group members. These non-linear patterns imply that the intra-group reinsurance participants tend to avoid posing excessive risk on their counterparties.

The major limitations and recommendations on future research directions are summarized as follows. First, the majority of the insurers in our sample are not publicly traded. The detailed data on corporate governance is not available for many insurers. Future works could address the issues regarding how corporate governance factors influence the provision and receipt of internal capital. Second, Duchin and Sosyura (2013) suggests that the social connection among division managers and headquarter is an important factor which influences internal capital allocation. Nevertheless, the detailed data on the social connections between parent companies' managers and affiliated insurers' managers are not available in NAIC database. Therefore, we are unable to consider this factor in our work. Future studies could consider the effect of social connections among affiliates in their analysis if the relevant data is available.

Appendix A

To test whether our main results are influenced by the special characteristics of pure providers and recipients, we exclude these two types of insurers and then rerun our regression analysis. The results are demonstrated in table A-1. To test the potential

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influences of the outliers in our sample, we also conduct the regression analysis by using the unwinsorized sample. The corresponding results are represented in table A-2.

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Table A- 1 Multivariate regression with consideration of potential endogeneity of the main explanatory variables (pure providers and recipients are excluded)

Variables	Internal Reinsurance Provision				Internal Reinsurance Receipt			
	(1) Participation		(2) Volume		(3) Participation		(4) Volume	
	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
Constant	-4.3414 ***	0.2977	-0.6167 ***	0.2225	-0.1049	0.7013	1.1022 ***	0.3035
External reinsurance usage	1.0452 ***	0.1525	0.4413	0.1250	-1.9585 ***	0.1272	-1.0201 ***	0.0578
External reinsurance square term	-1.0038 ***	0.2872	-2.2669 ***	0.2790				
Capital issuance	-2.7959	1.7700	0.8906	1.4798	3.6320	2.4893	0.5500	0.8569
Investment profitability	3.4709 ***	0.3649	0.4173 ***	0.2824	-4.6367 ***	0.4781	-2.3113 **	0.1968
Underwriting loss	0.0572	0.0686	0.0087 ***	0.0521	-0.0416	0.0936	0.0660 *	0.0345
Investment risk	19.9705 ***	1.6354	3.3788 ***	1.0422	-0.8195	0.6963	-1.8496 ***	0.3896
Investment risk square term	-240.2581 ***	18.2373	-68.1484 ***	11.8802				
Underwriting risk	-0.7455 ***	0.1497	-0.1424	0.0947	4.7443 ***	1.1113	2.4604 ***	0.4751
Underwriting risk square term					-1.5059 ***	0.4777	-0.8724 ***	0.1970
Hurricane exposure	-0.0632	0.0689	0.0806	0.0529	0.8217 ***	0.1911	0.5413 ***	0.0763
Hurricane exposure square term					-0.8804 ***	0.1822	-0.5281 ***	0.0761
Geographic concentration	0.1929 ***	0.0552	0.1979 ***	0.0428	-0.3680 ***	0.0765	-0.0550 *	0.0297
Line of business concentration	0.0278	0.0660	-0.0686	0.0502	-0.5789 ***	0.0830	-0.0895 ***	0.0304
Direct premiums written ratio	-0.3784 ***	0.0183	-0.1897 ***	0.0137	0.4305 ***	0.0231	0.1487 ***	0.0085
Firm size	0.2158 ***	0.0176	0.0195	0.0144	-0.1244 ***	0.0237	-0.1228 ***	0.0085
New York State	-0.1457 ***	0.0520	-0.1711 ***	0.0412	0.1544 ***	0.0546	0.0836 ***	0.0198
Organization Form	-0.1981 ***	0.0470	0.2197 ***	0.0369	0.3393 ***	0.0586	0.1311 ***	0.0235
Year dummies	Yes		Yes		Yes		Yes	
Wald test	3,555.58***				2,932.33***			
Pseudo Likelihood Ratio	-6,648.6331				-10,299.042			

Notes:

1.*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

2. The values of external reinsurance, capital issuance, investment risk, and underwriting risk are the fitted values obtained by estimating reduced form regressions. These variables are regressed on other control variables and the following instrumental variables: the lagged 2-year values of external reinsurance, capital issuance, investment risk, and underwriting risk, the volatility of ROA over the past 5 years, and unrealized capital gain.

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Table A- 2 Multivariate regression with consideration of potential endogeneity of the main explanatory variables (using unwinsorized sample)

Variables	Internal Reinsurance Provision				Internal Reinsurance Receipt			
	(1) Participation		(2) Volume		(3) Participation		(4) Volume	
	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
Constant	-6.1386 ***	0.2421	-0.3746 **	0.1901	2.1080 ***	0.6630	1.8628 ***	0.2312
External reinsurance usage	1.1750 ***	0.2075	0.2821	0.2026	-2.0785 ***	0.3252	-0.9798 ***	0.0807
External reinsurance square term	-0.8793 ***	0.2613	-2.0068 ***	0.2691				
Capital issuance	-1.7385	1.4038	1.3020	1.4689	0.7610	2.7618	-0.1159	0.5815
Investment profitability	0.0003 ***	0.0000	0.3164 ***	0.0902	-1.7777 ***	0.2875	-1.4967 ***	0.1918
Underwriting loss	-0.0003	0.0013	0.0001 ***	0.0000	0.0052 ***	0.0013	0.0008 ***	0.0001
Investment risk	18.2293 ***	1.8990	4.5606 ***	1.5632	-1.0951	2.5849	-2.0792 ***	0.6009
Investment risk square term	-227.1272 ***	14.6841	-65.5823 ***	9.5780				
Underwriting risk	-0.7658 ***	0.1591	-0.0232	0.1235	4.8086 ***	1.0150	2.0888 ***	0.3740
Underwriting risk square term					-1.5667 ***	0.4310	-0.7752 ***	0.1586
Hurricane exposure	-0.1063	0.0791	0.0391	0.0766	1.1128 ***	0.2200	0.4160 ***	0.0626
Hurricane exposure square term					-1.0285 ***	0.1777	-0.3629 ***	0.0580
Geographic concentration	0.2876 ***	0.0334	0.1694 ***	0.0213	-0.4459 ***	0.0462	-0.0666 ***	0.0164
Line of business concentration	0.0062	0.0603	-0.0921 *	0.0534	-0.5011 ***	0.0962	-0.0386 ***	0.0222
Direct premiums written ratio	-0.3921 ***	0.0151	-0.1841 ***	0.0142	0.4225 ***	0.0215	0.0917 ***	0.0050
Firm size	0.3190 ***	0.0144	0.0015	0.0139	-0.2423 ***	0.0256	-0.1400 ***	0.0064
New York State	-0.1244 **	0.0484	-0.1537 ***	0.0367	0.1244 **	0.0503	0.0429 ***	0.0153
Organization Form	-0.1598 ***	0.0396	0.2238 ***	0.0358	0.2858 ***	0.0593	0.0914 ***	0.0152
Year dummies	Yes		Yes		Yes		Yes	
Wald test	4,633.03***				3,828.26***			
Pseudo Likelihood Ratio	-6,760.5559				-11,617.271			

Notes:

1.*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

2. The values of external reinsurance, capital issuance, investment risk, and underwriting risk are the fitted values obtained by estimating reduced form regressions. These variables are regressed on other control variables and the following instrumental variables: the lagged 2-year values of external reinsurance, capital issuance, investment risk, and underwriting risk, the volatility of ROA over the past 5 years, and unrealized capital gain.

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Chapter 2: The Interrelations among Internal Capital Markets Activities, Capital Holding, and Risk-Taking: Evidence from the Intra-Group Reinsurance Transactions of the U.S. Non-Life Insurance Industry

1. Introduction

The relation between capital and risk-taking has been an important issue in banking and insurance literature as it is highly relevant to the solvency of financial institutions. These studies tend to focus on the tests of two competing hypotheses regarding the relationship between capital and risk: risk-subsidy hypothesis and finite-risk paradigm. Risk-subsidy hypothesis indicates that banks and insurers tend to take excessive risk since the deposit insurance and guarantee fund could absorb the deficit when these financial institutions become insolvent (e.g. Lee, Mayers, and Smith, 1997). On the contrary, finite-risk paradigm suggests that financial institutions tend to limit overall risk to avoid the costs associated with excessive risk-taking, such as regulatory and bankruptcy costs (e.g. Baranoff and Sager, 2002, 2003).

In addition to the literature on the relation between capital and risk, internal capital markets activities could be relevant to capital and risk-taking because these activities involve the allocation of risk and capacity among affiliates within business group. The

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receipt of internal capital from other group members could improve the solvency position of group-affiliated firms and, thus enable them to increase the amount of investment and take more risk. On the other hand, the levels of group firms' capital and risk-taking could also influence the direction of internal capital movement within group. Thus, there should be significant interrelations among internal capital markets activities, capital holding, and risk-taking. Nevertheless, to the best of our knowledge, the existing studies regarding the association between capital and risk do not incorporate internal capital markets in their empirical analysis. This work attempts to fill this void by analyzing the adjustments among internal capital markets activities, capital, and risk in the U.S non-life insurance industry.

In our study, we focus on intra-group reinsurance transactions as the main internal capital markets activities due to the pervasiveness and volume of these transactions suggested by previous works (e.g. Fier, McCullough, and Carson, 2013). Under intra-group reinsurance arrangements, we consider the insurers which assume reinsurance premiums are considered as "providers" since they provide capacity for other affiliates. On the contrary, the insurers which cede premiums to other affiliates are considered as "recipients" since they acquire underwriting capacity via these arrangements. In our work, we analyze how internal reinsurance provision and receipt are interrelated to capital and risk decisions. We expect that internal reinsurance provision is positively

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interrelated to capital holding as the providers may need more capital to support the provision of internal reinsurance and control their overall insolvency risk. On the contrary, internal reinsurance provision could be negatively associated with risk-taking as the providers may have to conserve their risk-bearing capacity.

With respect to recipients, we expect that internal reinsurance receipt is negatively interrelated to the level of capital holding in both directions as reinsurance is considered as the substitute for capital by literature. On the other hand, the receipt of internal reinsurance could enable recipients to increase investment risk. According to coordinated risk management hypothesis of Schrand and Unal (1998), risk management activities could be used for risk allocation among different sources of risk within a firm. The risk reduction in an activity could enable a firm to increase the risk-taking in another activity. In insurance industry, internal reinsurance usage could reduce the risk from underwriting activities, and may enable recipients to take additional risk in investment activities. Turning to another direction, the recipients with higher investment risk may use internal reinsurance to reduce the overall insolvency risk. Thus, we expect a positive relationship between internal reinsurance receipt and investment risk in both directions.

On the other hand, the relation between internal reinsurance receipt and underwriting risk could be more complicated. Higher underwriting risk could motivate

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recipients to use more internal reinsurance to reduce the volatility of underwriting results. Thus, the effect of underwriting risk on internal reinsurance receipt could be positive. Nevertheless, the receipt of internal reinsurance may negatively affect recipients' underwriting risk because these recipients could be subject to the monitoring by providers. From the perspective of providers, they may have the incentive to limit recipients' underwriting risk to as providers' financial positions could be influenced by recipients' underwriting results. Several studies suggest that affiliated reinsurers have more information advantage in monitoring and controlling cendants' underwriting behavior (e.g. Doherty and Smetter, 2005; Cole, He, McCullough, Semykina and Sommer, 2011). Thus, we anticipate that internal reinsurance receipt negatively affects underwriting risk.

In this study, we analyze the sample of group-affiliated insurers in the U.S. non-life insurance industry from 1999 to 2016 by employing 2SLS and 3SLS estimation methods. In our work, we firstly investigate the effects of the changes of insurers' intra-group reinsurance roles, such as the conversion from provider to recipient, on the adjustments of capital holding, investment risk, and underwriting risk. In our sample, there are three types of status: provider, recipient, and non-participant, which refers to the insurer without intra-group reinsurance transaction records. Under intra-group reinsurance transactions, providers' capacity is consumed, whereas recipients' capacity

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constraint could be mitigated. The changes of insurers' roles in intra-group reinsurance transactions could alter insurers' risk-bearing capacity and further exert pronounced effects on capital and risk decisions. Our aim is to test whether such status conversions significantly influence capital holding and risk-taking. Moreover, we further analyze how the adjustments of intra-group reinsurance volume, capital holding, investment risk, and underwriting risk are interrelated.

Our results are summarized as follows. First, the status changes from provider to both recipient and non-participant positively affect capital holding. The possible explanation for these results is the decrease in underwriting revenue caused by the conversions. Once these insurers do not assume internal reinsurance from other affiliates, they may not collect the income flows from internal reinsurance activities to replenish their capital positions. Thus, such conversions may motivate them to increase capital holding. Conversely, the status change from non-participant to provider exerts a negative effect on capital holding. In addition to the effects of status changes on capital holding, we also find that the conversion from provider to recipient is associated with the increase in investment risk. This result may indicate that the use of internal reinsurance could mitigate the risk in underwriting activities and enable recipients to take more investment risk.

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Secondly, capital holding positively affects internal reinsurance provision, suggesting that the provision of internal reinsurance is backed by capital holding. Nevertheless, the effect of internal reinsurance provision on capital holding is negative, which may be caused by the increase in reinsurance revenues. As these providers collect the income streams from internal reinsurance transactions, their demand for capital replenishment may reduce. For recipients, we find a negative relationship between internal reinsurance receipt and capital holding in both directions, which suggests that capital and internal reinsurance are substitutes. In addition, the adjustment of investment risk positively affects internal reinsurance receipt, indicating that recipients with greater investment risk may use internal reinsurance to reduce the risk from underwriting activities and overall insolvency risk.

Our research makes the following contributions. First, by providing empirical evidence on the interrelations among internal reinsurance activities, capital holding, investment risk, and underwriting risk, this study could bridge the literature on internal capital markets and the studies on the relationship between capital and risk. Second, we investigate and compare how internal reinsurance provision and receipt are interrelated to capital and risk decisions. In our work, we find some asymmetric patterns of these interrelations, such as the evidence that the adjustments of both internal reinsurance provision and receipt lead to the decrease in capital holding.

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In the work of Mankai and Belgacem (2016), they analyze the interrelations among reinsurance, capital, and risk-taking. Our study differs from that of Mankai and Belgacem (2016) in the following ways. First, we focus on internal reinsurance activities as the main variables and treat external reinsurance as a control variable because the majority of reinsurance activities occur within insurance groups. In addition, the cost and structural differences between internal and external reinsurance suggested by Powell and Sommer (2007) could imply that separating them as different variables in empirical analysis is more appropriate. Second, we consider internal reinsurance providers and recipients as the subgroups with different features and separately investigate the interrelations between internal reinsurance activities, capital, and risk for these subgroups. Under intra-group reinsurance arrangements, providers collect underwriting revenue from recipients and assume the risk transferred from recipients. From the perspective of group-wide solvency, providers' capital and risk decisions could be more crucial as the insolvencies of providers could result in more severe spillover effects over the rest of group. On the contrary, the recipients are the real users of internal reinsurance and receive additional capacity via internal reinsurance. Moreover, the recipients' underwriting results further influence the reinsurance reimbursement by the providers. This could induce the providers' incentive to monitor and limit recipients' risk-taking in underwriting activities. Due to the aforementioned

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features, we separately analyze the subsamples of internal reinsurance providers and recipients rather than pooling them together.

Third, we consider investment and underwriting risk as different types of business portfolio risk in our analysis. In the work of Mankai and Belgacem (2016), the authors use an overall risk measure in the empirical analysis. Specifically, they use the volatility of asset-liability ratio to proxy insurer's risk-taking. In our study, we separately measure investment and underwriting risk, and treat them as two different decision variables. Our main rationale is that internal reinsurance decisions could be interrelated to investment and underwriting risk in different manners. It could be more appropriate to consider them as different variables in our empirical analysis. Moreover, we can further compare the relation between internal reinsurance and investment risk with that between internal reinsurance and underwriting risk in our study.

The remainder of this work is organized as follows. In section 2, we review relevant studies and propose our research hypotheses. In section 3, we explain the data, methodology, and variables used in our empirical analysis. The empirical results are presented in section 4. Finally, we conclude our research in section 5.

2. Literature Review and Hypotheses Development

2.1 The Literature on Capital and Risk-Taking

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Based on the existing studies which investigate the relationship between capital and risk, there are two main competing hypotheses regarding the relationship between capital holding and risk-taking: risk-subsidy hypothesis and finite-risk paradigm. The existence of deposit insurance and guarantee funds could distort financial institutions' incentive and thus encourage them to adopt more risky strategies. Deposit insurance system is established to protect depositors in the event of bank's insolvency. Under this system, each bank makes insurance payment to pool the funds available to cover the depositors of insolvent banks. Such deposit insurance program is not risk-based since the premium paid by bank is flat-rate. Marcus (1984) suggest that such non risk-based feature of deposit insurance program could induce bank to adopt high-risk strategy when the charter value of bank decreases.

Similar with the deposit insurance system in banking industry, state guarantee fund is designed to protect the policyholders when an insurer becomes insolvent in the U.S non-life insurance industry. In guarantee funds system, the coverage is based on post-insolvency assessment. To collect the amount of funding for coverage, each insurers is required to pay a certain percentage of its premiums written. Some studies suggest that such flat-rate guarantee fund could induce insurers to increase risk-taking. For example, Cummins (1988) suggests that the guarantee fund could make insurers less subject to the penalty for excessive risk-taking imposed by insurance market and thus induce

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insurers to increase overall risk. In short, risk-subsidy hypothesis suggest that financial institutions tend to pursue high-risk strategies by either reduce the levels of capital holding or increase risk-taking. Thus, risk-subsidy hypothesis implies a negative relation between capital and risk. Several studies further document evidence that guarantee fund system lead to insurers' higher risk-taking (Lee, Mayers, and Smith, 1997; Brewer, Mondschean, and Strahan, 1997).

Although the existence of guarantee funds could potentially induce insurers to take more risk, the protection from guarantee funds is incomplete. Such incomplete features include upper limit of coverage, post assessment after insolvency of insurer, and delay payment to the policyholders of insolvent insurers. Several studies argue that the post assessment feature could create monitoring incentive of peer insurers and thus offset insurers' tendency to engage in excessive risk-taking behavior (e.g. Lee et al., 1997; Down and Sommer, 1999). If the monitoring effect is strong enough, insurers may not increase risk-taking even in the presence of guarantee funds.

Contrary to risk-subsidy hypothesis, finite-risk paradigm suggests a positive relationship between capital and risk-taking. In banking and insurance literature, many studies contend that financial institutions have incentive to limit risk-taking to avoid a variety of costs associated with excessive risk-taking, such as regulatory costs, bankruptcy costs, and the loss in franchise value (e.g. Shrieves and Dahl, 1992;

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Cummins and Sommer, 1996). Besides, Baranoff and Sager (2002, 2003) further elaborate on finite-risk paradigm from the perspective of transaction cost economics (TCE). These studies contend that insurers with more risky insurance products could be associated with greater uncertainty in fulfilling debt obligations and thus face more difficulty in obtaining debt financing. This argument leads to the prediction that higher amount of risky products is positively associated with equity financing. In addition, insurers' tendency to limit risk-taking could also be attributed to managerial risk aversion. Shrieves and Dahl (1992), Cummins and Sommer (1996) suggest that the separation of ownership and management could cause the misalignment of interest regarding risk-taking decisions. The compensation of managers could depend on the survival of firms rather than the residual profits. Thus, managers may be reluctant to adopt high-risk strategies. These rationales indicate that the increase in risk-taking should be accompanied with the increase in capital holding to limit insolvency risk.

Apart from finite-risk paradigm, excessive insolvency risk could have negative impact on insurance demand. Sommer (1996), Cummins and Sommer (1996), Cummins and Danzon (1997) suggest that policyholders are averse to insurers' insolvency risk and thus imply a negative relationship between insurance price charged by insurer and insolvency risk. Furthermore, Epermanis and Harrington (2006) find the evidence that insurer's downgrade in credit rating is followed by the decline in the

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volume of premiums written. In short, the deterioration in financial strength could be penalized by market discipline. To avoid these negative consequences, insurers could be more inclined to limit overall riskiness.

Many studies have documented a positive relationship between capital and risk in banking and insurance literature (e.g. Shrieves and Dahl, 1992; Cummins and Sommer, 1996; Rime, 2001; Shim, 2010; Shim, 2013; Mankai and Belgacem, 2016). In insurance literature, several studies differentiate portfolio risk into asset and product risk, which are the proxies for the risk in investment and underwriting activities respectively. Some of these studies find mixed results regarding the relationship between capital and risk. For instance, Baranoff and Sager (2002) find that capital ratio and asset risk are positively related, whereas capital ratio is negatively associated with product risk. The other studies generally find consistent results regarding the association between capital and risk-taking (e.g. Baranoff and Sager, 2003; Baranoff, Papadopoulos, and Sager, 2007; Cheng and Weiss, 2013). In more recent literature, Lin, Lai, and Powers (2014) further analyze the interrelationship among capital, asset risk, and product risk under different extent of regulatory pressure. Mankai and Belgacem (2016) analyze the interactions among capital, risk-taking, and reinsurance usage. The find that the increase in the extent of risk-taking is associated with more reinsurance usage. In contrast, reinsurance exerts a negative effect on capital holding, indicating the

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substitution effect between reinsurance and capital. Taken together, the majority of existing empirical results suggests a positive relationship between capital and risk.

To synthesize the studies on the relationship between capital and risk, the majority of empirical evidence and arguments tend to favor finite-risk paradigm over risk-subsidy hypothesis. Although the guarantee funds could potentially induce insurers to engage in excessive risk-taking, the incentive to adopt high-risk strategies is somewhat limited due to the incompleteness of the protection from guarantee funds. Furthermore, the costs and negative consequences associated with excessive insolvency risk could further hinder insurers from taking excessive risk.

2.2 Internal Capital Markets

In finance and insurance literature, many studies suggest that internal capital markets activities could be used for several purposes, such as capital management and facilitating investments. Regarding capital management function, Gopalan, Nanda, and Seru (2007) suggest that avoiding the negative spillover effect of affiliate's insolvency on the rest of group is an important motivation for business groups to utilize internal capital markets to support financially weak affiliates. In insurance literature, Fier et al. (2013) find the evidence that internal reinsurance activities are used for managing affiliates' capital levels toward target capital structure. Similarly, Niehaus (2018) find the evidence that the drop in profitability is associated with the receipt of internal capital

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transfer in the context of the U.S life insurance sector. In addition, internal capital markets could be more valuable when external capital markets frictions are more severe. For instance, Desai, Foley, and Hines (2004) find the evidence that the affiliates located in the countries with weak credit rights and less developed capital markets tend to receive more resources from business groups.

In addition to capital management function, internal capital markets also play important role in facilitating affiliates' investment. According to Gertner, Scharfstein and Stein (1994), and Stein (1997), the lower degree of information asymmetry and the control right over the resources makes the headquarters of multidivisional firms able to allocate funds to divisions with profitable investment projects and monitor how these funds are utilized. Several studies further find the evidence that the receipt of internal capital is associated with investment growth. For example, Powell, Sommer and Eckles (2008) find the evidence that capital received via internal capital markets lead to the growth of premiums written. In finance literature, Buchuk, Larrain, Francisco and Urzúa (2014) document the evidence that the receipt of intra-group loans leads to higher levels of investment and better financial performance. Almeida, Kim and Kim (2015) find that chaebol affiliated firms experienced less decline in valuation and had better profitability in the aftermath of the Asian financial crisis in comparison with stand-alone counterparts. Based on their results, the operation of internal capital markets

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reduces the negative consequences of the crisis. As the aforementioned studies suggest, the receipt of internal capital could improve affiliates' capital positions and enable affiliates to increase the amount of investment.

On the other hand, internal capital providers could have the incentive to monitor how recipients utilize internal capital as these providers have the stakes in the recipients. Furthermore, the extent of information asymmetry in internal capital markets tends to be lower than that in external capital markets. The reduced asymmetric information problem could enable providers to effectively monitor recipients' use of internal capital. Gertner et al. (1994) and Stein (1997) suggest that headquarters are able to monitor their divisions and allocate the resources to more profitable projects. In intra-group reinsurance arrangement, the underwriting results of recipients could affect providers' financial positions and performance. In insurance literature, several studies suggest the reduced information asymmetry between affiliated reinsurer and insurer leads to lower monitoring costs. Therefore, affiliated reinsures have the advantage in controlling insurers' potential moral hazard problems. Doherty and Smetter (2005) find the evidence that affiliated reinsurers extensively employ monitoring on insurers. Powell and Sommer (2007) suggest that the lower information asymmetry between affiliated reinsurer and insurer could contribute to the cost difference between internal and external reinsurance. Such cost difference could be related to the reduced monitoring

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cost. Cole et al. (2011) further document the negative relation between internal reinsurance use and risk-taking. On the contrary, the use of external reinsurance is positively related to risk-taking. These results may indicate that affiliated reinsurers have better capabilities in limiting insurers' underwriting risk.

To synthesize the relevant studies, the funds received via internal capital markets could improve affiliates financial position and facilitate affiliates' investment activities. Nevertheless, the recipients of internal capital may also be subject to the monitoring by the providers within the same group. In intra-group reinsurance arrangements, providers may limit recipients' risk-taking in underwriting activities.

2.3 Hypotheses Development

In this section, we firstly propose the hypotheses regarding the effects of intra-group reinsurance status conversions. Then we discuss the interrelations among the volume of internal reinsurance activities, capital holding, investment risk, and underwriting risk.

2.3.1 The Effects of Internal Reinsurance Status Conversions on Capital and Risk

In our work, we primarily formulate our hypotheses based on the premise that insurers tend to limit overall insolvency risk as the majority of previous related studies tend to favor finite-risk paradigm. In addition, the providers with excessive insolvency

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risk may pose substantial counterparty risk on the recipients of internal reinsurance. Such concern could be an additional reason for providers to control their overall risk.

Based on the aforementioned rationales, we anticipate that the conversions from other roles in intra-group reinsurance arrangements to providers should be positively related to capital ratio. After the status changes, these insurers' capacity is decreased via intra-group reinsurance transactions. To supplement the reduced capacity caused by the conversions, these insurers may need to raise capital holding. On the contrary, the insurers which convert to recipients could acquire additional capacity in internal reinsurance transactions. The increased capacity could exert a substitution effect on other sources of capital replenishment. Thus, the conversions to recipient could be followed by the drop in capital ratio. The corresponding hypotheses for the above-mentioned arguments are proposed as follows:

Hypothesis 1a: The changes from other roles in intra-group reinsurance arrangements to provider lead to a rise in capital holding.

Hypothesis 1b: The changes from other intra-group reinsurance roles to recipient lead to a decrease in capital holding.

Turing to investment risk, we expect that the conversions from other status to providers are negatively related to investment risk as these insurers may have to adopt more conservative risk-taking decisions in response to the decreased capacity caused

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by intra-group reinsurance transactions. Therefore, the hypothesis regarding the effect of the conversion to provider is stated as follows:

Hypothesis 2a: The changes from other intra-group reinsurance participation status to provider lead to a dip in investment risk.

In contrast, the insurers which experience status changes to recipients could receive additional protection against underwriting risk via internal reinsurance transactions and have lower insolvency risk. Such reduction in insolvency risk may enable these insurers to take risk in investment activities.

In risk management practices, although reinsurance is primarily used for managing underwriting risk rather than investment risk, we still expect there is a positive relationship between internal reinsurance receipt and investment risk. Based on the coordinated risk management hypothesis of Schrand and Unal (1998), risk management activities could be employed for risk allocation purpose. Specifically, firms can engage in risk management to reduce the risk in one activity and then increase the risk in another activity. In insurance literature, several studies provide the empirical evidence supporting the coordinated risk management hypothesis. For example, McShane, Zhang, and Cox (2012) find the negative effect of derivatives use on reinsurance, indicating that the insurers which hedge more investment risk are able to use less reinsurance to reduce the risk from underwriting activities. Che and Liebenberg (2017)

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further find the positive relation between line-of-business diversification and investment risk, implying that the decrease in underwriting risk due to diversification enables insurers to take more risk in investment activities.

Based on these studies, we conjecture that internal reinsurance usage could be used for allocating risk among investment and underwriting activities. The reinsurance coverage acquired from the conversions to recipients could enable insurers to take more risk in investment activities. Thus, we propose the corresponding hypothesis:

Hypothesis 2b: The changes from other intra-group reinsurance roles to recipient lead to a rise in investment risk.

In regards to underwriting risk, the provision and receipt of internal reinsurance could lead to the reduction in underwriting risk for different reasons. For providers, the provision of internal reinsurance could reduce their risk-bearing capacity. To limit insolvency risk, they may need to reduce underwriting risk after experiencing the reduction in capacity. On the other hand, the receipt of internal reinsurance could also be associated with lower risk-taking in underwriting activities due to the monitoring by providers. Under intra-group reinsurance arrangements, the providers' financial positions could be dependent upon recipients' underwriting performance. Thus, they may have the incentive to limit recipients' risk-taking in underwriting activities. Several

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studies further suggest that affiliated reinsurers have the advantage in limiting insurers' risk-taking behavior (Doherty and Smetter, 2005; Cole et al., 2011).

Because the aforementioned arguments suggest that both the provision and receipt of internal reinsurance could be related to lower underwriting risk, we do not predict the effect of the conversion from provider to recipient on underwriting risk and vice versa. Instead, we only propose the hypotheses regarding the conversions from non-participant to provider and recipient as follows:

Hypothesis 3a: The status change from non-participant to provider leads to a decrease in underwriting risk.

Hypothesis 3b: The status change from non-participant to recipient leads to a dip in underwriting risk.

2.3.2 The Volume of Internal Reinsurance Activities

Similar with the arguments regarding the status conversions to providers, internal reinsurance provision volume could positively affect capital holding as the providers may need to restore the reduced capacity after the provision of internal reinsurance. Turing to another direction, the rise in capital holding could enable providers to increase the volume of internal reinsurance. The corresponding hypotheses are proposed as follows:

Hypothesis 4a: internal reinsurance provision volume positively affects capital holding.

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Hypothesis 4b: capital holding positively affects internal reinsurance provision volume.

In insurance literature, reinsurance is considered as a substitute of capital as the use of reinsurance could increase insurers' capacity. Several studies find the evidence that the use of reinsurance could enable insurers to increase premiums written and leverage levels (e.g. Powell et al., 2008; Shiu, 2011). In the literature on capital and risk adjustment, Mankai and Belgacem (2016) find that reinsurance exerts a negative effect on capital holding. Turning to the opposite direction, the insurers with higher capital ratios could have lower insolvency risk and thus demand less for reinsurance. Therefore, we anticipate that the volume of internal reinsurance receipt and capital holding are negatively related in both directions. The corresponding hypotheses are stated as follows:

Hypothesis 4c: internal reinsurance receipt volume negatively affects capital holding.

Hypothesis 4d: capital holding negatively affects internal reinsurance receipt volume.

With respect to investment risk, we expect that internal reinsurance provision should be negatively interrelated to investment risk based on finite-risk paradigm. To limit insolvency risk, the provision of internal reinsurance should be followed by the decrease in investment risk. Likewise, the rise in investment risk could also reduce providers' capacity to assume more internal reinsurance from other affiliates. Thus, we

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propose the following hypotheses regarding the relationship between internal reinsurance provision and investment risk:

Hypothesis 5a: internal reinsurance provision volume negatively affects investment risk.

Hypothesis 5b: investment risk negatively affects internal reinsurance provision volume.

Turning to recipients, similar with the arguments regarding the effect of status conversions to recipients mentioned in previous section, the receipt of internal reinsurance could reduce recipients overall insolvency risk and enable recipients to increase risk-taking in investment activities. Turing to another direction, the recipients with greater investment risk could have higher insolvency risk, and thus may use more internal reinsurance to reduce overall insolvency risk. Therefore, we propose the following hypotheses:

Hypothesis 5c: internal reinsurance receipt volume positively affects investment risk.

Hypothesis 5d: investment risk positively affects internal reinsurance receipt volume.

With respect to the relation between internal reinsurance provision and underwriting risk, to conserve capacity and limit insolvency risk, we conjecture that an increase in underwriting risk could be followed by a reduction in the volume of internal reinsurance provision. Turing to the opposite direction, internal reinsurance provision

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could negatively affect risk-taking in underwriting activities as providers' capacity is reduced after the provision of internal reinsurance. The corresponding hypotheses are stated as follows:

Hypothesis 6a: internal reinsurance provision volume negatively affects underwriting risk.

Hypothesis 6b: underwriting risk negatively affects internal reinsurance provision volume.

In regards to the relation between internal reinsurance receipt and underwriting risk, we anticipate that the receipt of internal reinsurance has a negative effect on underwriting risk. After the completion of internal reinsurance transactions, providers could have incentives to monitor recipients' risk-taking behavior in underwriting activities as recipients' underwriting results could ultimately influence providers' financial positions. The corresponding hypothesis is stated as follows:

Hypothesis 6c: internal reinsurance receipt volume negatively affects underwriting risk.

Turning to another direction, several studies suggest that mitigating underwriting risk is a motivation for insurers to use reinsurance. For instance, Adams (1996), Kader, Adams, and Mouratidis (2010) use loss ratio as the proxy for underwriting risk and find that underwriting risk positively affects reinsurance use. In our study, we anticipate that the recipients with more premiums written in risky lines are more likely to have more

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volatile underwriting results, and thus have a stronger incentive to use internal reinsurance. Therefore, we anticipate that the adjustment of underwriting risk positively affects that of internal reinsurance receipt. The hypothesis is proposed as follows:

Hypothesis 6d: underwriting risk positively affects internal reinsurance receipt volume.

Our research hypotheses are summarized in Table 2-1.

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Table 2- 1 Summary of research hypotheses

Variable	Participation status changes	The volume of internal reinsurance activities
Capital holding	*Hypothesis 1a*: The changes from other roles in intra-group reinsurance arrangements to provider lead to a rise in capital holding (+). *Hypothesis 1b*: The changes from other intra-group reinsurance roles to recipient lead to a decrease in capital holding (-).	Provision *Hypothesis 4a*: internal reinsurance provision volume positively affects capital holding (+). *Hypothesis 4b*: capital holding positively affects internal reinsurance provision volume (+). Receipt *Hypothesis 4c*: internal reinsurance receipt volume negatively affects capital holding (-). *Hypothesis 4d*: capital holding negatively affects internal reinsurance receipt volume (-).
Investment risk	*Hypothesis 2a*: The changes from other intra-group reinsurance participation status to provider lead to a dip in investment risk (-). *Hypothesis 2b*: The changes from other intra-group reinsurance roles to recipient lead to a rise in investment risk (+).	Provision *Hypothesis 5a*: internal reinsurance provision volume negatively affects investment risk (-). *Hypothesis 5b*: investment risk negatively affects internal reinsurance provision volume (-). Receipt *Hypothesis 5c*: internal reinsurance receipt volume positively affects investment risk (+). *Hypothesis 5d*: investment risk positively affects internal reinsurance receipt volume (+).
Underwriting risk	*Hypothesis 3a*: The status change from non-participant to provider leads to a decrease in underwriting risk (-). *Hypothesis 3b*: The status change from non-participant to recipient leads to a dip in underwriting risk (-).	Provision *Hypothesis 6a*: internal reinsurance provision volume negatively affects underwriting risk (-). *Hypothesis 6b:* underwriting risk negatively affects internal reinsurance provision volume (-). Receipt *Hypothesis 6c:* internal reinsurance receipt volume negatively affects underwriting risk (-). *Hypothesis 6d:* underwriting risk positively affects internal reinsurance receipt volume (+).

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3. Data, Methodology, and Variables

3.1 Data

We retrieve the data of non-life insurers from National Association of Insurance Commissioners (NAIC) database. The following sample selections procedures are employed. First, we only include group-affiliated insurers since we focus on how intra-group reinsurance activities are related to capital and risk decisions. Second, only the insurers which are active and do not under regulatory process can be included in our sample. The inactive insurers, such as the insurers under liquidation, receivership, or merger and acquisition, may have extraordinary business decisions. Third, we exclude the insurers with negative values in direct premiums written, net premiums written, total assets, and surplus. Fourth, the insurers with extraordinary values in our variables, such as the insurers with the values in internal reinsurance provision (receipt) outside the range of 0 and 1, are excluded from our sample. Fifth, the insurers whose amount of external reinsurance premiums written exceeds 75% of gross premiums written are excluded since these insurers could be professional reinsurer (Powell and Sommer, 2007). After these procedures, the sample size is 25,131 firm/year observations. To reduce the effects of extreme values on our results, we winsorize the variables at the 0.05^{th} and 99.5^{th} percentiles.

3.2 Variables

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3.2.1 Variables of Interest

In our work, we measure the volume of internal reinsurance provision and receipt as the ratio of the net amount of internal reinsurance assumed and ceded to gross premiums written respectively. In our analysis, we also include the dummies indicating intra-group reinsurance status changes. There are three subsamples partitioned by initial participation status: provider, recipient, and non-participant. For each subsample, there are two indicator variables representing intra-group reinsurance participation status conversions.

In addition to internal reinsurance variables, capital holding and risk-taking variables are also the variables of interest in our study. We primarily follow the previous studies to measure these variables (e.g, Baranoff and Sager, 2002, 2003; Lin et al., 2014). Capital holding is measured as the ratio of insurer's surplus to total assets. To measure investment risk, we employ a risk-based capital (RBC) based measurement. In the calculation of investment risk variable, each type of invested asset is multiplied by its corresponding risk factor. The value of investment risk is the summation of these multiplied components, scaled by total invested assets. Likewise, underwriting risk is calculated in similar way. The amount of direct premiums written in each line of business is multiplied by its corresponding risk factor. These components are added together and then divided by total amount of direct premiums written. In the calculation

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of underwriting risk, we use direct premiums written as the basis rather than net premiums written, which is used by previous works. The main reason for using direct premiums written is to remove the effects of reinsurance arrangements on the measure of underwriting risk. Otherwise, we may not be able to test the relation between internal reinsurance decisions and underwriting risk.

3.2.2 Control Variables

The control variables included in our work are explained as follows. Firstly, we include firm size and direct premiums written ratio to control the effects of expected bankruptcy costs on the main decision variables. Firm size is defined as the logarithm of total assets. Following previous studies on reinsurance usage (e.g. Cole and McCullough, 2006; Garven and Lamm-Tennant, 2003), direct premiums written ratio is calculated as the amount of direct premiums written divided by surplus. This variable could be considered as insurer's underwriting leverage prior to any reinsurance arrangements. To account for the effects of regulatory pressure, we include the following two indicator variables suggested by Cheng and Weiss (2013): undercapitalized and marginally capitalized indicator. Specifically, if an insurer's RBC ratio falls below 200%, the value of undercapitalized indicator is 1, and 0 otherwise. If an insurer's RBC ratio falls within the range between 200% and 300%, the value of marginally capitalized indicator takes 1, and 0 otherwise. In addition, we also consider

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the effect of regulatory jurisdiction by including New York indicator variable. Following Cummins and Sommer (1996), the value of this variable is 1 if insurer is licensed in New York state, and 0 otherwise.

To control the effect of organization form, we include a dummy variable, which takes value of 1 for stock insurer and 0 otherwise. Moreover, we further consider the effect of profitability on the variables of interest as profitability is a source of capital replenishment. The insurers with superior profitability may raise less amount of capital and increase risk-taking. In our work, we include investment profitability and underwriting loss to control the effects of profitability. Investment profitability is defined as the ratio of net investment income to surplus. To remove the influence by reinsurance arrangements in underwriting results, we calculate underwriting loss as the ratio of the loss incurred from direct premiums written to total direct premiums written.

In addition to the aforementioned variables, we further control the effect of hurricane exposure on the main decision variables. Following Cheng and Weiss (2012), hurricane exposure is measured as the proportion of the amount of direct premiums written in hurricane-prone areas to total direct premiums written.[7] External reinsurance usage is also included as an explanatory variable, which is measured as the proportion

[7] In line with Cheng and Weiss (2012), we consider the following states as hurricane prone areas: Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina, and North Carolina.

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of the net amount of external reinsurance ceded to gross premiums written. In addition, we also consider the effects of business concentration in terms of line-of-business and geographic areas. Following Cole and McCullough (2006), Berry-Stolzle, Liebenberg, Ruhland, and Sommer (2012),we include geographic and line of business concentration variables, which are calculated as Herfindahl index of direct premiums written by geographic areas and line of business respectively. The variables definitions are summarized in Table 2-2.

Table 2- 2 Variable definitions

Variables	Definitions
Panel A: Internal reinsurance activities, capital holding, and portfolio risk	
Intra-group reinsurance status change indicator	If insurer experience intra-group reinsurance participation status change from year t-1 to year t, the value is 1, and 0 otherwise.
Internal reinsurance assumed	The amount of internal reinsurance assumed minus internal reinsurance ceded, scaled by gross premiums written.
Internal reinsurance receipt	The amount of internal reinsurance ceded minus internal reinsurance assumed, scaled by gross premiums written.
Investment risk	The summation of the types of invested assets multiplied by the corresponding RBC factor loading, scaled by total invested assets.
Underwriting risk	The summation of the direct premiums written in each line of business multiplied by the corresponding RBC factor loading, scaled by total amount of direct premiums written.
Capital holding	The ratio of surplus to total assets.

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Table 2-2 Variable definitions (continued)

Panel B: Other explanatory variables	
Firm size	The Natural logarithm of insurer's total assets.
Direct premiums written ratio	Direct premiums written divided by surplus.
Undercapitalized indicator	If insurer's RBC ratio is below 200%, the value takes 1, and 0 otherwise.
Marginally capitalized indicator	If insurer's RBC ratio lies between 200% and 300%, the value takes 1, and 0 otherwise.
New York indicator	For the insurer licensed in New York state, the value of this indicator is 1, and 0 otherwise.
Organization form	For stock insurer, the value of this variable is 1; and 0 otherwise.
Investment profitability	The amount of investment income divided by surplus.
Underwriting loss	The loss incurred from direct business divided by direct premiums written.
Hurricane exposure	The amount of direct premiums written in hurricane prone states, divided by total direct premiums written.
External reinsurance	The ratio of the net amount of external reinsurance ceded to gross premiums written.
Geographic concentration	Geographic Herfindahl index, which is calculated based on the amount of direct premiums written in each state.
Line of business concentration	Line-of-business Herfindahl index, which is calculated based on the amount of direct premiums written in each line of business.

3.3 Methodology and Endogeneity Tests

In our empirical works, we firstly analyze how intra-group reinsurance status changes affect the adjustments of capital holding, investment risk, and underwriting risk. Specifically, we divide our sample into the following three subsamples based on internal reinsurance participation status: providers, recipients, and non-participants. Among these groups, some insurers experience status changes, such as the changes from recipients to providers. We investigate how these status conversions are related to

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capital and risk decisions. Then we focus on the interrelations among the volume of internal reinsurance activities, capital holding, investment risk, and underwriting risk.

Following the majority of the studies on capital and risk adjustments, we adopt partial adjustment model in our empirical analysis. The regressions for our first part of analysis are constructed as follows

$$\Delta Y_{i,t} = \lambda\left(Y^{*}_{i,t} - Y_{i,t-1}\right) + \varepsilon_{i,t} \quad (1)$$

In equations (1) to (3), $\Delta Y_{i,t}$ represents the observed adjustment of the decision variable. The subscript i and t denote insurer i and year t. Y^{*} is the target level of decision variable. The coefficient λ denotes the speed of adjustments. If an insurer can perfectly adjust the level of Y without any costs, the value of λ in equation (1) will be equal to one. On the contrary, if an insurer does not make any adjustments, the values of λ will be zero. In most cases, λ takes the values between 0 and 1 due to the existence of adjustment costs.

The target level of Y is not observable. Previous studies suggest that the target is determined by insurers' characteristics in previous year, which is denoted as $X_{i,t-1}$. Therefore, the target can be represented as the following equation:

$$Y^{*}_{i,t} = \delta X_{i,t-1} \quad (2)$$

After substituting equation (2) into (1), the regression for partial adjustment model can be represented as follows:

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$$\Delta Y_{i,t} = \alpha\delta X_{i,t-1} - \alpha Y_{i,t-1} + \varepsilon_{i,t} \quad (3)$$

To test the interrelations among the capital holding, investment risk and underwriting risk, and the effects of the changes of intra-group reinsurance roles on the main decision variables, we construct the following equations:

$$\Delta ICM_{i,t} = \lambda_1 \Delta CAP_{i,t} + \lambda_2 \Delta INVRISK_{i,t} + \lambda_3 \Delta UNDRISK_{i,t} - \alpha ICM_{i,t-1} + CV_{1,i,t-1} + \varepsilon_{1,i,t} \quad (4)$$

$$\Delta CAP_{i,t} = \lambda_1 \text{Status Changes}_{i,t} + \lambda_2 \Delta ICM \times \text{Unchanged} + \lambda_3 \Delta INVRISK_{i,t} + \lambda_4 \Delta UNDRISK_{i,t} - \beta CAP_{i,t-1} + CV_{2,i,t-1} + \varepsilon_{2,i,t} \quad (5)$$

$$\Delta INVRISK_{i,t} = \lambda_1 \text{Status Changes}_{i,t} + \lambda_2 \Delta ICM \times \text{Unchanged} + \lambda_3 \Delta CAP_{i,t} + \lambda_4 \Delta UNDRISK_{i,t} - \gamma INVRISK_{i,t-1} + CV_{3,i,t-1} + \varepsilon_{3,i,t} \quad (6)$$

$$\Delta UNDRISK_{i,t} = \lambda_1 \text{Status Changes}_{i,t} + \lambda_2 \Delta ICM \times \text{Unchanged} + \lambda_3 \Delta CAP_{i,t} + \lambda_4 \Delta INVRISK_{i,t} - \delta UNDRISK_{i,t-1} + CV_{4,i,t-1} + \varepsilon_{4,i,t} \quad (7)$$

In equation (4) to (7), ΔICM, ΔCAP, ΔINVRISK and ΔUNDRISK represent the observed adjustments of internal reinsurance, capital holding, investment risk, and underwriting risk respectively. ICM^*, CAP^*, $INVRISK^*$, and $UNDRISK^*$ are the target levels of internal reinsurance, capital holding, investment risk, and underwriting risk. In equation (5) to (7), the changes of internal reinsurance activities include the changes of intra-group reinsurance status and the adjustment of intra-group reinsurance volume. Status Changes are the dummies representing intra-group reinsurance status

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conversions. ΔICM×Unchanged represents the change of internal reinsurance volume for the insurers without experiencing intra-group reinsurance status conversions. CV represents the control variable set. In our work, we employ both 2SLS and 3SLS methods to estimate these equations for the subsamples of providers, recipients, and non-participants. In 2SLS estimation, we separately estimate equation (4) to (7). In 3SLS estimation, all the equations are estimated simultaneously as this method recognizes the correlations of the error terms in these equations.

To cope with the potential endogeneity among our main decision variables and the variables representing intra-group reinsurance status conversions, we need additional instrumental variables which do not appear in control variable sets. Almeida and Campello (2010) conjecture that the lagged values of endogenous variables could convey limited information about the equations estimated. Thus, they use the lagged values of endogenous variables for 2 and 3 years as instrumental variables. In line with Almeida and Campello (2010), we use 2 years lagged values of internal reinsurance activities, capital holding, investment risk, and underwriting risk as instrumental variables. In addition, we also consider the following variables as the potential candidates of instruments. First, we consider the standard deviation of several profitability measures over the past 5 years, such as ROA, ROE, investment profitability, and underwriting profitability. Our reason is that the standard deviation of past

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profitability could be considered as the volatility of cash flows based on past experience. Insurers may make capital and risk-taking decisions based on their past cash flows volatility. In addition, we also consider the logarithm of the average surplus values over past 5 years as another candidate. This measurement may represent insurer' average underwriting capacity in past years and thus could be relevant to intra-group reinsurance, capital, and risk-taking decisions.

Before conducting regression analysis, we perform Wu-Hausman tests for intra-group reinsurance status conversion variables, the adjustment of internal reinsurance volume, capital holding, and risk-taking. Specifically, we treat the above-mentioned variables as endogenous variables and regress them on other control variables and the instrumental variables which do not appear in equation (4) to (7). Then we retrieve the residuals from the aforementioned reduced form regressions and include these residuals as additional explanatory variables in structural equation (4) to (7). If the coefficients on these residuals are jointly significant, these variables are considered as endogenous variables. For equation (5) to (7), we further test the joint significance regarding the residuals of intra-group reinsurance status changes variables. In this procedure, our goal is to determine whether we can treat the variables representing intra-group reinsurance role conversions as exogenous variables.

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These results are presented in Table 2-3.[8]In panel A of Table 2-3, we find that the coefficients on the residuals of intra-group reinsurance status changes variables are not jointly significant when dependent variables are the adjustment of capital holding and investment risk. In panel B, the coefficients on the residuals of status conversion variables are not significant when dependent variable is the adjustment of investment risk. In panel C, these coefficients are not significant in capital holding equation. Based on these results, we treat the variables representing intra-group reinsurance status changes as exogenous in capital holding equation for the subsamples of providers and non-participants, and in investment risk equation for the subsamples of providers and recipients in 2SLS estimation.[9] In 3SLS estimation, however, we must simultaneously treat intra-group reinsurance role conversion variables in equation (4) to (7) as endogenous or exogenous variables as this method consider the correlations among the error terms of these equations during the estimation process. Because we find the endogeneity of these status conversion variables in several equations, we treat them as endogenous variables when applying 3SLS method.

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[8] To test the validity of our instrumental variables, we also perform the over-identification tests. The statistics yielded from these tests are not statistically significant, which could confirm the validity of our instrumental variables. The detailed results can be found in table B-1 in Appendix B.

[9] In Row C of Panel B, the coefficients on the residuals of intra-group reinsurance status conversion variables are not significant in capital holding equation. Nevertheless, we find that the coefficients on the residuals of the variables representing both status and volume changes of intra-group reinsurance activities are jointly significant at 1% level in combination. This result could strongly indicate that the changes in intra-group reinsurance activities are endogenous. Therefore, it could be more appropriate to treat status changes variables as endogenous.

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Table 2- 3 The results of endogeneity tests

Panel A: the coefficients on the residuals of potential endogenous variables in Wu-Hausman tests

Residuals of variables\Dependent variable	Providers in year t-1 (N=6,844)				Recipients in year t-1 (N=14,841)				Non-participants in year t-1 (N=3,446)		
	ΔICMPRO	ΔCAP	ΔINVRISK	ΔUNDRISK	ΔICMREC	ΔCAP	ΔINVRISK	ΔUNDRISK	ΔCAP	ΔINVRISK	ΔUNDRISK
PROTORE		-0.0220	0.0011	-0.0182							
PROTONON		0.3399	0.0286	0.3369**							
ΔICMPRO*UN		-0.0074	-0.0128*	-0.0441*							
RETOPRO						-0.0142	-0.0001	-0.0886			
RETONON						0.0400	-0.0272	0.2156			
ΔICMREC*UN						0.2928	0.0133	0.1015			
NONTOPRO									-0.2899	-0.0316	-0.0598
NONTORE									0.0456	0.0060	0.0713**
ΔCAP	-2.4268***		0.1345***	0.0039	0.8257***		0.0212***	0.0374		0.0052	0.0675
ΔINVRISK	-2.7481	2.0354**		-0.6178	-7.0042***	2.2963		-1.2586	-0.6103		0.7117
ΔUNDRISK	0.1169	0.0254	-0.0170		-0.4264	-0.1979	-0.0175		-0.2136	0.0031	
$ICMPRO_{t-1}$	0.2702***										
$ICMREC_{t-1}$					-0.0014						
CAP_{t-1}		-0.0277				-0.0714***			0.0731***		
$INVRISK_{t-1}$			-0.1182***				-0.0624***			-0.0560***	
$UNDRISK_{t-1}$				-0.0170				0.0140			0.0307*

Panel B:the results of endogeneity tests

Row A: Wu-Hausman test (F-statistic)	38.66*** (0.0000)	1.20 (0.3018)	18.41*** (0.0000)	6.04*** (0.0000)	11.03*** (0.0000)	12.34*** (0.0000)	25.78*** (0.0000)	3.20*** (0.0039)	2.48** (0.0300)	2.51** (0.0283)	1.90* (0.0914)
Row B: F-test for the variables representing the changes in internal reinsurance status and volume		1.05 (0.3712)	1.97 (0.1164)	3.85*** (0.0092)		4.42*** (0.0041)	2.14* (0.0924)	3.76** (0.0104)			
Row C: F-test for the variables representing the changes in internal reinsurance status		1.35 (0.2595)	1.70 (0.1832)	5.54*** (0.0040)		0.04 (0.9610)	1.39 (0.2493)	3.42** (0.0327)	0.73 (0.4801)	2.31* (0.0999)	2.54* (0.0794)

Notes:

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level. The figures in parentheses are the p-values for the endogeneity tests.

(2) In panel A, the residuals are obtained by regressing variables of interests on instrumental variables and other control variables. When performing Wu-Hausman tests, the residuals of the potential endogenous variables are treated as additional explanatory variables in structural models. The results in Row A of panel B are the F-statistics for the joint tests of the residuals' coefficients.

(3) In Row B of panel B, we test the joint significance of the variables representing the changes in internal reinsurance activities. For providers subsample, these variables include PROTORE, PROTONON, and ΔICMPRO*UN. PROTORE and PROTONON are the dummies indicating that the provider in year t-1 becomes recipient and non-participant in year t respectively. ΔICMPRO*UN denotes the change in the amount of internal reinsurance provision for the providers without status changes. For recipients subsample, these variables are RETOPRO, RETONON, and ΔICMREC*UN. RETOPRO and RETONON are the dummies indicating that the recipient in year t-1 becomes provider and non-participant in year t respectively. ΔICMREC*UN represents the change in the amount of internal reinsurance receipts for the recipients without status changes.

(4) In Row C of panel B, we test the joint significance of the variables that representing the changes in internal reinsurance status. For providers, these variables are PROTORE and PROTONON. For recipients, the variables include RETOPRO and RETONON. For non-participants subsample, the variables are NONTOPRO and NONTORE, which represent the situations that non-participant in year t-1 becomes provider and recipient in year t respectively.

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4. Empirical Results

4.1 Descriptive Statistics, Univariate Analysis, and Correlations

In Table 2-4, we present the descriptive statistics of the variables for the three subsamples partitioned by intra-group reinsurance participation status. Regarding the status changes, we find that 8.52% and 1.48% of the providers in previous year become recipients and non-participants respectively. On the other hand, 3.97% and 1.17% of the recipients in year t-1 become providers and non-participants in year t respectively. Moreover, we also find that nearly 13% of the insurers without intra-group involvement in year t-1 begin to participate in internal reinsurance transactions in year t. In general, the insurers which experience status conversions only account for small fraction in each subsample.

Table 2-5 shows the results of the univariate analysis on the adjustments of internal reinsurance, capital holding, and risk. In Table 2-5, we further partition our subsamples based on whether insurers experience intra-group reinsurance status changes. We find that the conversion from provider to recipient is associated with the increase in both capital holding and investment risk. Symmetrically, the conversion from recipient to provider is followed by the reduction in capital holding and investment risk. In addition, the change from non-participant to provider is also associated with a significant drop in capital holding.

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Table 2- 4 Descriptive statistics for the subsamples categorized by intra-group reinsurance participation status

Variables	Providers (N=6,844)					Recipients (N=14,841)					Non-Participants (N=3,446)				
	Mean	Median	St. dev.	Max	Min	Mean	Median	St. dev.	Max	Min	Mean	Median	St. dev.	Max	Min
PROTORE	0.0852	0.0000	0.2792	1.0000	0.0000										
PROTONON	0.0148	0.0000	0.1206	1.0000	0.0000										
ΔICMPRO	-0.0203	-0.0004	0.1590	0.9271	-1.7925										
$ICMPRO_{t-1}$	0.2896	0.1998	0.2655	0.9966	0.0001										
RETOPRO						0.0397	0.0000	0.1952	1.0000	0.0000					
RETONON						0.0117	0.0000	0.1076	1.0000	0.0000					
ΔICMREC						-0.0140	0.0000	0.1505	0.9930	-1.9998					
$ICMREC_{t-1}$						0.5974	0.6649	0.3751	1.0000	0.0007					
NONTOPRO											0.0482	0.0000	0.2142	1.0000	0.0000
NONTORE											0.0807	0.0000	0.2724	1.0000	0.0000
ΔCAP	0.0005	0.0025	0.0538	0.2791	-0.2208	-0.0061	0.0003	0.0934	0.3789	-0.5283	-0.0080	0.0001	0.0848	0.3170	-0.3728
ΔINVRISK	0.0005	0.0002	0.0079	0.0399	-0.0345	0.0001	0.0000	0.0064	0.0333	-0.0360	0.0007	0.0001	0.0087	0.0511	-0.0405
ΔUNDRISK	-0.0006	0.0000	0.0419	0.1772	-0.1929	-0.0010	0.0000	0.0407	0.1626	-0.1991	-0.0019	0.0000	0.0434	0.1790	-0.2157
CAP_{t-1}	0.3967	0.3678	0.1403	0.9059	0.1475	0.5556	0.4887	0.2656	1.0000	0.0686	0.4847	0.4394	0.2079	0.9921	0.0922
$INVRISK_{t-1}$	0.0278	0.0214	0.0250	0.1232	0.0018	0.0146	0.0039	0.0221	0.1188	0.0000	0.0195	0.0109	0.0216	0.1111	0.0000
$UNDRISK_{t-1}$	0.9615	0.9545	0.0951	1.6333	0.7980	0.9573	0.9519	0.0830	1.5413	0.7986	0.9531	0.9490	0.1000	1.6327	0.7706
FS	19.7127	19.6027	1.8045	24.4916	15.5992	18.0688	17.9787	1.6933	22.6949	14.5385	17.7334	17.6715	1.5724	21.5501	13.6999
DPWRA	0.8800	0.6740	0.8414	6.0595	0.0004	4.6669	2.0730	10.0409	103.2105	0.0048	1.6895	1.2182	1.8801	15.9844	0.0003
UNDCAP	0.0048	0.0000	0.0693	1.0000	0.0000	0.0046	0.0000	0.0680	1.0000	0.0000	0.0200	0.0000	0.1401	1.0000	0.0000
MARCAP	0.0361	0.0000	0.1865	1.0000	0.0000	0.0224	0.0000	0.1481	1.0000	0.0000	0.0699	0.0000	0.2551	1.0000	0.0000
NYSTATE	0.0525	0.0000	0.2230	1.0000	0.0000	0.0505	0.0000	0.2191	1.0000	0.0000	0.0427	0.0000	0.2021	1.0000	0.0000
OF	0.7509	1.0000	0.4325	1.0000	0.0000	0.8599	1.0000	0.3471	1.0000	0.0000	0.7980	1.0000	0.4015	1.0000	0.0000
INVPERF	0.1051	0.0918	0.0702	0.4678	-0.0528	0.0705	0.0558	0.0579	0.3758	-0.0512	0.0824	0.0693	0.0702	0.5127	-0.0979
UNDLOSS	0.5683	0.5504	0.6814	5.4877	-4.5222	0.5818	0.5559	0.4483	4.3600	-1.0674	0.5745	0.5093	1.9010	19.6634	-13.6337
EXTRE	0.0791	0.0269	0.1670	0.7921	-0.5079	0.0496	0.0001	0.1457	0.9997	-0.9889	0.1942	0.1146	0.2780	1.0000	-0.6948
HUREXP	0.2120	0.1079	0.2894	1.0000	0.0000	0.3016	0.1806	0.3538	1.0000	0.0000	0.3225	0.0113	0.4174	1.0000	0.0000
GEOCON	0.4537	0.3388	0.3633	1.0000	0.0367	0.4881	0.3666	0.3829	1.0000	0.0392	0.7064	0.9512	0.3488	1.0000	0.0364
LOBCON	0.5806	0.5068	0.2878	1.0000	0.1453	0.6199	0.5589	0.2882	1.0000	0.1625	0.7693	0.9325	0.2651	1.0000	0.2119

Notes:

(1) Providers are the insurers whose internal reinsurance assumed exceeds internal reinsurance ceded; recipients are the insurers whose internal reinsurance ceded exceeds internal reinsurance assumed; non-participants are the insurers which do not participate in intra-group reinsurance activities.

(2) PROTORE: if the provider in year t-1 becomes recipient in year t, the value of this indicator is 1 and 0 otherwise; PROTONON: if the provider in year t-1 becomes non-participant in year t, the value of this indicator is 1 and 0 otherwise; ΔICMP*UN: if the provider does not experience status change, the value of this variable is the change in the amount of internal reinsurance provision, and 0 otherwise; $ICMPRO_{t-1}$: internal reinsurance provision in previous year; RETOPRO: if the recipient in year t-1 becomes provider in year t, the value of this indicator is 1 and 0 otherwise; RETONON: if the recipient in year t-1 becomes non-participant in year t, the value of this indicator is 1 and 0 otherwise; ΔICMR*UN: if the recipient does not experience status change, the value of this variable is the change in the amount of internal reinsurance receipt, and 0 otherwise; $ICMREC_{t-1}$: internal reinsurance receipt in previous year; NONTOPRO: if the non-participant in year t-1 becomes provider in year t, the value of this indicator is 1 and 0 otherwise; NONTORE: if the non-participant in year t becomes recipient in year t, the value of this indicator is 1 and 0 otherwise; ΔCAP: change in capital holding; ΔINVRISK: change in investment risk; ΔUNDRISK: change in underwriting risk;

$INVRISK_{t-1}$: investment risk in previous year; $UNDRISK_{t-1}$: underwriting risk in previous year; CAP_{t-1}: capital holding in previous year; FS: firm size; DPWRA: direct premiums written ratio; UNDCAP: undercapitalized indicator; MARCAP: marginally capitalized indicator; NYSTATE: New York state indicator; OF: organization form; INVPROF: investment profitability; UNDLOSS: underwriting loss; EXTRE: external reinsurance; HUREXP: hurricane exposure; GEOCON: geographic concentration; LOBCON: line of business concentration.

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Table 2- 5 Univariate analysis on the adjustments of internal reinsurance activities, capital holding, and portfolio risk

Panel A Providers in year t-1 (N=6,844)

Variable	(1) become recipients in year t (N=583)				(2) become non-participants in year t (N=101)				(3) without status change (N=6,160)			
	Year t	Year t-1	Diff.	T-test	Year t	Year t-1	Diff	T-test	Year t	Year t-1	Diff	T-test
ICMPRO									0.3129	0.3082	0.0047	3.2814 ***
CAP	0.4039	0.3867	0.0172	4.3581 ***	0.4413	0.4284	0.0128	1.2461	0.3962	0.3971	-0.0008	-1.2043
INVRISK	0.0224	0.0211	0.0012	2.4252 ***	0.0243	0.0242	0.0001	0.1125	0.0289	0.0285	0.0005	4.3458 ***
UNDRISK	0.9625	0.9612	0.0013	0.6747	0.9691	0.9687	0.0004	0.0503	0.9608	0.9615	-0.0007	-1.0734

Panel B: Recipients in year t-1 (N=14,841)

Variable	(1) become providers in year t (N=589)				(2) become non-participants in year t (N=174)				(3) without status change (N=14,078)			
	Year t	Year t-1	Diff.	T-test	Year t	Year t-1	Diff	T-test	Year t	Year t-1	Diff	T-test
ICMREC									0.6215	0.6195	0.0019	2.1726 **
CAP	0.3959	0.4391	-0.0433	-7.5557 ***	0.4844	0.4919	-0.0075	-0.6954	0.5567	0.5613	-0.0045	-5.4717 ***
INVRISK	0.0200	0.0210	-0.0009	-2.0787 **	0.0159	0.0161	-0.0002	-0.2900	0.0145	0.0144	0.0002	2.7104 ***
UNDRISK	0.9645	0.9622	0.0023	1.0461	0.9614	0.9670	-0.0056	-2.1206 **	0.9559	0.9570	-0.0011	-2.8735 ***

Panel C: Non-participants in year t-1 (N=3,446)

Variable	(1) become providers in year t (N=166)				(2) become recipients in year t (N=278)				(3) without status change (N=3,002)			
	Year t	Year t-1	Diff	T-test	Year t	Year t-1	Diff	T-test	Year t	Year t-1	Diff	T-test
CAP	0.4161	0.4646	-0.0485	-4.9191 ***	0.4871	0.4980	-0.0108	-1.2477	0.4789	0.4846	-0.0057	-3.8080 ***
INVRISK	0.0257	0.0243	0.0014	1.5096	0.0188	0.0174	0.0014	1.7039 *	0.0201	0.0194	0.0007	3.9309 ***
UNDRISK	0.9706	0.9721	-0.0015	-0.2727	0.9564	0.9547	0.0017	0.3887	0.9497	0.9519	0.0022	-2.4759 **

Notes:
(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.
(2) ICMPRO: the amount of internal reinsurance provision; ICMREC: the amount of internal reinsurance receipt; CAP: capital holding; INVRISK: investment risk; UNDRISK: underwriting risk.

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The followings are the possible explanations for the results reported in Table 2-5. First, the receipt of internal reinsurance could reduce the risk from underwriting activities and thus enable insurers to take more investment risk. Second, the change in capital holding due to the status conversions may be explained by the change in the underwriting revenue via internal reinsurance transactions. Specifically, the conversions from both recipient and non-participant to provider could increase the income streams collected by insurers via internal reinsurance arrangements. Such income flows may replenish insurers' capital and further reduce insurers' incentive to supplement capital positions from other sources. On the contrary, the conversion from provider to recipient could reduce an insurer's underwriting income. The insurers which experience such role conversion could lose the income streams generated from internal reinsurance transactions to supplement their surplus, and thus may need to adopt more conservative capital decisions in response of such conversion. In short, the changes of the underwriting incomes via intra-group reinsurance caused by the role conversions could drive insurers' subsequent capital decisions.

For the insurers without status changes, we further find significant changes in the levels of internal reinsurance activities, capital holding, and risk-taking. The providers without status conversions experience the increase in the amount of internal reinsurance provision and investment risk, which may indicate the same direction of the movements

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of internal reinsurance provision and investment risk. For the recipients without status changes, we find that both internal reinsurance receipt and investment risk significantly increase from year t-1 to year t. In contrast, the levels of capital and underwriting risk are reduced. These results may suggest that the adjustment of internal reinsurance receipt volume is positively related to investment risk, whereas it is negatively related to capital holding and underwriting risk.

In addition to the univariate analysis, we also present the correlations between internal reinsurance activities, capital, and risk in Table 2-6. The detailed correlation coefficients tables are available in Appendix B. Consistent with the results of univariate analysis reported in Table 2-5, the correlation between the indicator variable representing the change from provider to recipient and investment risk is positive and significant in Table 2-6. Similarly, the correlation between the dummy variable indicating the conversion from recipient to provider is negatively related to investment risk. Moreover, we also find that the dummy indicating the change from non-participant to provider is negatively related to capital holding. These correlations are generally consistent with the univariate analysis results in Table 2-5.

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Table 2- 6 Correlations among internal reinsurance activities, capital, and risk

Variable	Panel A: Providers in year t-1 (N=6,844)						
	$\Delta ICMPRO_t$	PROTOREC	PROTONON	$\Delta ICMP*UN_t$	ΔCAP_{tt}	$\Delta INVRISK_t$	$\Delta UNDRISK_t$
PROTORE	-0.4758 ***						
PROTONON	-0.0743 ***	-0.0373 ***					
ΔICMPRO*UN	0.6817 ***	-0.0121	-0.0049				
ΔCAP	-0.1663 ***	0.0824 ***	0.0208 *	-0.0922 ***			
ΔINVRISK	-0.0281 **	0.0269 **	-0.0085	-0.0132	0.1322 ***		
ΔUNDRISK	-0.0063	0.0123	0.0019	-0.0180	0.0205 *	0.0160	

Variable	Panel B: Recipients in year t-1 (N=14,841)						
	$\Delta ICMREC_t$	RETOPRO	RETONON	$\Delta ICMR*UN_t$	ΔCAP_t	$\Delta INVRISK_t$	$\Delta UNDRISK_t$
RETOPRO	-0.4397 ***						
RETONON	-0.1340 ***	-0.0221 ***					
ΔICMREC*UN	0.6867 ***	-0.0033	-0.0017				
ΔCAP	0.2058 ***	-0.0752 ***	-0.0061	0.1417 ***			
ΔINVRISK	0.0069	-0.0239 ***	-0.0091	0.0008	0.0683 ***		
ΔUNDRISK	0.0064	0.0086	-0.0129	0.0122	0.0475 ***	0.0126	

Variable	Panel C: Non-participants in year t-1 (N=3,446)				
	NONTOPRO	NONTOREC	ΔCAP_t	$\Delta INVRISK_t$	$\Delta UNDRISK_t$
NONTOREC	-0.0666 ***	1.0000			
ΔCAP	0.0212	0.0089	1.0000		
ΔINVRISK	0.0002	0.0159	0.0316 *	1.0000	
ΔUNDRISK	-0.1010 ***	-0.0017	0.0419 **	0.0243	1.0000

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level, and * indicates statistical significance at the 10% level.

(2) PROTORE: if the provider in year t-1 becomes recipient in year t, the value of this indicator is 1 and 0 otherwise; PROTONON: if the provider in year t-1 becomes non-participant in year t, the value of this indicator is 1 and 0 otherwise; ΔICMPRO*UN: if the provider does not experience status change, the value of this variable is the change in the amount of internal reinsurance provision, and 0 otherwise; RETOPRO: if the recipient in year t-1 becomes provider in year t, the value of this indicator is 1 and 0 otherwise; RETONON: if the recipient in year t-1 becomes non-participant in year t, the value of this indicator is 1 and 0 otherwise; ΔICMREC*UN: if the recipient does not experience status change, the value of this variable is the change in the amount of internal reinsurance receipt, and 0 otherwise; NONTOPRO: if the non-participant in year t-1 becomes provider in year t, the value of this indicator is 1 and 0 otherwise; NONTORE: if the non-participant in year t becomes recipient in year t, the value of this indicator is 1 and 0 otherwise; ΔCAP: change in capital holding; ΔINVRISK: change in investment risk; ΔUNDRISK: change in underwriting risk.

4.2 Regression Results

4.2.1 The Effect of Intra-Group Reinsurance Status Changes

The regression results for the subsamples of internal reinsurance providers, recipients, and non-participants are represented in Table 2-7, 2-8, and 2-9 respectively. Based on the over-identification tests results, the insignificance of the statistics could suggest the validity of the instrumental variables used in 2SLS and 3SLS estimation.

In Table 2-7, we find that the status conversions from provider to both recipient and

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non-participant are associated with the increase in capital holding when we use 2SLS method to estimate the structural equations. Likewise, Table 2-9 shows that the indicator representing the role change from non-participant to provider negatively affects capital holding. These results are generally consistent with the results of the univariate analysis presented in Table 2-5. These changes in capital holding could be caused by the changes in underwriting revenues via internal reinsurance transactions. As the aforementioned explanations in previous section, under intra-group reinsurance arrangements, the provision of internal reinsurance could increase insurers' underwriting revenues. Such increase in income flows may reduce insurers' demand for other sources of capital replenishment. Therefore, the conversions from other roles in internal reinsurance arrangements to provider could result in the decrease in capital holding. Conversely, the conversions from provider to recipient could substantially decrease the cash flows from internal reinsurance transactions and induce insurers to raise the level of capital holding to compensate for the reduced sources of capital replenishment. Based on the above-mentioned results, both hypothesis 1a and 1b are not supported.

In addition to capital holding, intra-group reinsurance participation status conversion is also related to the investment risk. Specifically, Table 2-7 reveals that the conversion from provider to recipient is associated with an increase in investment

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risk. This result is consistent with coordinated risk management hypothesis of Schrand and Unal (1998). As the receipt of internal reinsurance could reduce the risk from underwriting activities and insolvency risk, insurers can take more risk in investment activities. Hypothesis 2b receives support in Table 2-7.

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Table 2- 7 The effects of intra-group reinsurance status changes: the subsample of internal reinsurance providers in previous year

Variable	2SLS								3SLS							
	ΔICMPRO		ΔCAP		Δ INVRISK $_t$		ΔUNDRISK $_t$		ΔICMPRO		ΔCAP		Δ INVRISK $_t$		ΔUNDRISK $_t$	
	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev
Constant	-0.0864***	0.0405	0.0121	0.0115	-0.0049**	0.0021	0.0696***	0.0160	-0.0875**	0.0405	0.0284	0.0186	-0.0003	0.0035	0.0691***	0.0160
PROTOREC			0.0226***	0.0030	0.0028***	0.0008	0.0160	0.0482			0.0264	0.0492	-0.0035	0.0096	0.0188	0.0479
PROTONON			0.0176***	0.0071	0.0001	0.0014	-0.3333	0.3066			-0.2177	0.3078	-0.0201	0.0573	-0.3494	0.3047
ΔICMPRO*UN $_t$			-0.0547***	0.0078	0.0051	0.0071	0.0388	0.0440			-0.0386	0.0588	0.0143	0.0098	0.0371	0.0440
ΔCAP $_t$	1.8107***	0.5955			-0.0871***	0.0266	-0.0121	0.2729	1.8980***	0.5795			-0.1062**	0.0468	-0.0349	0.2710
ΔINVRISK $_t$	2.6368	3.5826	-0.6688	0.8664			0.6080**	1.0810	3.0139	3.5715	-1.2343	1.2475			0.5427	1.0773
ΔUNDRISK $_t$	0.0882	0.7059	0.0383	0.1857	0.0316	0.0348			0.0628	0.7051	-0.0473	0.2422	0.0169	0.0428		
ICMPRO $_{t-1}$	-0.1207***	0.0160							-0.1213***	0.0158						
CAP$_{t-1}$			-0.0476***	0.0069							-0.0402***	0.0134				
INVRISK$_{t-1}$					-0.0363***	0.0071							-0.0357***	0.0089		
UNDRISK$_{t-1}$							-0.0467***	0.0084							-0.0458***	0.0083
FS $_{t-1}$	0.0087***	0.0018	-0.0006	0.0005	0.0002**	0.0001	-0.0010	0.0008	0.0088***	0.0018	-0.0013	0.0008	0.0000	0.0002	-0.0010	0.0007
DPWRA $_{t-1}$	-0.0234***	0.0057							-0.0238***	0.0054						
UNDCAP $_{t-1}$	-0.1912***	0.0464	0.0253**	0.0114	0.0002	0.0023	0.0557	0.0370	-0.1934***	0.0463	0.0539	0.0332	0.0049	0.0073	0.0578	0.0368
MARCAP $_{t-1}$	-0.0292*	0.0170	0.0089**	0.0042	0.0006	0.0009	0.0018	0.0048	-0.0304*	0.0169	0.0097*	0.0052	0.0011	0.0011	0.0020	0.0048
NYSTATE $_{t-1}$	-0.0225*	0.0123	-0.0058*	0.0032	-0.0014**	0.0006	-0.0017	0.0039	-0.0220*	0.0123	-0.0062	0.0043	-0.0013	0.0008	-0.0019	0.0039
OF $_{t-1}$	0.0081	0.0068	-0.0033*	0.0017	-0.0012***	0.0003	-0.0032	0.0031	0.0083	0.0068	-0.0042	0.0031	-0.0011	0.0006	-0.0033	0.0031
INVPROF $_{t-1}$	-0.1839***	0.0584	0.0204	0.0136	0.0024	0.0029	0.0105	0.0169	-0.1877***	0.0582	0.0250	0.0181	0.0044	0.0037	0.0114	0.0168
UNDLOSS $_{t-1}$	-0.0023	0.0044	0.0010	0.0012	0.0001	0.0002	-0.0028*	0.0016	-0.0025	0.0044	-0.0002	0.0022	0.0000*	0.0004	-0.0029*	0.0016
EXTRE $_{t-1}$	0.0064	0.0210	-0.0088*	0.0046			0.0085*	0.0049	0.0119	0.0174	-0.0060	0.0053			0.0083*	0.0049
HUREXP $_{t-1}$	0.0017	0.0098	-0.0004	0.0026			0.0000	0.0023	0.0035	0.0081	-0.0009	0.0022			-0.0001	0.0023
GEOCON $_{t-1}$	0.0329***	0.0086	0.0021	0.0023	-0.0003	0.0004	0.0002	0.0033	0.0333***	0.0086	0.0015	0.0039	-0.0008	0.0008	0.0004	0.0033
LOBCON $_{t-1}$	-0.0248*	0.0111	0.0072***	0.0028	0.0013**	0.0005	0.0061	0.0050	-0.0253	0.0111	0.0095**	0.0043	0.0016*	0.0009	0.0063	0.0050
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Chi-Square statistic	154.13***		619.11***		238.88***		3,392.54***		154.33***		325.96***		184.06***		3,391.64***	
Over-identification:																
Sargan	0.9928 (0.8030)		3.0967 (0.6851)		5.8366 (0.4417)		0.5285 (0.7678)									
Basmann	0.9855 (0.8048)		3.0733 (0.6887)		5.7970 (0.4463)		0.5245 (0.7693)									
Hansen-Sargan													3.672 (0.9786)			

Notes:

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level. The figures in parentheses are the p-values for the over-identification tests. All the statistics in over-identification tests are chi-square distributed.

(2) PROTOREC, PROTONON, ΔICMPRO*UN are the variables representing the changes in internal reinsurance activities. If the providers in previous year become recipient (non-participants) in current year, the value of PROTOREC (PROTONON) is 1 and 0 otherwise. ΔICMPRO*UN is the change in the amount of internal reinsurance provision only for the providers which do not experience status changes. The remaining variable abbreviations are the same as previous tables.

(3) The instrumental variables include the standard deviation of ROA, ROE, and underwriting profitability in previous 5 years, and the lagged 2 values of the following variables: investment risk, underwriting risk, and capital holding.

(4) In 2SLS estimation, PROTOREC and PROTONON are treated as exogenous variables when dependent variables are the adjustment on investment risk and capital holding. In other specifications, these two variables are treated as endogenous variables.

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Table 2- 8 The effects of intra-group reinsurance status changes: the subsample of internal reinsurance recipients in previous year

Variable	2SLS								3SLS							
	$\Delta ICMREC_t$		ΔCAP_t		$\Delta INVRISK_t$		$\Delta UNDRISK_t$		$\Delta ICMREC_t$		ΔCAP_t		$\Delta INVRISK_t$		$\Delta UNDRISK_t$	
	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev
Constant	-0.0163	0.0325	0.0059	0.0692	-0.0042	0.0029	0.0817***	0.0182	-0.0204	0.0324	-0.0388	0.0581	-0.0045	0.0029	0.0842***	0.0167
RETOPRO			-0.0206	0.3321	-0.0008	0.0082	0.0916	0.1139			-0.2294	0.2763	-0.0009	0.0082	0.1049	0.1013
RETONON			-0.0468	1.3842	0.0270	0.0528	-0.2160	0.5068			0.8460	1.1515	0.0285	0.0528	-0.2608	0.4530
$\Delta ICMREC*UN_t$			-0.1657	0.4484	-0.0139	0.0295	-0.0974	0.1854			-0.4134	0.3907	-0.0152	0.0295	-0.1003	0.1730
ΔCAP_t	-0.4786***	0.1724			-0.0156*	0.0081	-0.0365	0.0754	-0.5281***	0.1706			-0.0173**	0.0081	-0.0505	0.0696
$\Delta INVRISK_t$	7.2253**	3.0917	-1.2814	2.8599			1.2891	1.3576	7.0888	3.0911	-0.3303	2.6524			1.3792	1.2879
$\Delta UNDRISK_t$	0.3313	0.3661	0.2101	0.4623	0.0205	0.0277			0.3341	0.3659	0.4623	0.4050	0.0221	0.0277		
$ICMREC_{t-1}$	-0.0201***	0.0061							-0.0206***	0.0061						
CAP_{t-1}			-0.0471***	0.0100							-0.0526***	0.0088				
$INVRISK_{t-1}$					-0.0311***	0.0065							-0.0313***	0.0065		
$UNDRISK_{t-1}$							-0.0671***	0.0116							-0.0668***	0.0108
FS_{t-1}	-0.0015	0.0014	-0.0010	0.0041	0.0002	0.0001	-0.0012	0.0015	-0.0014	0.0014	0.0016	0.0034	0.0002	0.0001	-0.0014	0.0013
$DPWRA_{t-1}$	0.0007***	0.0002							0.0007***	0.0002						
$UNDCAP_{t-1}$	0.0322	0.0250	0.0130	0.0408	-0.0011	0.0018	0.0054	0.0161	0.0325	0.0249	0.0368	0.0351	-0.0010	0.0018	0.0049	0.0148
$MARCAP_{t-1}$	0.0218*	0.0112	0.0181	0.0269	-0.0003	0.0010	0.0092	0.0104	0.0228**	0.0112	0.0011	0.0226	-0.0002	0.0010	0.0105	0.0093
$NYSTATE_{t-1}$	-0.0045	0.0071	-0.0049	0.0124	0.0002	0.0005	-0.0003	0.0051	-0.0046	0.0071	0.0030	0.0106	0.0002	0.0005	-0.0009	0.0046
OF_{t-1}	0.0014	0.0049	-0.0001	0.0069	-0.0006**	0.0003	0.0001	0.0027	0.0015	0.0049	0.0044	0.0060	-0.0006**	0.0003	-0.0002	0.0025
$INVPROF_{t-1}$	0.0908*	0.0485	0.1419***	0.0333	0.0028	0.0023	0.0089	0.0215	0.1001**	0.0483	0.1255***	0.0301	0.0031	0.0022	0.0119	0.0199
$UNDLOSS_{t-1}$	0.0022	0.0039	0.0085*	0.0048	-0.0001	0.0002	0.0007	0.0015	0.0026	0.0039	0.0112***	0.0041	-0.0001	0.0002	0.0007	0.0014
$EXTRE_{t-1}$	0.0611***	0.0117	0.0051	0.0353			0.0164	0.0122	0.0604***	0.0117	-0.0167	0.0299			0.0187*	0.0110
$HUREXP_{t-1}$	0.0020	0.0048	-0.0027	0.0030			0.0001	0.0013	0.0020	0.0048	0.0002	0.0028			-0.0007	0.0012
$GEOCON_{t-1}$	-0.0029	0.0054	0.0098**	0.0047	-0.0001	0.0004	-0.0019	0.0026	-0.0023	0.0054	0.0075*	0.0043	-0.0001	0.0004	-0.0017	0.0024
$LOBCON_{t-1}$	-0.0082*	0.0059	0.0028	0.0139	0.0000	0.0005	0.0019	0.0053	-0.0080	0.0059	-0.0060	0.0117	0.0000	0.0005	0.0024	0.0048
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Chi-Square statistic	145.59***		628.83***		191.70***		9,570.18***		149.49***		631.92***		192.51***		9,571.15***	
Over-identification:																
Sargan	1.2245 (0.8747)		5.0157 (0.1707)		6.4218 (0.2688)		0.9341 (0.8172)									
Basmann	1.2207 (0.8740)		5.0019 (0.1717)		6.4048 (0.2673)		0.9312 (0.8179)									
Hansen-Sargan													13.185 (0.5880)			

Notes:

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level. The figures in parentheses are the p-values for the over-identification tests. All the statistics in over-identification tests are chi-square distributed.

(2) RETOPRO, RETONON, ΔICMREC*UN are the variables representing the changes in internal reinsurance activities. If the providers in previous year become providers (non-participants) in current year, the value of RETOPRO (RETONON) is 1 and 0 otherwise. ΔICMREC*UN is the change in the amount of internal reinsurance receipt only for the recipients which do not experience status changes. The remaining variable abbreviations are the same as previous tables.

(3) The instrumental variables include the standard deviation of ROE, investment profitability, underwriting profitability in previous 5 years, the mean value of surplus in previous 5 years, and the lagged 2 values of the following variables: investment risk, underwriting risk, and capital holding.

(4) In 2SLS estimation, RETOPRO and RETONON are treated as exogenous variables when dependent variables are the adjustment on investment risk and capital holding. In other specifications, these two variables are treated as endogenous variables.

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Table 2- 9 The effects of intra-group reinsurance status changes: the subsample of non-participants in previous year

Variable	2SLS						3SLS					
	ΔCAP $_t$		Δ INVRISK $_t$		ΔUNDRISK $_t$		ΔCAP $_t$		Δ INVRISK $_t$		ΔUNDRISK $_t$	
	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev
Constant	0.0858***	0.0283	0.0011	0.0033	0.0776***	0.0176	0.0999	0.0392	0.0011	0.0033	0.0803***	0.0173
NONTOPRO	-0.0528***	0.0089	0.0337	0.0283	0.0658	0.1600	0.3350	0.3876	0.0311	0.0283	0.1154	0.1530
NONTOREC	0.0000	0.0068	-0.0042	0.0098	-0.0679	0.0445	-0.0350	0.1129	-0.0051	0.0098	-0.0640	0.0427
ΔCAP			-0.0029	0.0204	-0.0702	0.0720			-0.0046	0.0203	-0.0631	0.0714
ΔINVRISK	1.9334	1.6341			-0.5433	0.9859	0.4182	2.3387			-0.7774	0.9677
ΔUNDRISK	0.0863	0.2019	0.0125	0.0334			0.1970	0.3499	0.0049	0.0333		
CAP$_{t-1}$	-0.0870***	0.0111					-0.0899 **	0.0168				
INVRISK$_{t-1}$			-0.0456***	0.0128					-0.0451***	0.0128		
UNDRISK$_{t-1}$					-0.0900***	0.0126					-0.0913***	0.0123
FS $_{t-1}$	-0.0020	0.0013	-0.0001	0.0003	0.0009	0.0013	-0.0047	0.0037	0.0000	0.0003	0.0005	0.0013
UNDCAP $_{t-1}$	0.0237**	0.0122	0.0008	0.0019	0.0075	0.0072	0.0321 *	0.0169	0.0008	0.0019	0.0086	0.0072
MARCAP $_{t-1}$	0.0134**	0.0069	-0.0010	0.0010	-0.0016	0.0040	0.0106	0.0089	-0.0010	0.0010	-0.0021	0.0039
NYSTATE $_{t-1}$	-0.0068*	0.0085	-0.0003	0.0012	0.0011	0.0046	-0.0049	0.0111	-0.0003	0.0012	0.0014	0.0045
OF $_{t-1}$	0.0002*	0.0042	-0.0009	0.0007	-0.0024	0.0030	-0.0010	0.0070	-0.0009	0.0007	-0.0029	0.0029
INVPROF $_{t-1}$	0.0023	0.0284	-0.0036	0.0040	-0.0098	0.0144	-0.0013 *	0.0365	-0.0038	0.0040	-0.0099	0.0143
UNDLOSS $_{t-1}$	0.0021	0.0009	0.0001	0.0001	-0.0002	0.0005	0.0020	0.0012	0.0001*	0.0001	-0.0002*	0.0005
EXTRE $_{t-1}$	-0.0228*	0.0062			0.0060	0.0052	-0.0133	0.0123			0.0066*	0.0048
HUREXP $_{t-1}$	-0.0001	0.0041			-0.0022	0.0027	-0.0047	0.0063			-0.0034	0.0025
GEOCON $_{t-1}$	0.0042	0.0048	0.0002	0.0011	-0.0050	0.0045	0.0098	0.0125	0.0001	0.0011	-0.0040	0.0043
LOBCON $_{t-1}$	-0.0028***	0.0062	0.0012	0.0016	0.0052	0.0084	0.0136	0.0199	0.0011*	0.0016	0.0077	0.0081
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes	
Chi-Square statistic	250.90***		83.66***		1,822.41***		140.95***		82.84***		1,821.01***	
Over-identification:												
Sargan	1.9614 (0.7429)		2.0457 (0.7274)		3.9525 (0.1386)							
Basmann	1.9331 (0.7481)		2.0179 (0.7325)		3.9020 (0.1421)							
Hansen-Sargan									8.216 (0.4127)			

Notes:

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level. The figures in parentheses are the p-values for the over-identification tests. All the statistics in over-identification tests are chi-square distributed.

(2) NONTOPRO and NONTOREC are dummy variables. If the non-participants in previous year become providers (recipients) in current year, the value of NONTOPRO (NONTOREC) is 1 and 0 otherwise. The remaining variable abbreviations are the same as previous tables.

(3) The instrumental variables include the standard deviation of ROE, underwriting profitability in previous 5 years, the mean value of surplus in previous 5 years, and the lagged 2 values of the following variables: investment risk, underwriting risk, and capital holding.

(4) In 2SLS estimation, NONTOPRO and NONTORE are treated as exogenous variables when dependent variable is the adjustment on capital holding. In other specifications, these two variables are treated as endogenous variables.

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4.2.2 The Interrelations among the Adjustments of Internal Reinsurance Volume, Capital Holding, and Risk-Taking

In our empirical work, we also pay attention to the interrelations among the adjustments of internal reinsurance volume, capital holding, investment risk, and underwriting risk. In addition to the results displayed in Table 2-7 to 2-9, we further conduct regression analysis for the providers and recipients without experiencing status conversions. The detailed results are shown in Appendix B.

In Table 2-7, the coefficient on internal reinsurance provision volume is negative and significant in capital holding equation, which indicates that the provision of internal reinsurance reduces insurers' capital holding. This result is consistent with the aforementioned results regarding the effects of intra-group reinsurance status changes on capital holding. The decrease in capital holding could be caused by the increase in underwriting revenues collected from internal reinsurance transactions. Such cash flows may substitute the demand for other sources of capital injection, and thus reduce the level of capital holding. With respect to the effects of capital holding on the volume of internal reinsurance provision, we find a positive effect of capital holding on the volume of internal reinsurance provision in Table 7, which is consistent with the notion that an increase in capital holding enables insurers to provide more internal reinsurance

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for other affiliates. Based on these results, hypothesis 4a is not supported whereas hypothesis 4b receives support in our study.

Turning to the recipients, our results shown in Appendix B reveal that the adjustment of internal reinsurance receipt volume negatively affects capital holding for the recipients without changing their roles in internal reinsurance transactions.[10] This negative relation is different from the aforementioned results regarding the relation between intra-group reinsurance status conversions and capital holding. To reconcile these results, the change in capital holding caused by the role conversions to recipient could be dictated by the decrease in the underwriting incomes via intra-group reinsurance transactions. For the insurers which convert to the recipient, they will experience the outflows of underwriting incomes. To cope with the decrease in the income flows followed by such role conversion, these insurers may need to increase capital ratios.

Nevertheless, the drop in capital holding caused by the adjustment of internal reinsurance receipt volume may be driven by the substitution effect and the expansion of premiums written after receiving additional capacity via internal reinsurance arrangements. Once the recipients receive the additional capacity from the providers, they have lower demand for other financing sources to supplement their capital, and

[10] Please refer to Table B-6 in Appendix B.

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more capacity to increase the premiums written. Then their capital ratios are ultimately reduced. Based on the results available in Appendix B, hypothesis 4c is supported.

Turning to another direction, the coefficients on the adjustment of capital holding are negative and significant in internal reinsurance receipt adjustment equation in Table 8, suggesting that capital financing substitutes the demand for internal reinsurance. Therefore, hypothesis 4d receives support.

In addition to the relation between internal reinsurance activities and capital holding, we also find that investment risk positively affects that of internal reinsurance receipt in Table 2-8. This result could imply that the insurers with greater investment risk may use internal reinsurance to reduce the risk in underwriting activities and limit their overall insolvency risk. Hypothesis 5d is supported in our work. With respect to the relation between internal reinsurance and underwriting risk, we do not find any significant relationship between them based on our results. None of the hypotheses regarding underwriting risk is supported.

4.2.3 Other Results

In this section, we further compare the relation between internal reinsurance receipt and risk-taking with that between capital holding and risk-taking. Contrary to the positive relation between internal reinsurance receipt and investment risk, the interrelation between capital and investment risk is negative. Specifically, in Table 2-7

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and 2-8, the coefficients on the adjustment of capital holding are negative and significant in investment risk equation. The possible explanation regarding the negative relation between capital and investment risk is the inclination for the insurers with higher capital buffer to limit insolvency risk. Specifically, these safer insurers may exhibit greater tendency to limit risk-taking.

Furthermore, our results regarding the association between capital and risk are generally different from those found in previous works. For example, Baranoff and Sager (2002, 2003), Cheng and Weiss (2013) find a positive relationship between asset risk and capital ratio by analyzing the sample of the U.S life insurers and non-life insurers respectively. With respect to underwriting risk, many of the aforementioned studies find a negative relationship between capital holding and underwriting risk. In our study, we do not find a significant relation between these two variables.

The followings are the possible reasons contributing to the above-mentioned differences. First, we include the equation of internal reinsurance activities in our empirical analysis. Most previous studies do not incorporate internal reinsurance in their empirical settings. Second, the instrumental variables used to cope with the endogeneity problems are different from those in previous studies. Moreover, as we attempt to remove the influences of reinsurance arrangements on the risk in underwriting activities, our underwriting risk variable is calculated based on direct

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premiums written rather than net premiums written. These reasons could lead to the aforementioned differences regarding the relation between capital ratio and risk-taking.

In addition to the aforementioned results, we also find some important results regarding the control variables. Take the variables representing regulatory pressure as an example, both undercapitalized and marginally capitalized indicators are negatively related to internal reinsurance provision volume in Table 2-7, suggesting that financially weak providers need to curtail the volume of internal reinsurance provision. In contrast, marginally capitalized indicator is positively related to internal reinsurance receipt in Table 2-8. When recipients are not sufficiently capitalized, they could receive the supports from other group members. Moreover, undercapitalized and marginally capitalized indicators are also positively associated with capital holding in Table 2-7 and 2-9, suggesting that insurers increase capital buffer in response to regulatory pressure.

5. Conclusion

In this research, we analyze how internal capital markets activities are interrelated to capital holding, investment risk, and underwriting risk in the context of the U.S non-life insurers. We focus on intra-group reinsurance transactions as the main internal capital markets activities in our work. Based on our findings, the changes of intra-group reinsurance participation status significantly affect capital ratio. Specifically, the

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conversions to provider (recipient) results in the decrease (increase) in capital ratio. We interpret such results as the changes of underwriting income. Through the collection of the internal reinsurance premiums from other group members, the insurers which convert to the providers could to accumulate sufficient cash flows to supplement their capital positions. Thus, they may be able to adopt less conservative capital decision after such role conversions. On the contrary, the insurers who become internal reinsurance recipients could have less underwriting incomes after the conversions. Thus, these insurers may need to increase their capital ratios in response to the decreased underwriting revenues.

With respect to the volume adjustments, both internal reinsurance provision and receipt are associated with the reduction in capital holding. The explanation for the negative relation between internal reinsurance provision and capital is similar with that for the association between the conversions from other roles to provider and capital holding. On the other hand, the negative relation between internal reinsurance receipt and capital ratio could be attributed to the substitution effect as internal reinsurance could be considered as alternative source of underwriting capacity. Turing to another direction, the adjustment of capital holding positively affects internal reinsurance provision, indicating that capital is used for supporting the provision of internal reinsurance. The positive effect of capital ratio on internal reinsurance could be crucial

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for group-wide solvency. Without capital replenishment, the provision of internal reinsurance could worsen the providers' solvency positions and pose substantial reinsurance counterparty risk on the rest of group. Turning to recipients, capital ratio exerts negative effect on internal reinsurance receipt. This result is consistent with the notion that capital and internal reinsurance are substitutes.

In addition to the relation between internal reinsurance and capital, we also document the positive relationship between internal reinsurance receipt and investment risk. Such relation may indicate that recipients utilize internal reinsurance to allocate the risk between investment and underwriting activities. The use of internal reinsurance may not be limited to the purpose of managing underwriting risk.

Appendix B

In Table B-1, we provide the results of over-identification tests regarding the instrumental variables used in the endogeneity tests performed in Table 2-3. Based on the insignificance of the statistics in Table B-1, we could confirm the validity of our instrumental variables. The full coefficient correlation tables for the subsamples of providers, recipients, and non-participants are shown in Table B-2 to B-4. The regression results for the providers and recipients without intra-group reinsurance status changes are provided in Table B-5 and B-6 respectively.

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Table B- 1 The results of over-identification tests

Panel A: the coefficients on the residuals of potential endogenous variables in Wu-Hausman tests

Dependent variable	Providers in year t-1 (N=6,844)				Recipients in year t-1 (N=14,841)				Non-participants in year t-1 (N=3,446)		
	ΔICMPRO	ΔCAP	ΔINVRISK	ΔUNDRISK	ΔICMREC	ΔCAP	ΔINVRISK	ΔUNDRISK	ΔCAP	ΔINVRISK	ΔUNDRISK
Sargan test	0.9928 (0.8030)	0.0526 (0.9741)	0.0192 (0.9905)	0.5311 (0.7668)	1.2245 (0.8740)	2.2462 (0.5229)	0.3315 (0.9540)	1.2923 (0.7310)	0.3753 (0.8289)	2.0457 (0.7274)	3.9525 (0.1386)
Baseman test	0.9854 (0.8048)	0.0522 (0.9742)	0.0191 (0.9905)	0.5272 (0.7683)	1.2207 (0.8747)	2.2397 (0.5242)	0.3305 (0.9542)	1.2885 (0.7319)	0.3700 (0.8311)	2.0179 (0.7325)	3.9020 (0.1421)

Notes:

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

(2) For the subsample of providers, the instrumental variables include the standard deviation of ROA, ROE, and underwriting profitability in previous 5 years, and the lagged 2 values of the following variables: investment risk, underwriting risk, and capital holding. For the subsample of recipient, the instrumental variables include the standard deviation of ROE, investment profitability, underwriting profitability in previous 5 years, the mean value of surplus in previous 5 years, and the lagged 2 values of the following variables: investment risk, underwriting risk, and capital holding. For the subsample of non-participants, the instrumental variables include the standard deviation of ROE, underwriting profitability in previous 5 years, the mean value of surplus in previous 5 years, and the lagged 2 values of the following variables: investment risk, underwriting risk, and capital holding.

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Table B- 2 Correlation Coefficients (Providers)

Variable	ΔICMPRO $_t$	PROTOREC	PROTONON	ΔICMP*UN $_t$	ΔCAP $_{t\,t}$	ΔINVRISK $_t$	ΔUNDRISK $_t$
PROTORE	-0.4758 ***						
PROTONON	-0.0743 ***	-0.0373 ***					
ΔICMPRO*UN	0.6817 ***	-0.0121	-0.0049				
ΔCAP	-0.1663 ***	0.0824 ***	0.0208 *	-0.0922 ***			
ΔINVRISK	-0.0281 **	0.0269 **	-0.0085	-0.0132	0.1322 ***		
ΔUNDRISK	-0.0063	0.0123	0.0019	-0.0180	0.0205 *	0.0160	
ICMPRO$_{t-1}$	-0.1121 ***	-0.1913 ***	-0.0797 ***	-0.1793 ***	0.0226 *	-0.0233 *	0.0005
CAP $_{t-1}$	0.0143	-0.0216	0.0277 **	0.0237 **	-0.1793 ***	0.0270 **	0.0167
INVRISK$_{t-1}$	0.0620 **	-0.0816 ***	-0.0176	0.0121	-0.0455 ***	-0.1142 ***	-0.0200 *
UNDRISK $_{t-1}$	0.0288 **	-0.0011	0.0092	0.0290 **	-0.0228 *	0.0052	-0.2300 ***
FS $_{t-1}$	0.1048 ***	-0.1160 ***	-0.0976 ***	0.0173	0.0161	0.0150	0.0070
DPWRA $_{t-1}$	-0.0267 **	0.1456 ***	0.1227 ***	0.0129	0.0460 ***	-0.0094	-0.0375 ***
UNDCAP $_{t-1}$	-0.0596 ***	0.0392 ***	0.0789 ***	-0.0167	0.0701 ***	-0.0169	0.0270 **
MARCAP $_{t-1}$	-0.0123	0.0027	0.0348 ***	-0.0131	0.0526 ***	-0.0214	-0.0694 ***
NYSTATE $_{t-1}$	-0.0197	0.0151	0.0038	-0.0019	-0.0049	-0.0166	-0.0031
OF $_{t-1}$	-0.0616 ***	0.0802 ***	0.0061	-0.0142	0.0038	-0.0265 **	-0.0073
INVPROF $_{t-1}$	-0.0403 ***	0.0127	0.0123	-0.0364 ***	0.0357 ***	-0.0045	-0.0135
LOSSRA $_{t-1}$	0.0232 *	0.0075	-0.0092	0.0535 ***	0.0117	0.0057	-0.0331 ***
EXTRE $_{t-1}$	-0.0426 ***	0.0487 ***	0.0703 ***	-0.0324 ***	-0.0373 ***	-0.0034	-0.0066
HUREXP $_{t-1}$	-0.0195	0.0028	0.0518 ***	-0.0075	-0.0100	0.0115	0.0001
GEOCON $_{t-1}$	-0.0030	-0.0247 **	0.0467 ***	0.0013	0.0089	-0.0144	0.0056
LOBCON $_{t-1}$	-0.0445 ***	0.0224 *	0.0438 ***	-0.0105	0.0109	0.0124	0.0003

Variable	ICMPRO$_{t-1}$	CAP $_{t-1}$	INVRISK$_{t-1}$	UNDRISK $_{t-1}$	FS $_{t-1}$	DPWRA $_{t-1}$	UNDCAP $_{t-1}$	MARCAP $_{t-1}$
CAP $_{t-1}$	-0.0144	1.0000						
INVRISK$_{t-1}$	-0.0849 ***	0.3136 ***	1.0000					
UNDRISK $_{t-1}$	-0.0191	-0.1054 ***	-0.0618 ***	1.0000				
FS $_{t-1}$	-0.0233	-0.1874 ***	0.3485 ***	0.0207 *	1.0000			
DPWRA $_{t-1}$	-0.4825 ***	-0.3165 ***	-0.1234 ***	-0.0962 ***	-0.1346 ***	1.0000		
UNDCAP $_{t-1}$	-0.0017	-0.1062 ***	-0.0231 *	0.0232 *	-0.0349 ***	0.1515 ***	1.0000	
MARCAP $_{t-1}$	-0.0202 *	-0.1782 ***	0.0440 ***	0.0538 ***	0.0321 ***	0.1839 ***	-0.0135	
NYSTATE $_{t-1}$	-0.0446 ***	-0.0961 ***	-0.0769 ***	0.0133	0.0834 ***	-0.0343 ***	0.0309 **	0.0704 ***
OF $_{t-1}$	0.2107 ***	-0.1652 ***	-0.2960 ***	-0.0772 ***	-0.0747 ***	-0.0294 **	0.0157	0.0553 ***
INVPROF $_{t-1}$	0.0302 **	-0.4578 ***	-0.1515 ***	0.0765 ***	0.1675 **	0.1153 ***	0.1411 ***	0.1132 ***
LOSSRA $_{t-1}$	-0.0196	-0.0786 ***	0.0007	0.0081	0.0462 ***	0.0400 ***	0.0434 ***	0.0705 ***
EXTRE $_{t-1}$	-0.1460 ***	0.0409 ***	0.0491 ***	0.0367 ***	-0.1276 ***	0.4548 ***	0.0503 ***	0.0984 ***
HUREXP $_{t-1}$	0.0466 ***	0.0325 ***	-0.0130	-0.0099	-0.0462 ***	0.1083 ***	0.0061	0.0254 **
GEOCON $_{t-1}$	0.1369 ***	0.1413 ***	-0.1555 ***	0.0067	-0.4272 ***	-0.0319 ***	0.0109	-0.0404 ***
LOBCON $_{t-1}$	0.1061 ***	0.1423 ***	-0.1166 ***	0.1519 ***	-0.2882 ***	-0.0344 ***	0.0133	-0.0257 **

Variable	NYSTATE $_{t-1}$	OF $_{t-1}$	INVPROF $_{t-1}$	UNDLOSS $_{t-1}$	EXTRE $_{t-1}$	HUREXP $_{t-1}$	GEOCON $_{t-1}$	LOBCON $_{t-1}$
OF $_{t-1}$	-0.0145	1.0000						
INVPER $_{t-1}$	0.0540 ***	0.1527 ***	1.0000					
UNDLOSS $_{t-1}$	0.0204 *	-0.0075	0.1003 ***	1.0000				
EXTRE $_{t-1}$	0.0231 *	-0.0410 ***	-0.0559 ***	-0.0007	1.0000			
HUREXP $_{t-1}$	-0.0765 ***	0.0961 ***	-0.0489 ***	-0.0074	0.1725 ***	1.0000		
GEOCON $_{t-1}$	-0.0245 **	-0.0879 ***	-0.1519 ***	-0.0173	-0.0284 **	-0.0220 *	1.0000	
LOBCON $_{t-1}$	-0.0755 ***	0.0788 ***	-0.1549 ***	-0.0345 ***	-0.0804 ***	0.0535 ***	0.3262 ***	1.0000

Notes:

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

(2) PROTORE: if the provider in year t-1 becomes recipient in year t, the value of this indicator is 1 and 0 otherwise; PROTONON: if the provider in year t-1 becomes non-participant in year t, the value of this indicator is 1 and 0 otherwise; ΔICMPRO*UN: if the provider does not experience status change, the value of this variable is the change in the amount of internal reinsurance provision, and 0 otherwise; ΔCAP: the change in capital holding; ΔINVRISK: the change in investment risk; ΔUNDRISK: the change in underwriting risk; ICMPRO$_{t-1}$: internal reinsurance provision in previous year; CAP$_{t-1}$: capital holding in previous year; INVRISK$_{t-1}$: investment risk in previous year; UNDRISK$_{t-1}$: underwriting risk in previous year; FS: firm size; DPWRA: direct premiums written ratio; UNDCAP: undercapitalized indicator; MARCAP: marginally capitalized indicator; NYSTATE: New York state indicator; OF: organization form; INVPROF: investment profitability; UNDLOSS: underwriting loss; EXTRE: external reinsurance; HUREXP: hurricane exposure; GEOCON: geographic concentration; LOBCON: line of business concentration.

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Table B- 3 Correlation Coefficients (Recipients)

Variable	ΔICMREC $_t$	RETOPRO	RETONON	ΔICMR*UN $_t$	ΔCAP $_t$	ΔINVRISK $_t$	ΔUNDRISK $_t$
RETOPRO	-0.4397 ***						
RETONON	-0.1340 ***	-0.0221 ***					
ΔICMREC*UN	0.6867 ***	-0.0033	-0.0017				
ΔCAP	0.2058 ***	-0.0752 ***	-0.0061	0.1417 ***			
ΔINVRISK	0.0069	-0.0239 ***	-0.0091	0.0008	0.0683 ***		
ΔUNDRISK	0.0064	0.0086	-0.0129	0.0122	0.0475 ***	0.0126	
ICMREC$_{t-1}$	-0.0636 ***	-0.2225 ***	-0.1157 ***	-0.1438 ***	-0.0423 ***	-0.0132	-0.0000
CAP $_{t-1}$	-0.0157 *	-0.0892 ***	-0.0261 ***	-0.0305 ***	-0.1884 ***	-0.0078	-0.0126
INVRISK$_{t-1}$	-0.0026	0.0586 ***	0.0072	-0.0026	-0.0034	-0.1447 ***	0.0037
UNDRISK $_{t-1}$	-0.0177 **	0.0119	0.0127	-0.0081	-0.0235 ***	0.0166	-0.2703 ***
FS $_{t-1}$	0.0302 ***	0.0809 ***	-0.0229 ***	0.0183 **	0.0772 ***	0.0121	0.0228 ***
DPWRA $_{t-1}$	0.0229 ***	-0.0626 ***	-0.0245 ***	-0.0072	0.0328 ***	-0.0102	-0.0065
UNDCAP $_{t-1}$	-0.0042	0.0013	0.0478 ***	0.0070	0.0310 ***	-0.0210 **	-0.0041
MARCAP $_{t-1}$	0.0250 ***	0.0181 **	0.0511 ***	0.0406 ***	0.0446 ***	-0.0037	-0.0200 **
NYSTATE $_{t-1}$	-0.0036	0.0098	-0.0108	-0.0004	-0.0045	0.0054	0.0088
OF $_{t-1}$	-0.0067	0.0114	-0.0065	0.0062	-0.0127	-0.0142 *	0.0045
INVPROF $_{t-1}$	0.0072	0.0909 ***	0.0399 ***	0.0409 ***	0.0888 ***	0.0122	-0.0186 *
LOSSRA $_{t-1}$	-0.0152 *	0.0184	0.0050	0.0049	0.0371 ***	-0.0140 *	-0.0095
EXTRE $_{t-1}$	0.0782 ***	0.0335 ***	0.0682 ***	0.1248 ***	-0.0167 **	0.0014	-0.0045
HUREXP $_{t-1}$	0.0071	-0.0392 ***	0.0102	-0.0057	-0.0097	-0.0144 *	0.0022
GEOCON $_{t-1}$	-0.0300 ***	-0.0099	0.0428 ***	-0.0165 **	0.0044	-0.0019	-0.0111
LOBCON $_{t-1}$	-0.0221 ***	-0.0050	0.0501 ***	-0.0023	-0.0067	0.0088	-0.0055

Variable	INVRISK$_{t-1}$	UNDRISK $_{t-1}$	CAP $_{t-1}$	ICMREC$_{t-1}$	FS $_{t-1}$	DPWRA $_{t-1}$	UNDCAP $_{t-1}$	MARCAP $_{t-1}$
CAP $_{t-1}$	0.4895 ***	1.0000						
INVRISK$_{t-1}$	-0.2797 ***	-0.0215 ***	1.0000					
UNDRISK $_{t-}$	-0.0099	-0.0278 ***	-0.0331 ***	1.0000				
FS $_{t-1}$	-0.5093 ***	-0.5282 ***	0.3045 ***	0.0503 ***	1.0000			
DPWRA $_{t-1}$	0.2596 ***	-0.1004 ***	-0.1494 ***	-0.0938 ***	-0.1175 ***	1.0000		
UNDCAP $_{t-1}$	-0.0222 ***	-0.0979 ***	0.0004	0.0591 ***	-0.0101	0.1613 ***	1.0000	
MARCAP $_{t-1}$	-0.0869 ***	-0.1427 ***	0.0336 ***	0.0360 ***	0.0720 ***	-0.0006	-0.0104	
NYSTATE $_{t-1}$	-0.0172 **	-0.0515 ***	-0.0337 ***	0.0187 **	0.0528 ***	-0.0248 ***	0.0114	0.0336 ***
OF $_{t-1}$	-0.0038	0.0068	-0.1617 ***	0.0619 ***	0.1117 ***	-0.1734 ***	-0.0723 ***	0.0126
INVPROF $_{t-1}$	-0.3662 ***	-0.4297 ***	-0.0067	0.0707 ***	0.3303 ***	-0.0638 ***	0.0932 ***	0.1235 ***
LOSSRA $_{t-1}$	0.0331 ***	-0.0008	-0.0167 **	-0.0205 **	-0.0023	0.0174 **	0.0494 ***	0.0561 ***
EXTRE $_{t-1}$	-0.3070 ***	-0.0773 ***	0.0481 ***	0.0138 *	0.0328 ***	-0.0107	0.1001 ***	0.0903 ***
HUREXP $_{t-1}$	0.1324 ***	0.1017 ***	-0.1086 ***	-0.0681 ***	-0.1956 ***	0.1831 ***	0.0285 ***	-0.0216 **
GEOCON $_{t-1}$	0.1521 ***	0.1581 ***	-0.1370 ***	-0.0853 ***	-0.4943 ***	0.0805 ***	0.0407 ***	-0.0431 ***
LOBCON $_{t-1}$	0.1071 ***	0.0689 ***	-0.1410 ***	0.0619 ***	-0.2697 ***	0.0558 ***	0.0216 ***	-0.0266 ***

Variable	NYSTATE $_{t-1}$	OF $_{t-1}$	INVPROF $_{t-1}$	UNDLOSS $_{t-1}$	EXTRE $_{t-1}$	HUREXP $_{t-1}$	GEOCON $_{t-1}$	LOBCON $_{t-1}$
OF $_{t-1}$	0.0071	1.0000						
INVPER $_{t-1}$	0.0505 ***	0.0909 ***	1.0000					
UNDLOSS $_{t-1}$	0.0149	-0.0018	0.0677 ***	1.0000				
EXTRE $_{t-1}$	-0.0147	0.0217 ***	0.0224 ***	0.0040	1.0000			
HUREXP $_{t-1}$	-0.1084 ***	-0.2563 ***	-0.1218 ***	-0.0128	0.0884 ***	1.0000		
GEOCON $_{t-1}$	-0.0464 **	-0.2555 ***	-0.1957 ***	0.0003	-0.0159	0.2140 ***	1.0000	
LOBCON $_{t-1}$	-0.0725 ***	0.0218 ***	-0.1661 ***	0.0215 ***	-0.0412 ***	0.1211 ***	0.2858 ***	1.0000

Notes:

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.

(2) RETOPRO: if the recipient in year t-1 becomes provider in year t, the value of this indicator is 1 and 0 otherwise; RETONON: if the recipient in year t-1 becomes non-participant in year t, the value of this indicator is 1 and 0 otherwise; ΔICMREC*UN: if the recipient does not experience status change, the value of this variable is the change in the amount of internal reinsurance receipt, and 0 otherwise; ΔCAP: the change in capital holding; ΔINVRISK: the change in investment risk; ΔUNDRISK: the change in underwriting risk; ICMREC$_{t-1}$: internal reinsurance receipt in previous year; CAP$_{t-1}$: capital holding in previous year; INVRISK$_{t-1}$: investment risk in previous year; UNDRISK$_{t-1}$: underwriting risk in previous year; FS: firm size; DPWRA: direct premiums written ratio; UNDCAP: undercapitalized indicator; MARCAP: marginally capitalized indicator; NYSTATE: New York state indicator; OF: organization form; INVPROF: investment profitability; UNDLOSS: underwriting loss; EXTRE: external reinsurance; HUREXP: hurricane exposure; GEOCON: geographic concentration; LOBCON: line of business concentration.

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Table B- 4 Correlation Coefficients (Non-participants)

Variable	NONTOPRO		NONTOREC		ΔCAP_t		$\Delta INVRISK_t$		$\Delta UNDRISK_t$		CAP_{t-1}		$INVRISK_{t-1}$	
NONTOREC	-0.0666	***	1.0000											
$\Delta INVRISK_t$	0.0212		0.0089		1.0000									
$\Delta UNDRISK_t$	0.0002		0.0159		0.0316	*	1.0000							
ΔCAP_t	-0.1010	***	-0.0017		0.0419	**	0.0243		1.0000					
$INVRISK_{t-1}$	0.0507	***	-0.0277		-0.2520	***	0.0016		-0.0076		1.0000			
$UNDRISK_{t-1}$	0.0427	**	0.0047		-0.0146		-0.1519	***	0.0139		0.0417	***	1.0000	
CAP_{t-1}	-0.0218		0.0189		-0.0139		-0.0044		-0.2548	***	-0.1078	***	0.0381	
FS_{t-1}	0.0821	***	-0.0027		0.0992	***	0.0228		0.0228		-0.4112	***	0.1466	***
$DPWRA_{t-1}$	-0.0365	**	0.0412	**	0.1112	***	-0.0185		-0.0237		-0.4743	***	-0.1233	***
$UNDCAP_{t-1}$	-0.0225		-0.0119		0.0936	***	-0.0146		-0.0166		-0.1949	***	0.0140	
$MARCAP_{t-1}$	0.0021		-0.0060		0.0778	***	-0.0244		-0.0147		-0.2524	***	0.0050	
$NYSTATE_{t-1}$	-0.0005		0.0007		-0.0056		0.0032		0.0133		-0.0841	***	-0.0677	***
OF_{t-1}	-0.0590	***	0.0349	**	-0.0173		-0.0112		-0.0209		0.0043		-0.2393	***
$INVPER_{t-1}$	0.0357	**	-0.0077		0.1273	***	-0.0180		-0.0102		-0.4138	***	-0.0168	
$LOSSRA_{t-1}$	0.0109		-0.0095		0.0589	***	0.0186		0.0062		-0.0333	*	-0.0361	*
$EXTRE_{t-1}$	-0.0306	*	0.0672	***	-0.0658	***	-0.0127		0.0140		0.0408	**	-0.1033	***
$HUREXP_{t-1}$	-0.0108		0.0098		-0.0204		0.0282	*	0.0058		0.0592	***	-0.0240	
$GEOCON_{t-1}$	-0.0392	**	-0.0672	***	-0.0157		0.0024		-0.0042		0.0779	***	-0.0265	
$LOBCON_{t-1}$	-0.0498	***	-0.0354	**	-0.0079		-0.0008		-0.0252		0.0714	***	-0.1446	***

Variable	$UNDRISK_{t-1}$		FS_{t-1}		$DPWRA_{t-1}$		$UNDCAP_{t-1}$		$MARCAP_{t-1}$		$NYSTATE_{t-1}$		OF_{t-1}	
FS_{t-1}	0.1523	***	1.0000											
$DPWRA_{t-1}$	-0.1002	***	0.0030		1.0000									
$UNDCAP_{t-1}$	-0.0115		-0.0309	*	0.4103	***	1.0000							
$MARCAP_{t-1}$	0.0105		-0.0240		0.2534	***	-0.0392	*	1.0000					
$NYSTATE_{t-1}$	0.0176		0.0245		-0.0086		0.0108		0.0266		1.0000			
OF_{t-1}	-0.1313	***	-0.2131	***	0.0176		0.0100		0.0388	*	0.0347	**	1.0000	
$INVPROF_{t-1}$	0.0823	***	0.2538	***	0.2069	***	0.1975	***	0.1372	***	0.0683	***	-0.0165	
$LOSSRA_{t-1}$	-0.0179		0.0141		-0.0001		0.0580	***	0.0130		-0.0207		-0.0298	*
$EXTRE_{t-1}$	-0.0156		-0.1384	***	0.3467	***	0.0107		0.0549	***	0.0044		-0.0404	**
$HUREXP_{t-1}$	-0.1089	***	-0.1487	***	0.1949	***	0.0508	***	0.0567	***	-0.1230	***	0.0532	***
$GEOCON_{t-1}$	-0.0465	***	-0.2621	***	0.0597	***	0.0396	**	0.0482	***	-0.0509	***	-0.0735	***
$LOBCON_{t-1}$	0.0652	***	-0.1945	***	0.0201		0.0814	***	0.0970	***	-0.0554	***	0.1289	***

Variable	$INVPROF_{t-1}$		$UNDLOSS_{t-1}$		$EXTRE_{t-1}$		$HUREXP_{t-1}$		$GEOCON_{t-1}$	
$LOSSRA_{t-1}$	0.0796	***	1.0000							
$EXTRE_{t-1}$	-0.1292	***	-0.0123		1.0000					
$HUREXP_{t-1}$	-0.1029	***	0.0057		0.1568	***	1.0000			
$GEOCON_{t-1}$	-0.1147	***	0.0121		0.0240		0.0968	***	1.0000	
$LOBCON_{t-1}$	-0.0347	**	0.0361	**	-0.0867	***	0.1070	***	0.1806	***

Notes:
(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.
(2)NONTOPRO: if the non-participant in year t-1 becomes provider in year t, the value of this indicator is 1 and 0 otherwise; NONTORE: if the non-participant in year t becomes recipient in year t, the value of this indicator is 1 and 0 otherwise; ΔCAP: change in capital holding; $\Delta INVRISK$: change in investment risk; $\Delta UNDRISK$: change in underwriting risk; CAP_{t-1}: capital holding in previous year; $INVRISK_{t-1}$: investment risk in previous year; $UNDRISK_{t-1}$: underwriting risk in previous year; FS: firm size; DPWRA: direct premiums ratio; UNDCAP: undercapitalized indicator; MARCAP: marginally capitalized indicator; NYSTATE: New York state indicator; OF: organization form; INVPROF: investment profitability; UNDLOSS: underwriting loss; EXTRE: external reinsurance; HUREXP: hurricane exposure; GEOCON: geographic concentration; LOBCON: line of business concentration.

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Table B- 5 Regression analysis for the subsample of the internal reinsurance providers without status changes

Variable	2SLS								3SLS							
	ΔICMPRO		ΔCAP		Δ INVRISK $_t$		ΔUNDRISK $_t$		ΔICMPRO		ΔCAP		Δ INVRISK $_t$		ΔUNDRISK $_t$	
	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev
Constant	0.1123***	0.0326	0.0105	0.0114	-0.0050**	0.0019	0.0482***	0.0078	0.1280***	0.0321	0.0073	0.0113	-0.0052***	0.0019	0.0455***	0.0078
ΔICMPRO $_t$			-0.0815**	0.0333	-0.0026	0.0056	-0.0087	0.0191			-0.0712**	0.0328	-0.0018	0.0056		
ΔCAP $_t$	1.6213***	0.3848			-0.0806***	0.0198	0.1886***	0.0675	1.8436***	0.3717			-0.0878***	0.0193	0.1929***	0.0678
ΔINVRISK $_t$	2.5067	2.4799	-1.6352**	0.8067			0.8136*	0.4772	3.1840	2.4648	-1.9030**	0.7944			1.1244**	0.4745
ΔUNDRISK $_t$	0.5832	0.5778	-0.0393	0.2014	0.0124	0.0358			0.4017	0.5761	0.0921	0.1983	0.0388	0.0352		
ICMPRO $_{t-1}$	-0.1295***	0.0121							-0.1313***	0.0120						
CAP$_{t-1}$			-0.0597***	0.0073							-0.0576***	0.0071				
INVRISK$_{t-1}$					-0.0408***	0.0064							-0.0385***	0.0063	0.0099	0.0178
UNDRISK$_{t-1}$							-0.0442***	0.0052							-0.0413***	0.0051
FS $_{t-1}$	-0.0013	0.0013	-0.0002	0.0005	0.0002***	0.0001	0.0122	0.0074	-0.0016	0.0013	-0.0001	0.0005	0.0002***	0.0001	-0.0001	0.0003
DPWRA $_{t-1}$	-0.0212***	0.0040							-0.0251***	0.0035						
UNDCAP $_{t-1}$	-0.1019**	0.0395	0.0229*	0.0134	0.0014	0.0025	-0.0022	0.0023	-0.0983**	0.0394	0.0210	0.0134	0.0012	0.0025	0.0137*	0.0075
MARCAP $_{t-1}$	-0.0234*	0.0121	0.0057	0.0041	0.0009	0.0008	0.0006	0.0018	-0.0242**	0.0120	0.0059	0.0041	0.0010	0.0008	-0.0019	0.0023
NYSTATE $_{t-1}$	-0.0061	0.0094	-0.0088***	0.0032	-0.0018***	0.0006	-0.0011	0.0010	-0.0053	0.0094	-0.0089***	0.0032	-0.0018***	0.0006	0.0010	0.0018
OF $_{t-1}$	0.0228***	0.0055	-0.0053***	0.0017	-0.0013***	0.0003	-0.0022	0.0023	0.0231***	0.0054	-0.0052***	0.0017	-0.0013***	0.0003	-0.0009	0.0010
INVPROF $_{t-1}$	-0.1186***	0.0408	-0.0003	0.0144	0.0020	0.0025	0.0041	0.0078	-0.1249***	0.0406	0.0016	0.0144	0.0024	0.0025	0.0043	0.0079
UNDLOSS $_{t-1}$	0.0050	0.0031	0.0019*	0.0011	0.0001	0.0002	-0.0011*	0.0006	0.0046	0.0031	0.0019*	0.0011	0.0002*	0.0002	-0.0013**	0.0006
EXTRE $_{t-1}$	-0.0065	0.0154	-0.0091*	0.0047			0.0039	0.0027	-0.0015	0.0136	-0.0064*	0.0033			0.0037	0.0024
HUREXP $_{t-1}$	0.0075	0.0071	0.0003	0.0025			-0.0003	0.0014	0.0091	0.0064	-0.0003	0.0017			-0.0002	0.0012
GEOCON $_{t-1}$	0.0138**	0.0064	0.0015	0.0022	-0.0003	0.0004	0.0003	0.0012	0.0134**	0.0064	0.0013	0.0022	-0.0003	0.0004	0.0003	0.0012
LOBCON $_{t-1}$	-0.0172**	0.0083	0.0088***	0.0027	0.0013**	0.0005	0.0014	0.0016	-0.0196**	0.0083	0.0092***	0.0027	0.0013	0.0005	0.0010	0.0016
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Chi-Square statistic	517.02***		160.89***		259.65***		8,600.73***		518.67***		163.73***		261.60***		8,399.40***	
Over-identification:																
Sargan	1.2063 (0.7515)		3.8579 (0.4256)		2.1470 (0.9057)		0.4305 (0.9339)									
Basmann	1.1978 (0.7535)		3.8362 (0.4291)		2.1322 (0.9071)		0.4275 (0.9345)									
Hansen-Sargan													23.574 (0.1315)			

Notes:

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level. The figures in parentheses are the p-values for the over-identification tests. All the statistics in over-identification tests are chi-square distributed.

(2) In this table, the sample consists of the providers which do not change the intra-group reinsurance participation status. The sample size is 6,160 observations.

(3) The abbreviations of the variables are the same as previous tables.

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Table B- 6 Regression analysis for the subsample of the internal reinsurance recipients without status changes

Variable	2SLS								3SLS							
	ΔICMREC $_t$		ΔCAP $_t$		Δ INVRISK $_t$		ΔUNDRISK $_t$		ΔICMREC $_t$		ΔCAP $_t$		Δ INVRISK $_t$		ΔUNDRISK $_t$	
	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev
Constant	0.0918***	0.0236	0.0094	0.0172	-0.0028**	0.0011	0.0715***	0.0052	0.0906***	0.0231	0.0053	0.0171	-0.0029***	0.0011	0.0717***	0.0052
ΔICMREC $_t$			-0.2382***	0.0793	0.0034	0.0038	-0.0276	0.0208			-0.2479***	0.0768	0.0031	0.0038	-0.0255	0.0199
ΔCAP $_t$	-0.3259***	0.1332			-0.0134*	0.0074	0.0352	0.0275	-0.3662***	0.1298			-0.0146**	0.0074	0.0393	0.0274
ΔINVRISK $_t$	6.5281**	2.8613	-1.4739	2.3409			1.3228**	0.5841	7.3879***	2.8425	-2.3723	2.3256			1.6162***	0.5781
ΔUNDRISK $_t$	0.4038	0.2536	0.3079	0.2061	0.0104	0.0141			0.3896	0.2533	0.3417*	0.2058	0.0139*	0.0141		
ICMREC $_{t-1}$	-0.0439***	0.0045							-0.0438***	0.0043						
CAP $_{t-1}$			-0.0426***	0.0049							-0.0417***	0.0048				
INVRISK $_{t-1}$					-0.0205***	0.0036							-0.0188***	0.0036		
UNDRISK $_{t-1}$							-0.0698***	0.0037							-0.0689***	0.0037
FS $_{t-1}$	-0.0053***	0.0010	-0.0013	0.0008	0.0002***	0.0001	-0.0002	0.0002	-0.0053***	0.0010	-0.0011	0.0008	0.0002***	0.0001	-0.0002	0.0002
DPWRA $_{t-1}$	0.0004***	0.0001							0.0004***	0.0001						
UNDCAP $_{t-1}$	0.0207	0.0181	0.0179	0.0146	-0.0018*	0.0010	0.0073**	0.0037	0.0242	0.0180	0.0159	0.0146	-0.0017*	0.0010	0.0078**	0.0037
MARCAP $_{t-1}$	0.0222***	0.0083	0.0161**	0.0066	-0.0001	0.0005	0.0028	0.0018	0.0234***	0.0083	0.0159**	0.0066	-0.0001	0.0005	0.0028	0.0018
NYSTATE $_{t-1}$	-0.0004	0.0051	-0.0043	0.0042	0.0000	0.0003	0.0019*	0.0010	-0.0010	0.0051	-0.0039	0.0042	0.0000	0.0003	0.0018*	0.0010
OF $_{t-1}$	0.0054	0.0036	0.0007	0.0029	-0.0005***	0.0002	0.0009	0.0007	0.0050	0.0036	0.0009	0.0029	-0.0005**	0.0002	0.0008	0.0007
INVPROF $_{t-1}$	0.0707**	0.0368	0.1445***	0.0221	0.0030	0.0020	-0.0055	0.0078	0.0759**	0.0362	0.1490***	0.0220	0.0034 *	0.0020	-0.0072	0.0077
UNDLOSS $_{t-1}$	0.0068**	0.0029	0.0086***	0.0022	-0.0002	0.0002	0.0010	0.0006	0.0073**	0.0028	0.0084***	0.0022	-0.0001	0.0002	0.0010*	0.0006
EXTRE $_{t-1}$	0.0527***	0.0087	0.0089	0.0096			0.0025	0.0024	0.0516***	0.0083	0.0106	0.0091			0.0021	0.0022
HUREXP $_{t-1}$	0.0002	0.0035	-0.0033	0.0028			-0.0002	0.0007	-0.0021	0.0033	-0.0015	0.0027			-0.0008	0.0007
GEOCON $_{t-1}$	-0.0040	0.0040	0.0095***	0.0029	0.0002	0.0002	-0.0021***	0.0008	-0.0033	0.0040	0.0095***	0.0029	0.0002	0.0002	-0.0021***	0.0008
LOBCON $_{t-1}$	0.0043	0.0042	0.0030	0.0034	0.0001**	0.0002	-0.0001	0.0009	0.0046	0.0042	0.0032	0.0034	0.0001	0.0002	-0.0001	0.0009
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Chi-Square statistic	272.58***		544.06***		198.64***		24,419.16***		275.86***		547.09***		195.39***		24,415.45***	
Over-identification:																
Sargan	1.8768 (0.7584)		4.6189 (0.4641)		9.3490 (0.2286)		7.3571 (0.1954)									
Basmann	1.8708 (0.7595)		4.6053 (0.4659)		9.3255 (0.2301)		7.3373 (0.1967)									
Hansen-Sargan													29.520 (0.1021)			

Notes:

(1)*** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level. The figures in parentheses are the p-values for the over-identification tests. All the statistics in over-identification tests are chi-square distributed.

(2) In this table, the sample consists of the recipients which do not change the intra-group reinsurance participation status. The sample size is 14,078 observations.

(3) The abbreviations of the variables are the same as previous tables.

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Chapter 3: The Roles of Internal Capital Markets, External Financing, and Premiums Growth in Capital Structure Adjustment: Evidence from the U.S Non-Life Insurance Industry

1. Introduction

In finance literature, capital structure could be considered as one of the mainstream research issues due to the relevance of capital structure to the operation and solvency of firms. Many studies have provided the evidence that firms have target capital structure and actively manage their actual capital structure toward target levels (e.g. Flannery and Rangan, 2006; Oztekin and Flannery, 2012; De Jonghe and Oztekin, 2015). In capital management practices of insurance industry, group-affiliated insurers could have more options than stand-alone counterparts due to the access to internal capital markets, such as intra-group reinsurance. Several studies have suggested the active role of internal capital markets in capital management. For instance, Fier, McCullough, and Carson (2013) document a positive relationship between the deviation from target leverage and the amount of internal reinsurance usage. Niehaus (2018) finds that insurance groups transfer capital to manage the solvency positions of group-affiliated insurers.

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In addition to internal capital markets activities, group-affiliated insurers could manage capital structure by seeking external financing and reinsurance. For example, Berry-Stolzle, Nini, and Wende (2014) find that insurers issue new capital to replenish depleted capital and support business growth. Apart from external capital markets, adjusting the amount of premiums written is also a feasible way for insurers to manage capital structure. Capital constraint theory suggests that insurance supply is determined by insurers' net worth since raising capital externally is costly (e.g. Gron, 1994a, 1994b; Winter, 1994). When negative shocks cause depletion in insurers' capital, insurers tend to reduce the supply of insurance in response to capital depletion. Thus, insurers could reduce the extent of capital shortage by curtailing the amount of premiums written.

Despite the various channels of capital adjustment indicated by previous works, the studies on how insurers adjust their capital levels toward targets are still relatively unexplored. To the best of our knowledge, previous studies tend to focus on the existence of target leverage and the speed of adjustment. These works pay relatively less attention to the channels through which firms adjust capital structure, with the exception of the following two studies. Fier et al. (2013) find that internal reinsurance can be used for capital adjustment. De Jonghe and Oztekin (2015) analyze the changes in the values of banks' balance sheet items in response to the deviation from target

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capital structure. To fill this void, we investigate how insurers adjust capital structure toward target levels in the context of U.S non-life insurance industry.

Our aim is twofold. First, we analyze how group-affiliated insurers adjust capital structure to their target levels by investigating the effects of the deviation from target leverage on the following capital adjustment channels: internal reinsurance and internal capital transfer, external reinsurance and capital issuance, and premiums growth. The deviation is measured as the difference between actual leverage and target leverage level. It could be considered as the extent of undercapitalization as the insurers with positive deviation have excessive leverage. Second, we further explore whether insurers' roles in intra-group reinsurance transactions can influence the ways through which group-affiliated insurers adjust capital structure. In this study, we define the insurers with positive net amount of internal reinsurance assumed as "providers" because these insurers provide coverage for other affiliates. Conversely, we consider the insurers with positive net amount of internal reinsurance premiums ceded as "recipients" since these insurers acquire coverage from other group members. In addition, we define the insurers without intra-group reinsurance transactions as "non-participants" in our work.

In line with the empirical evidence documented by Niehaus (2018), we expect that the funds via internal capital transfer can be used for managing affiliates' financial position and the degree of undercapitalization is positively associated with the internal

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funds received. Among the aforementioned three intra-group reinsurance status, providers and recipients have economic ties in terms of internal reinsurance arrangements. Such interconnectedness makes their financial performance and solvency positions dependent upon their reinsurance counterparties, and thus indicates that severe undercapitalization of providers could exert more severe negative effects on the rest of insurance group. To avoid such consequence, insurance groups may be more inclined to support undercapitalized providers. Thus, we expect that the positive effect of undercapitalization on the funds received via internal capital transfer is stronger for providers than the other two groups.

Furthermore, intra-group reinsurance participation status may also influence the effects of target leverage deviation on external financing and premiums growth. Internal reinsurance recipients could benefit from the capacity provided by other affiliates. Such capacity replenishment via internal reinsurance could affect the capital adjustment decisions in the following ways. First, it may weaken the roles of external financing sources in capital management as such capital relief could substitute the demand for external financing. Second, such capacity replenishment could also weaken the negative effect of the deviation from target leverage on recipients' premiums growth. When recipients are undercapitalized, they still have the access to internal reinsurance

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to replenish their capacity and thus may not have to curtail substantial amount of premiums to reduce leverage.

In our empirical work, we employ the following two steps of empirical analysis. In the first step, we employ system GMM model of Arellano and Bover (1995) and Blundell and Bond (1998) to estimate target leverage and the deviation from target leverage ratios. In the second part, we regress the variables representing capital adjustment channels on the deviation from target leverage and other explanatory variables. To test whether the effects of the deviation on the channels of capital adjustments vary with intra-group reinsurance participation status, we further perform coefficient equality tests to compare the regression coefficients on the deviation from target leverage among the subsamples partitioned by insurers' roles in intra-group reinsurance.

Our main results are summarized as follows. First, the deviation from target leverage exerts positive and significant effect on the amount of internal reinsurance receipt. This result reconfirms the conclusion of Fier (2013), which states that internal capital markets activities play important roles in adjusting capital structure. Second, the effects of the deviation from target leverage on the funds received via internal capital transfer are positive and significant for internal reinsurance providers and recipients. On the contrary, such relationship is not significant for the insurers without internal

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reinsurance involvement. With respect to coefficient equality, there is no significant difference between providers and recipients in term of the magnitude of coefficients. These results suggest that both types of internal reinsurance participants are supported when they are undercapitalized. The possible explanation for these results could be attributed to the negative impact of recipients' deterioration in financial positions on providers. From the perspective of supplier-buyer relation, recipients could be regarded as a source of underwriting income. When recipients are severely undercapitalized, providers may lose such revenue source. Thus, recipients are also supported via internal capital transfer.

Third, the deviation from target leverage is positively associated capital issuance, indicating that raising capital is still an important channel for group-affiliated insurers to make capital adjustment in spite of the existence of internal capital markets. Nevertheless, we do not find the evidence indicating that the deviation from target leverage leads to more external reinsurance use. Such result may be attributed to the higher costs associated with external reinsurance. Fourth, the effects of target leverage deviation on premiums growth vary with intra-group reinsurance participation status. Specifically, we do not find that the deviation from target capital structure exerts negative effect on recipients' premiums growth. On the contrary, we find that the deviation from target exerts negative effect on providers' net premiums growth. These

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results could indicate that the capacity acquired from internal reinsurance offsets the negative effect of undercapitalization on recipients' premiums growth.

Our contribution is twofold. First, we provide more comprehensive understanding on how group-affiliated insurers adjust capital structure by testing the effects of deviation from target leverage on various capital adjustment channels. The work of Fier et al. (2013) finds a significant relation between the deviation from target leverage and internal reinsurance activities. Our research extends the work of Fier et al. (2013) by examining the effects of target leverage deviation on the movement of internal capital, external financing decisions, and premiums growth. Second, we provide the evidence that intra-group reinsurance participation status influences the ways by which group-affiliated manage their capital structure. Based on our results, the economic connections generated by intra-group reinsurance transactions could influence the direction of internal capital transfer. Moreover, the access to the capital relief via internal reinsurance arrangements could mitigate the negative effect of undercapitalization on premiums growth.

The remainder of this essay is organized as follows. In section 2, we discuss the literature on target capital structure and the potential capital adjustment channels, and then propose our hypotheses. The data and methodology will be explained in section 3. Section 4 presents and discusses the empirical results, and section 5 concludes.

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2. Literature Review and Hypotheses Development

2.1 The Literature on Target Capital Structure

In finance literature, there are several theories regarding capital structure. Trade-off theory indicates that firms actively manage the capital structure toward optimal levels by balancing the tax benefits associated with debt and the exacerbated bankruptcy costs due to the use of debt (e.g. Frank and Goyal, 2009). On the other hand, pecking order theory indicates that the decision to raise capital is driven by the shortage of internal funds. According to Myers and Majluf (1984), the issuance of capital could be considered as negative signal of firms due to the information asymmetry between firms' managers and external investors. Thus, raising capital externally could be costly. Firms could prefer using internal funds and consider equity financing as the last resort. Based on pecking order theory, capital issuance is driven by the shortage of internally generated funds. Another theoretical argument regarding capital structure is market timing hypothesis, which states that the issuance and repurchase of equity are determined by the market valuation of firms' equity (Baker and Wurgler, 2002).

Among the aforementioned theories regarding capital structure, trade-off theory implies the existence of optimal capital structure and firms actively manage their capital structure toward their target levels. In finance literature, many studies have documented the existence of target capital structure (e.g. Leary and Roberts, 2005; Flannery and

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Rangan, 2006; Hovakimian and Li, 2011; Faulkender, Flannery, Hankins, and Smith, 2012; Öztekin and Flannery, 2012; Flannery and Hankins, 2013; De Jonghe and Öztekin, 2015; Zhou, Tan, Faff, and Zhu, 2016). In addition, these studies also suggest that the existence of adjustment costs prevents firms from fully adjusting leverage to their target levels. Thus, these studies generally employ partial adjustment model in their empirical analysis. Moreover, many of these studies also pay attention to adjustment speed and the factors influencing the adjustment speed.

In insurance literature, several studies suggest that the financially sound insurers could command higher insurance price as policyholders are sensitive to insurers' insolvency risk (Cummins and Sommer, 1996; Sommer, 1996; Cummins and Danzon, 1997). To avoid the negative consequences of excessive insolvency risk on insurance demand and price, insurers tend to limit insolvency at certain levels and thus have target levels of capital and risk-taking. Several studies further find that insurers have target capital structure (e.g. Cheng and Weiss, 2012a; Fier et al. 2013).

Drawing from the relevant studies in literature, the works on how firms reduce the deviation from target leverage seem to be relatively scant. In insurance literature, Fier et al. (2013) investigate whether internal capital markets activities are relevant to capital structure adjustment and focus on internal reinsurance transactions as the main internal capital markets activity. Their empirical results show that group-affiliated insurers use

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internal reinsurance to reduce the deviation from target leverage. In banking literature, De Jonghe and Öztekin (2015) analyze the adjustments in the values of balance sheet items in response of the deviation from target leverage ratios. Their findings suggest that banks reduce leverage primarily by increasing the amount of equity when they are undercapitalized. On the other hand, banks increase leverage by decreasing the amount of earnings retention and expanding the amount of assets. Other relevant studies generally do not pay much attention to the ways through which firms manage their capital structure toward their target levels.

2.2 The Possible Capital Adjustment Channels

In the U.S non-life insurance industry, there are a variety of instruments and channels for insurers to manage capital structure, such as capital issuance, reinsurance, and the amount of premiums written. For group-affiliated insurers, intra-group activities, including internal reinsurance transactions and internal capital transfer, could also play important roles in capital management decisions. In this section, we discuss how group-affiliated insurers utilize these capital adjustment channels and propose our research hypotheses. Specifically, we discuss how the deviation from target leverage level, which is defined as the difference between actual leverage and target leverage, influence insurers' capital management decisions. The insurers with positive values in the

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deviation from their targets are considered as undercapitalized insurers and may need to reduce their leverage levels.

In our work, we further discuss whether intra-group reinsurance participation status affects the ways by which group-affiliated insurers manage their leverage ratios due to the pervasiveness and large volume of intra-group reinsurance transactions in the U.S non-life industry (e.g. Powell and Sommer, 2007; Fier, 2013). In the following contents, we categorize the group affiliated insurers into the following three groups: providers, recipients, and the insurers without intra-group reinsurance participation. The providers are the insurers whose volume of internal reinsurance assumed is larger than that of internal reinsurance ceded. On the contrary, the insurers whose volume of internal reinsurance ceded is above that of internal reinsurance assumed are classified as recipients. On the other hand, non-participants are the insurers without intra-group reinsurance participation

2.2.1 Internal Capital Markets

Compared with external financing, the funds available in internal capital markets could be less costly. Gertner, Scharfstein and Stein (1994) and Stein (1997) suggest that the information asymmetry between headquarter and divisions of multidivisional firms. The lower degree of information asymmetry could enable the headquarters to efficiently allocate the funds to the divisions with more profitable projects. These studies indicate

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that the reduced information asymmetry between fund providers and recipients could contribute to lower cost of internal capital. In insurance literature, Powell and Sommer (2007) also suggest that the cost difference between internal and external reinsurance could be attributed to the decreased information asymmetry among affiliated reinsurer and insurer. In short, previous studies suggest that less severe asymmetric information problem reduces the costs associated with internal capital markets transactions.

In previous literature, several studies further indicate that internal capital markets play important roles in mitigating affiliates' financial constraint and solvency management. For example, Desai, Foley, and Hines (2004) investigate how internal capital markets work in the context of multinational corporations. Their empirical evidence shows that the multinational affiliates located in the countries with more external financing frictions are more likely to be financed with the funds provided by parent companies. Gopalan, Seru, and Nanda (2007) find that internal capital markets activities are used for assisting financially weak affiliates to avoid the negative spillover effects of affiliates' insolvencies on the rest of group. In banking literature, Holod and Peek (2010) analyze the directions of internal capital transfer and how internal secondary loan markets operate in the context of multibank holding companies (MBHCs). They find a negative relationship between the extent of capitalization and the receipt of internal capital, which indicates that the internal capital markets could be

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used for mitigating affiliates' financial constraint or meeting regulatory requirement. Moreover, they find that intra-group loan transactions are also crucial in bank subsidiaries' capital management. The banks with better loan origination opportunities tend to sale their loans to other subsidiaries. In insurance literature, Fier et al. (2013) regard internal reinsurance as main internal capital markets activity and find the evidence that the internal reinsurance is used for reducing the deviation from optimal leverage level. Niehaus (2018) focuses on the changes in capital contributions via internal capital transfer and find that less capitalized insurers tend to receive more funds from other affiliates. Based on the empirical evidence above, internal capital markets are crucial for group-affiliated firms' capital management practices.

Drawing from previous studies, we expect that internal capital markets are used for managing affiliates' capital structure. In line with the work of Fier et al. (2013), we firstly reexamine the relationship between the deviation from target leverage and internal reinsurance activities. In our study, we further differentiate the intra-group reinsurance participants into providers and recipients based on the amount of internal reinsurance assumed and ceded. When providers' actual leverage levels exceed their targets, they may need to reduce the amount of internal reinsurance assumed from other affiliated. On the contrary, recipients could use internal reinsurance to reduce the

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leverage ratios in their capital management decisions. The corresponding hypotheses are stated as follows:

***Hypothesis 1a*:** The deviation from target leverage negatively affects the amount of internal reinsurance provision.

***Hypothesis 1b*:** The deviation from target leverage positively affects the amount of internal reinsurance receipt.

In our study, we also investigate whether the direction of internal capital transfer is driven by the deviation from target leverage. We expect that the insurers with larger deviation from their target leverage receive more funds via internal capital movements within their groups. The hypothesis is stated as follows:

***Hypothesis 2*:** The deviation from target leverage positively affects the amount of capital received via internal capital transfer.

Under intra-group reinsurance transactions, both providers and recipients are economically linked since their financial performance and solvency can be influenced by their counterparties. In insurance literature, several studies on systematic risk also suggest that the interconnectedness created by reinsurance transactions could be a potential source of systematic risk since the deterioration of reinsurers' financial strength could exert contagion effects on insurers (e.g. Cummins and Weiss, 2014; Park and Xie, 2014). The intra-group reinsurance arrangements are essentially a potential

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channel of contagion effect within insurance group. Due to the interconnectedness created by intra-group reinsurance transactions, the deterioration of providers' financial soundness could increase the default risk recipients' reinsurance receivable. To avoid such consequence, providers could be supported when they are undercapitalized. The effect of target leverage deviation on internal capital transfer variable could be stronger for providers. The corresponding hypothesis is proposed as follows:

***Hypothesis 2a*:** The positive effect of the deviation from target leverage on the amount of capital received via internal capital transfer is stronger for internal reinsurance providers than other two groups.

2.2.2 External Reinsurance and Capital Issuance

Group-affiliated insurers may still seek for external sources of financing to manage their capital levels in spite of the higher costs associated with external financing, especially when the resources available in insurance group are scarce. Powell and Sommer (2007) point out that external reinsurance could be a better option if the rest of group does not have sufficient capacity to bear risk. Regarding capital issuance, Berry-Stolzle, Nini, and Wende (2014) find the evidence that life insurers raise new capital in response to capital depletion. In our work, we expect that both external reinsurance and capital issuance are used for reducing the deviation from target leverage. The hypotheses are proposed as follows:

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***Hypothesis 3*:** The deviation from target leverage positively affects the usage of external reinsurance.

Hypothesis 4: The deviation from target leverage positively affects capital issuance.

In intra-group reinsurance arrangements, recipients are the real users of internal reinsurance and thus can benefit from the capacity replenishment provided by other affiliates. Such capacity replenishment may exercise substitution effects on recipients' demand for external financing sources. Thus, we expect that the positive effects of the deviation from target leverage on external reinsurance and capital issuance are weaker for internal reinsurance recipients. The corresponding hypotheses are stated as follows.

***Hypothesis 3a*:** The positive effect of target leverage deviation on external reinsurance is weaker for internal reinsurance recipients.

***Hypothesis 4a*:** The positive effect of target leverage deviation on capital issuance is weaker for internal reinsurance recipients.

2.2.3 Premiums Growth

The literature on underwriting cycle suggests that insurer's capital is an important determinant of the amount of premiums written According to capital constraint theory, the industry-wide capital shocks could reduce aggregate underwriting capacity and cause the backward shift of insurance supply (e.g. Gron, 1994a, 1994b; Winter, 1994). Another line of studies conjecture that insurance demand is influenced by insurers'

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financial strength because policyholders are sensitive to insurers' insolvency risk (e.g. Cummins and Sommer, 1996; Sommer, 1996; Cummins and Danzon, 1997). Thus, financially weak insurers may be forced to reduce the amount of premiums written in response of capital shortage. Both these two strands of studies could imply that insurer's undercapitalization reduces the growth of premiums written. Thus, we expect a negative relationship between the deviation from target and premiums growth. The hypothesis is proposed as follows.

***Hypothesis 5*:** the deviation from target leverage negatively affects premiums growth.

The negative effect of target leverage deviation on premiums growth could vary with insurer's participation status of intra-group reinsurance. Specifically, internal reinsurance recipients can access additional underwriting capacity provided by other affiliates. Such capacity replenishment could offset the negative effect of capital shortage on premiums growth. In finance literature, several studies further suggest that in comparison with stand-alone firms, the firms with the access to internal capital markets experience less reduction in the amount of investment during economic downturns (e.g. Matvos and Seru, 2014; Almeida, Kim, and Kim, 2015). In insurance literature, Powell, Sommer, and Eckles (2008) find the evidence that the receipt of internal capital enables insurers to increase the amount of premiums written. These studies could imply that the access to internal capital markets mitigate the negative

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impact of adverse shocks on business growth. Thus, we anticipate that the negative effect of undercapitalization on premiums growth could be mitigated for internal reinsurance recipients. The hypothesis is proposed as follows:

***Hypothesis 5a*:** The negative effect of target leverage deviation on premiums growth is weaker for internal reinsurance recipients.

Our research hypotheses are summarized as Table 3-1.

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Table 3- 1 Summary of research hypotheses

Adjustment channel	Main hypotheses	The influence of intra-group reinsurance participation status
Internal reinsurance	*Hypothesis 1a*: target leverage deviation negatively affects internal reinsurance provision (-). *Hypothesis 1b*: target leverage deviation positively affects internal reinsurance receipt (+).	None
Internal capital transfer	*Hypothesis 2*: target leverage deviation positively affects the amount of capital received via internal capital transfer (+).	Hypothesis 2a: The positive effect of target leverage deviation on internal capital transfer is stronger for the providers.
External reinsurance	*Hypothesis 3*: target leverage deviation positively affects the usage of external reinsurance (+).	*Hypothesis 3a:* The positive effect of target leverage deviation on external reinsurance is weaker for the recipients.
Capital issuance	*Hypothesis 4*: target leverage deviation positively affects capital issuance (+).	*Hypothesis 4a:* The positive effect of target leverage deviation on capital issuance is weaker for the recipients.
Premiums growth	*Hypothesis 5*: target leverage deviation negatively affects premiums growth (-).	*Hypothesis 5a:* The negative effect of target leverage deviation on premiums growth is weaker for the recipients.

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3. Data, Methodology, and Variables

3.1 Data

We retrieve group-affiliated insurers' data in the U.S non-life insurance industry from National Association of Insurance Commissioners (NAIC) database for the period of 1999 to 2016. The following sample screening procedures are applied. First, non-affiliated insurers are excluded as they do not have access to internal capital markets activities. Second, we only keep active insurers in our sample because the insurers in other conditions, such as liquidation, receivership, merger and acquisition, may exhibit unusual business activities and decisions. Third, the insurers with negative surplus and non-positive net premiums written are removed. Fourth, the insurers whose amount of external reinsurance premiums assumed is above 75% of gross premiums written are excluded as they are considered as professional reinsurers by Powell and Sommer (2007). Fifth, we exclude the observations with extraordinary values, such as the insurers whose values of internal reinsurance provision or receipt variable lie outside the range from 0 to 1. After these procedures, the total sample size is 15,729 firm/year observations. To mitigate the effects of extraordinary values in our variables, we winsorize the 0.5^{th} and 99.5^{th} percentiles of the variables in our work, with the exception of risk-based capital (RBC) ratio to keep the variation of this variable (Fier et al., 2013).

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3.2 Methodology

Our analysis consists of two parts. In the first part, we employ system GMM developed by Arellano and Bover (1995) and Blundell and Bond (1998) to estimate the target leverage levels and deviation. This estimation method has been adopted by several recent studies on capital structure (e.g. Fier et al. 2013; De Jonghe and Oztekin, 2015). The reason behind the use of system GMM is to address the concern regarding potential endogenous explanatory variables. During the estimation process, the instrumental variables are derived by taking first differences of the endogenous variables. The following contents explain how the target leverage regression is constructed. According to Flannery and Rangan (2006), the target leverage level is expressed as the following equation:

$$\mathrm{Lev}^{*}_{i,t} = \delta \mathrm{X}_{1,t-1} \quad (1)$$

In equation (1), $\mathrm{Lev}^{*}_{i,t}$ represents target leverage ratio of firm i at year t. $\mathrm{X}_{i,t-1}$ denotes the vector of explanatory variables. All the explanatory variables are lagged for 1 period, with the exception of yearly dummies. The partial adjustment model suggested by Flannery and Rangan (2006) is expressed as follows:

$$\mathrm{Lev}_{i,t} - \mathrm{Lev}_{i,t-1} = \lambda\left(\mathrm{Lev}^{*}_{i,t} - \mathrm{Lev}_{i,t-1}\right) + \varepsilon_{1,t} \quad (2)$$

In equation (2), λ denotes the speed of adjustment toward target. If insurer can fully adjust leverage to target, the value of λ would be 1. Nevertheless, due to the

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existence of adjustment costs, λ is likely to fall within the range from 0 to 1. By substituting equation (1) to (2), we can construct partial adjustment model as follows:

$$\mathrm{Lev}_{i,t} = \lambda\delta \mathrm{X}_{i,t-1} + (1-\lambda)\mathrm{Lev}_{i,t-1} + \varepsilon_{i,t} \quad (3)$$

After the estimation of equation (3), we get the target leverage ratios and the deviation from target leverage ratios. In our second part of the analysis, we investigate how the deviation from target leverage affects the variables representing the channels of capital adjustment. The regression is constructed as follows:

$$\text{Adjustment channel}_{i,t+1} = \delta_1 \text{Deviation from target}_{i,t} + \delta \mathrm{X}_{i,t} + \beta_t + \varepsilon_{i,t} \quad (4)$$

In equation (4), capital adjustment channel variable is forwarded for 1 year and regressed on the deviation from target leverage and other explanatory variables. Yearly dummies are denoted as β_t. In this stage, we attempt to investigate whether the deviation from target leverage can motivate insurers to take financing decisions to manage their capital structure. In the second part of our empirical work, we regress the capital adjustment channel variables on the deviation from target and other control variables for the following three subsamples: providers, recipients, and non-participants.

As the insurers included in our analysis are affiliated to groups, they may not make independent financing decisions as stand-alone counterparts do. It is possible that the financing decisions are made on group basis. Such concern should be addressed in our empirical strategies. In our study, the insurers which belong to the same insurance group

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could be classified into different subsamples or the same subsample based on the amount of internal reinsurance assumed and ceded. Therefore, it is necessary to account for the between-group and within-group correlations in the estimation of equation (4). To address the issue of between-group correlations, we adopt seemingly unrelated estimation method to simultaneously estimate equation (4) for the three subsamples. This method involves the use of simultaneous covariance matrix, which is also obtained by White (1982), when estimating the parameters. During the estimation process, all the information in the three subsamples is incorporated. Therefore, the coefficients estimated are robust to between-group correlations. To consider within-group correlation, we use of cluster-robust error in the estimation of regression coefficients.

After the above-mentioned procedures, the estimated coefficients could be robust to both between-group and within-group correlations. Then we perform coefficient equality tests to investigate whether the effects of the deviation from target leverage on the capital adjustment channels vary with insurers' roles in intra-group reinsurance arrangements. The statistics of coefficient equality tests follow chi-square distribution with the degree of freedom of 1.

3.3 Variables

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3.3.1 Leverage and Capital Adjustment Channels

Following Fier et al. (2013), we measure leverage as the ratio of total liabilities to surplus. In the first stage, we regress leverage variable on previous year leverage and other explanatory variables to estimate target leverage ratios. Then we calculate the deviation from target leverage ratios by taking the difference between actual leverage and target leverage.

The variables representing capital adjustment channels include internal reinsurance provision and receipt, internal capital transfer, external reinsurance, capital issuance, and premiums growth. The definitions are explained as follows. Internal reinsurance provision (receipt) is the net amount of internal reinsurance assumed (ceded), scaled by gross premiums written. Referring to Niehaus (2018), internal capital transfer is measured as the net amount of capital contribution received via internal capital transfer, divided by insurer's previous year surplus.[11] Following Powell et al. (2008), external reinsurance usage is defined as the difference between the reinsurance premiums ceded to non-affiliates and the reinsurance premiums assumed from non-affiliates, scaled by gross premiums written. To construct the measurement of capital issuance, we refer to the study of Berry-Stolzle, Nini, and Wende (2014). In their study, they consider the changes in the following items on insurers' financial reports: paid-in

[11] The negative value of this variable indicates the net outflow of capital to other group members.

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capital, paid-in surplus, surplus note, and treasury stock. As the transactions regarding treasury stocks are more likely to serve for other purposes, such as managing stock prices, rather than altering capital positions, we exclude treasury stock in the calculation of capital issuance variable. Specifically, we measure capital issuance as the summation of the change in paid-in capital, paid-in surplus, and surplus notes, scaled by insurer's surplus in previous year.[12]

Referring to the work of Epermanis and Harrington (2006), we consider both direct premiums and net premiums growth in our study. These two measurements are calculated as the difference between the premiums written in current year and previous year, scaled by the premiums written in previous year.

3.3.2 Control Variables

In the estimation of target leverage and the analysis on the channels of capital adjustment, we include the following control variables. In our work, we include gross premiums growth as a control variable when estimating an insurer's target leverage ratio. Insurers with greater premiums growth may need to conserve more capital to support their growth and thus have lower leverage. However, the growth of premiums

[12] Niehaus (2018) points out that the capital issuance measure of Berry-Stolzle et al. (2014) may contain the effect of internal capital transfer. Therefore, our proxy for capital issuance may not be a pure measurement of external financing. Nevertheless, we are unable to identify whether the change in paid-in capital, paid-in surplus, and surplus note on insurer's balance sheet are caused by internal and external financing decisions. Therefore, we do not attempt to exclude the capital change due to internal capital transfer in our capital issuance measure.

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could naturally increase the amount of liabilities, and thus drive up leverage level. Due to these divergent arguments, we do not predict the effect of gross premiums growth on leverage. To control the effects of insolvency risk on capital structure, we include firm size and RBC ratio as control variables. As Warner (1977) suggests, larger firms are associated with lower expected financial distress costs. Thus, we expect a positive relation between firm size and leverage. On the other hand, insurers with higher RBC ratio could have sufficient capital positions to increase leverage. Therefore, we expect that RBC ratio exerts a positive effect on leverage. In New York State, insurers are subject to more stringent regulation. We include an indicator as an explanatory variable to consider the effect of regulatory jurisdiction. Following Cummins and Sommer (1996), if an insurer is licensed in New York State, the value of this indicator is 1, and 0 otherwise. We expect that New York State indicator is negatively related to leverage.

In the U.S non-life insurance industry, insurer's organization form could be an important factor which influences capital structure and other financing decisions. Compared with stock insurers, mutual insurers could have more limited sources of financing. Thus, mutual insurers may need to maintain higher capital buffer. To consider the effect of organization form on leverage and capital adjustment channels, we include stock dummy which takes the value of 1 for stock insurer and 0 otherwise. In addition, the profitability could also influence insurers' leverage. Insurers with higher

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profitability could have more sufficient capital replenishment to increase their leverage. Nevertheless, these insurers may conserve their cash flows from profitability and thus result in lower leverage levels. In our study, we use returns on equities (ROE) as the proxy for profitability.

In addition to the aforementioned variables, we also consider insurer's underwriting portfolio in our analysis. Following Cheng and Weiss (2012b), we include hurricane exposure, which is defined as the ratio of the amount of direct premiums written in hurricane-prone states to the aggregate amount of direct premiums written, as a control variable.[13] The insurers with higher hurricane exposure may need to conserve more capital and thus have lower leverage. Moreover, the extent of business concentration in terms of line of business and geographic area is also considered in our study. Specifically, we calculate the geographic concentration and line of business concentration Herfindahl index, and include them as explanatory variables.

Insurers' capital structure could also be influenced by their business mix. Cummins and Nini (2002) mention that the proportion of long-tail lines of business could influence insurer's capital structure due to the exacerbated information asymmetry between insurer and external investors. The insurers with more premiums written in

[13] Hurricane prone states are listed as follows: Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina, and North Carolina.

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long-tail lines could have more discretion in the estimation of loss reserves as the payout period is longer for long-tail lines. Therefore, external investors could have more difficulties in evaluating the accuracy of reserves. Such information asymmetry could make these insurers more prone to opportunistic behavior. To limit such behavior, the insurers with more premiums written in long-tail lines of business may have less financial slack and thus have higher leverage levels. Furthermore, Cummins and Nini (2002) also suggest that corporate insurance buyers tend to be equipped with the expertise to assess insurers' financial quality. In addition, corporate insurance buyers could face lower switching costs as they can benefit from economy of scale and the access to insurance brokers. Thus, they are more likely to discontinue insurance purchase from financially weak insurers and choose more financially sound insurers. These reasons imply that the insurers which have more premiums written in commercial lines may be less levered. The variable definitions are summarized in Table 3-2.

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Table 3- 2 Variable definitions

Variables	Definitions
Panel A: the proxy for capital structure and the deviation from target capital structure	
Leverage	The ratio of total liabilities to surplus
Deviation from target leverage	The difference between actual leverage and target leverage.
Panel B: the channels of capital adjustments	
Internal reinsurance provision	If the amount of internal reinsurance assumed is above internal reinsurance ceded, the value is the difference between internal reinsurance assumed and internal reinsurance ceded, scaled by gross premiums written.
Internal reinsurance receipt	If the amount of internal reinsurance ceded is above internal reinsurance assumed, the value is the difference between internal reinsurance ceded and internal reinsurance assumed, scaled by gross premiums written.
Internal capital transfer	The change in capital contribution due to internal capital transfer arrangements within group, scaled by the surplus in previous year.
External reinsurance	The amount of external reinsurance ceded minus external reinsurance assumed, scaled by gross premiums written.
Capital issuance	The amount of capital issuance scaled by total amount of surplus in previous year.
Direct premiums growth	The difference between the amount of direct premiums written in current year and that in previous year, scaled by the amount of premiums written in previous year.
Net premiums growth	The difference between the amount of net premiums written in current year and that in previous year, scaled by the amount of premiums written in previous year.
Panel C: Control variables	
Gross premiums growth	The growth in the amount of gross premiums written from previous year to current year.
Firm size	The logarithm of insurer's total assets.
RBC ratio	The ratio of adjusted surplus to risk-based capital requirement.
New York indicator	The value of this variable is 1 for the insurer licensed in New York state and 0 otherwise.
Organization form	The value of this variable is 1 for stock insurer, and 0 otherwise.
Returns on equities	The ratio of net profits to surplus.
Hurricane exposure	The ratio of the direct premiums written in hurricane prone areas to insurer's aggregate amount of direct premiums written.
Geographic concentration	Herfindahl index of geographic concentration. The variable calculation is based on direct premiums written.
Line of business concentration	Herfindahl index of lines of business concentration. The variable calculation is based on direct premiums written.
Long-tail lines	The proportion of direct premiums written in long tail lines of business to total direct premiums written,
Commercial lines	The proportion of direct premiums written in commercial lines of business to total direct premiums written,

Note: Gross premiums growth is included as an explanatory variable only in the estimation of target leverage.

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4. Empirical Results

4.1 Descriptive Statistics

The descriptive statistics are demonstrated in Table 3-3. These statistics indicate that the average leverage of the providers is higher than those of other subsamples. In addition, the providers' average RBC ratio is lower than the other two groups. These results could be attributed to the increase in liabilities caused by intra-group reinsurance transactions. The statistics presented in Table 3-3 also suggest that providers are associated with larger size and lower hurricane exposure. These results may indicate that the insurers with better capabilities to assume risk are more likely to be providers within insurance group.

4.2 Partial Adjustment Model

The estimation results of partial adjustment model are shown in table 3-4. The positive and significant coefficients on lagged leverage suggest the existence of target leverage ratios. Moreover, the coefficients on lagged leverage are different among the three subsamples in term of magnitude. For providers, the coefficient on lagged leverage is larger than those of other two subsamples. This result implies that the providers' adjustment speed is the lowest among the three groups.

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Table 3- 3 Descriptive statistics of the variables used in the estimation of target leverage

Variable	Panel A: providers (N=5,574)					Panel B: recipients (N=7,695)					Panel C: non-participants (N=2,420)				
	Mean	Median	St. dev.	Min	Max	Mean	Median	St. dev.	Min	Max	Mean	Median	St. dev.	Min	Max
Leverage $_{t}$	1.8409	1.7187	0.9832	0.1623	5.7476	1.7155	1.5229	1.1850	0.0322	7.6293	1.6488	1.3243	1.6605	0.0191	14.5846
Leverage $_{t-1}$	1.8116	1.6994	0.9508	0.1239	5.6633	1.6944	1.5225	1.1178	0.0314	6.6517	1.6000	1.3204	1.4784	0.0197	12.2343
Gross premiums growth $_{t-1}$	0.1154	0.0414	0.5101	-0.6589	5.0918	0.3035	0.0579	1.6427	-0.6279	19.6232	0.2807	0.0423	1.6054	-0.8655	18.1578
Firm size $_{t-1}$	19.7442	19.6252	1.8004	15.5142	24.5235	18.7614	18.7092	1.5667	15.0370	23.4201	17.8404	17.8319	1.5523	14.1786	21.5218
RBC ratio $_{t-1}$	9.4513	7.1873	13.4313	0.7232	416.9016	20.6503	8.8686	94.7181	0.2758	6,624.846	15.0542	7.7713	43.8205	0.0003	1766.102
New York State $_{t-1}$	0.0511	0.0000	0.2203	0.0000	1.0000	0.0615	0.0000	0.2402	0.0000	1.0000	0.0354	0.0000	0.1847	0.0000	1.0000
Organization Form $_{t-1}$	0.7512	1.0000	0.4324	0.0000	1.0000	0.8741	1.0000	0.3318	0.0000	1.0000	0.7988	1.0000	0.4010	0.0000	1.0000
Returns on equities $_{t-1}$	0.0580	0.0638	0.1122	-0.4502	0.4150	0.0530	0.0570	0.1150	-0.5482	0.4459	0.0371	0.0537	0.1928	-1.1170	0.7603
Hurricane exposure $_{t-1}$	0.2117	0.1018	0.2914	0.0000	1.0000	0.2576	0.1651	0.3130	0.0000	1.0000	0.3262	0.0144	0.4183	0.0000	1.0000
Geographic concentration $_{t-1}$	0.4617	0.3454	0.3660	0.0371	1.0000	0.4317	0.2928	0.3652	0.0387	1.0000	0.7003	0.9379	0.3508	0.0431	1.0000
Line of business concentration $_{t-1}$	0.5842	0.5103	0.2898	0.1465	1.0000	0.5927	0.5240	0.2881	0.1603	1.0000	0.7676	0.9229	0.2656	0.2119	1.0000
Long-tail lines $_{t-1}$	0.4960	0.4904	0.3085	0.0000	1.0000	0.4984	0.5035	0.3000	0.0000	1.0000	0.4028	0.4063	0.3576	0.0000	1.0000
Commercial lines $_{t-1}$	0.4922	0.4936	0.3880	0.0000	1.0000	0.4665	0.4587	0.3859	0.0000	1.0000	0.3230	0.0464	0.4085	0.0000	1.0000

Note: the providers are the insurers with positive amount of net internal reinsurance provision; the recipients are the insurers with positive amount of net internal reinsurance ceded; non-participants are the insurers which do not have records on intra-group reinsurance transactions.

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Table 3- 4 The estimation of target leverage for the subsamples partitioned by intra-group reinsurance participation status

Variables	(1) Providers (N=5,574)		(2) Recipients (N=7,695)		(3) Non-Participants (N=2,460)	
	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
Constant	0.2857 **	0.1111	-0.1753	0.1449	0.1842	0.2244
Leverage $_{t-1}$	0.9689 ***	0.0292	0.8672 ***	0.0209	0.8637 ***	0.0152
Gross premiums growth $_{t-1}$	0.1182	0.0732	0.0292	0.0207	0.1476 ***	0.0382
Firm size $_{t-1}$	-0.0129 ***	0.0049	0.0170 **	0.0077	0.0070	0.0113
RBC ratio $_{t-1}$	0.0058 ***	0.0016	-0.0004	0.0002	-0.0062 ***	0.0013
New York State $_{t-1}$	0.0825 **	0.0350	0.0627 *	0.0359	-0.0330	0.0788
Organization Form $_{t-1}$	0.0035	0.0183	0.0552 ***	0.0208	-0.0339	0.0407
Returns on equities $_{t-1}$	0.4041 ***	0.1440	-0.2245	0.2577	-0.1058	0.1635
Hurricane exposure $_{t-1}$	0.0204	0.0249	0.0349	0.0219	-0.0345	0.0326
Geographic concentration $_{t-1}$	-0.0192	0.0199	-0.0415 *	0.0215	-0.0651	0.0441
Line of business concentration $_{t-1}$	-0.0997	0.0297	0.0399	0.0307	0.0521	0.0536
Long-tail lines $_{t-1}$	0.0921 ***	0.0338	0.0806 **	0.0317	0.0754	0.0498
Commercial lines $_{t-1}$	-0.0527 ***	0.0213	-0.0310	0.0206	-0.0151	0.0470
Year dummies	Yes		Yes		Yes	
Wald test	6,716.49***		6,892.97***		32,773.99***	
AR (1)	-5.93***		-7.85***		-3.59***	
AR (2)	-0.81		0.90		1.40	
Sargan test	32.49 (0.984)		46.10 (0.704)		62.17 (0.158)	
Hansen test	52.63 (0.450)		63.86 (0.125)		51.44 (0.496)	

Notes:

1. *** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.
2. Gross premiums growth, RBC ratio, and returns on assets are treated as the endogenous variables. The instrumental variables are the first-differenced values of the endogenous variables, which include the first-differenced values between the variables' values in year t and year t-1, and the first-differenced values between the variables' values in year t-1 and year t-2. Sargan and Hansen tests are over-identification tests for the variability of instrumental variables. The figures in the parentheses are the p-values for over-identification tests.

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With respect to other explanatory variables, the results show that firm size and RBC ratio do not influence capital structure in consistent ways. Specifically, we find a negative coefficient on firm size for providers, whereas a positive coefficient on firm size for recipients. Moreover, RBC ratio exerts a positive effect on leverage for providers, whereas it negatively affects leverage for non-participants. For providers, the possible explanation for the negative coefficient on firm size is that the providers with larger size could be associated with more liabilities. Thus, these providers may need to reduce their leverage ratios. On the other hand, providers with higher RBC ratio are more financially sound and able to increase the leverage ratios. Turning to recipients, the positive coefficient on firm size is consistent with the notion that larger insurers have lower expected bankruptcy costs and thus can increase leverage ratios. The negative coefficient on RBC ratio for non-participants subsample may indicate that the insurers with higher solvency positions are more prudent in capital structure decisions.

In addition to the aforementioned variables, we further find that the insurers licensed in New York State are associated with higher leverage ratios for providers and recipients. This result is not consistent with our expectation. For recipients, the positive coefficient on organization form suggests that stock insurers have higher leverage ratio. As stock insurers have advantage in raising capital from external investors, they are able to maintain higher leverage ratios. For providers, we find a positive relation

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between returns on equities and leverage, indicating that the providers with profitability generate more cash flows and thus can increase leverage ratios. Furthermore, several coefficients on business mix variables are significant in table 3-4. The insurers with larger proportion of premiums written in long-tail lines of business are associated greater leverage for both providers and recipients. Besides, the insurers with more premiums written in commercial lines tend to have lower leverage ratios. These results are consistent with the arguments by Cummins and Nini (2002).

4.3 The Correlations between the Deviation from Target Leverage and Capital Adjustment Channels

After the estimation of target leverage ratios, we calculate the deviation from target as the difference between actual and target leverage levels. Then we treat the deviation as the main explanatory variable in the analysis of capital adjustment channels. Before regression analysis, we calculate the correlations between the deviation and capital adjustment channel variables. The results are summarized in table 3-5. The deviation from target is positively related to internal capital transfer, external reinsurance, and capital issuance. On the contrary, the deviation is negatively related to net premiums growth. Most correlations are consistent with our expectation, only with the exception of the positive correlation between the deviation from target and direct premiums growth for recipients subsample.

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Table 3- 5 The correlations between the deviation from target leverage and the channels of capital adjustments

Variable\subsample	Providers (N=4,347)	Recipients (N=6,050)	Non-participants (N=1,842)
Internal reinsurance provision	-0.0213		
Internal reinsurance receipt		0.0204	
Internal capital transfer	0.1584 ***	0.1838 ***	0.0237
External reinsurance	0.0395 ***	0.0270 ***	0.0231
Capital issuance	0.1723 ***	0.2037 ***	0.1800 ***
Direct premiums growth	0.0003	0.0299 **	-0.0194
Net premiums growth	-0.1059 ***	-0.0305 **	-0.0475 **

Notes:
1. *** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.
2. All the variables representing the capital adjustments channels are forwarded for 1 year. This procedure leads to a reduction in sample size.
3. The deviation from target leverage is calculated as the difference between actual leverage and target leverage, which represent the extent of undercapitalization. The figures are the correlation coefficients between the degree of undercapitalization and the variables of potential capital adjustments channels.

4.4 Univariate Analysis

In Table 3-6, we perform the univariate analysis on the capital adjustment channels among the three subsamples. We find that recipients are associated with the least amount of external reinsurance usage. This result could be contributed to the access to the capacity replenishment via internal reinsurance substitute the demand for external reinsurance. Turning to non-participants, these insurers have the largest amount of external reinsurance and capital issuance. As these insurers do not participate in intra-group reinsurance, they may need to rely on external financing sources.

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Table 3- 6 Univariate analysis on capital adjustment channels by intra-group reinsurance participation status

Panel A: Total sample (N=12,239)	Providers (N=4,347)	Recipients (N=6,050)	Non-participants (N=1,842)	(1) vs (2)		(1) vs (3)		(2) vs (3)	
	Mean	Mean	Mean						
External reinsurance	0.0751	0.0622	0.1827	4.3237	***	-20.5283	***	-26.1422	***
Capital issuance	0.0290	0.0401	0.0459	-3.4732	***	-3.9064	***	-1.1894	
Internal capital transfer	0.0174	0.0276	0.0284	-3.6026	***	-2.9502	***	-0.2003	
Direct premiums growth	0.0569	0.1118	0.1072	-5.7566	***	-3.4833	***	0.3526	
Net premiums growth	0.1209	0.0958	0.1726	2.2232	**	-2.5281	**	-4.0361	***

Notes:
1. *** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level; and * indicates statistical significance at the 10% level.
2. All the variables representing the potential channels of capital adjustments are forwarded for 1 year. This procedure reduces the sample size.

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Among these three groups, our results indicate that the insurers without intra-group reinsurance engagement tend to receive more funds via internal capital transfer. With respect to premiums growth, we find that the providers have the lowest values in direct premiums growth. As these providers need to conserve more capacity to assume the risk from other affiliates, they may need to maintain lower levels of direct premiums growth. Finally, the recipients have the lowest values of net premiums growth. Such low net premiums growth may be caused by the amount of internal reinsurance ceded by the recipients.

4.5 The Effects of the Deviation from Target Leverage on Capital Adjustment Channels

4.5.1 Internal Capital Markets Activities

Table 3-7 presents the effects of the deviation from target leverage ratio on internal reinsurance and internal capital transfer variables. In Panel A, we find the positive effect of the deviation from target leverage on internal reinsurance receipt, which is consistent with the results of Fier et al. (2013). The recipients can use internal reinsurance to reduce the deviation from target leverage. Thus, hypothesis 1b is supported in our work. Nevertheless, the effect of the deviation on internal reinsurance provision is negative but not statistically significant. There is no sufficient evidence indicating that the providers reduce internal reinsurance provision in response to undercapitalization.

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Table 3- 7 The effects of capital structure deviation on internal reinsurance and internal capital transfer

Variable	Panel A: Dependent variable: internal reinsurance $_{t+1}$				Panel B: Dependent variable: internal capital transfer t+1					
	Column (1) Providers		Column (2) Recipients		Column (1) Providers		Column (2) Recipients		Column (3) Non-participants	
	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev
Constant	-0.2315	0.1439	1.4858***	0.1414	0.0973***	0.0323	0.0959***	0.0366	-0.0201	0.0469
Deviation from target leverage	-0.0102	0.0072	0.0199**	0.0081	0.0324***	0.0080	0.0396***	0.0066	-0.0169*	0.0088
Firm size $_t$	0.0147**	0.0067	-0.0633***	0.0066	-0.0032**	0.0014	-0.0034**	0.0015	0.0004	0.0023
RBC ratio	0.0002	0.0007	0.0002	0.0002	0.0001	0.0002	0.0000	0.0000	-0.0002*	0.0001
New York State	-0.0558*	0.0337	0.0921**	0.0362	0.0064	0.0107	0.0012	0.0084	0.0041	0.0170
Organization Form	0.1271***	0.0209	0.0668**	0.0284	0.0194***	0.0042	0.0194***	0.0069	0.0340***	0.0078
Returns on equities	0.0440	0.0552	0.0082	0.0505	-0.1270***	0.0310	-0.1666***	0.0348	-0.2018***	0.0518
Hurricane exposure	0.0092	0.0361	0.0351	0.0343	0.0017	0.0075	0.0164**	0.0081	0.0211*	0.0115
Geographic concentration	0.1500***	0.0292	-0.0918***	0.0320	-0.0074	0.0069	-0.0133	0.0082	-0.0086	0.0100
Line of business concentration	0.0508	0.0366	-0.0794**	0.0388	0.0043	0.0082	0.0108	0.0098	0.0082	0.0155
Long-tail lines $_t$	-0.0143	0.0404	0.1485***	0.0399	-0.0023	0.0086	0.0049	0.0100	-0.0149	0.0154
Commercial lines $_t$	0.0791**	0.0313	-0.0584*	0.0329	-0.0068	0.0070	0.0015	0.0074	0.0042	0.0126
Year dummies	Yes		Yes		Yes		Yes		Yes	
Chi-Square statistic	15.38***		30.22***		11.26***		17.81***		5.65***	
Adjusted R-square	0.0792		0.1116		0.0578		0.0674		0.0617	
Coefficient equality test (Wald test)					(1) vs (2)		(1) vs (3)		(2) vs (3)	
					0.46		16.90***		26.42***	

Notes:
1. The figures in parentheses are the standard errors of the coefficients. ***, **, and * represent statistical significance levels of 1%, 5%, and 10% respectively.
2. For providers (recipients), the dependent variable is the ratio of net internal reinsurance assumed (net internal reinsurance ceded) to gross premiums written.

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These providers may manage their capital structure through other channels. Hypothesis 1a does not receive support.

Turning to internal capital transfer, Panel B reveals that the deviation from target leverage exerts a positive and significant effect on the capital received via internal capital transfer for both providers and recipients. In contrast, the coefficient of target leverage deviation is not statistically significant for non-participants. Hypothesis 2 receives supports in the subsamples of providers and recipients. Moreover, the results of coefficient equality test indicate that the coefficients on target leverage deviation of both providers and recipients are significantly larger than that of non-participants. Nevertheless, hypothesis 2a is not supported as there is no significant difference between providers and recipients regarding the magnitude of the coefficients on target leverage deviation. In our study, both providers and recipients receive the supports from internal capital transfer when they are undercapitalized. Under intra-group reinsurance arrangement, financially weak providers could potentially pose greater reinsurance counterparty risk on recipients. On the other hand, the recipients could be considered as a source of underwriting income for providers from the perspective of supplier-buyer relationship. When recipients are considerably undercapitalized or even insolvent, the providers may not be able to collect reinsurance revenues from them. These reasons may explain why both providers and recipients are supported via internal capital transfer.

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In addition to the aforementioned results, firm size exerts negative effects on both internal reinsurance receipt and internal capital transfer variable. On the contrary, firm size is positively related to internal reinsurance provision. These findings are consistent with the notion the insurers with less insolvency risk receive the supports from other group members and have greater capability to support other affiliates. Moreover, the coefficient on New York indicator is positive (negative) in internal reinsurance receipt (provision) equation. These results may indicate that the recipients licensed in New York State use more internal reinsurance as they could be subject to more stringent regulation. In contrast, the providers licensed in New York State may need to reduce the volume of internal reinsurance provision in response to greater regulatory pressure.

With respect to profitability, the coefficients on returns on equities are negative and significant in internal capital transfer equation, which could imply that the insurers with greater profitability can supplement their capital positions, and thus require less capital injection from other affiliates. The positive coefficient on hurricane exposure in internal capital transfer equation may indicate that the insurers with more premiums written in hurricane-prone areas are more likely to incur large loss, and thus need more supports from other group members. In regards to line of business and geographic concentration variables, we find that geographic concentration exerts a positive effect on internal reinsurance provision. Conversely, both types of business concentration

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variables negatively affect internal reinsurance receipt. For the providers, the positive relation between geographic concentration and internal reinsurance provision may be explained by the lower underwriting risk. The providers with more concentrated underwriting portfolio may specialize in a few geographic areas to limit underwriting risk. Therefore, they are able to assume risk from other affiliates. Likewise, the recipients with more concentrated underwriting portfolio may have lower risk and thus need less internal reinsurance from other affiliates.

4.5.2 External Reinsurance and Capital Issuance

Table 3-8 presents the regression results regarding external reinsurance and capital issuance. In external reinsurance equation, the coefficients on the deviation from target leverage are not statistically significant for both providers and recipients. But the coefficient is negative and significant for the non-participants. The possible explanation for the negative coefficient found in non-participants subsample is the shortage of financial resource to purchase external reinsurance. Hypothesis 3 is not supported in our work. On the contrary, raising capital is an important way for both providers and receivers due to the positive and significant coefficients on target leverage deviation found in Panel B of Table 3-8. Hypothesis 4 receives supports in the subsamples of providers and recipients.

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Table 3- 8 The effects of capital structure deviation on external reinsurance and capital issuance

Variable	Panel A: Dependent variable: external reinsurance $_{t+1}$						Panel B: Dependent variable: capital issuance $_{t+1}$					
	Column (1) Providers		Column (2) Recipients		Column (3) Non-participants		Column (1) Providers		Column (2) Recipients		Column (3) Non-participants	
	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev
Constant	0.4070***	0.0847	0.1818***	0.0545	0.5966***	0.2035	0.0732**	0.0319	0.1000***	0.0375	0.0344	0.0598
Deviation from target leverage	0.0053	0.0057	0.0054	0.0048	-0.0040***	0.0105	0.0403***	0.0084	0.0509***	0.0085	0.0184	0.0152
Firm size $_t$	-0.0133***	0.0039	-0.0061**	0.0025	-0.0161**	0.0104	-0.0022	0.0014	-0.0035**	0.0017	-0.0012	0.0028
RBC ratio	-0.0015***	0.0004	-0.0000**	0.0000	-0.0011***	0.0004	0.0001	0.0002	0.0000	0.0000	-0.0003**	0.0001
New York State	0.0262	0.0176	-0.0132	0.0183	0.0222	0.0926	0.0051	0.0113	-0.0031	0.0093	0.0071	0.0187
Organization Form	-0.0290**	0.0124	0.0173	0.0115	-0.0335***	0.0315	0.0260***	0.0040	0.0201**	0.0079	0.0384***	0.0112
Returns on equities	-0.0569	0.0402	-0.0504*	0.0284	-0.1321***	0.0588	-0.1080***	0.0323	-0.2152***	0.0375	-0.2424***	0.0603
Hurricane exposure	0.1066***	0.0234	0.0726***	0.0154	0.0531	0.0354	0.0158*	0.0089	0.0236***	0.0088	0.0396***	0.0129
Geographic concentration	-0.0200	0.0173	-0.0064	0.0131	-0.0197	0.0390	-0.0148*	0.0075	-0.0189*	0.0097	-0.0014	0.0119
Line of business concentration	-0.0508**	0.0239	-0.0170	0.0170	-0.0532	0.0490	0.0125	0.0089	0.0197*	0.0109	-0.0181	0.0172
Long-tail lines $_t$	-0.0328	0.0270	-0.0855***	0.0198	-0.0880	0.0465	-0.0027	0.0098	0.0114	0.0107	-0.0003	0.0170
Commercial lines $_t$	0.0326**	0.0158	0.0306**	0.0125	0.0097	0.0392	-0.0009	0.0076	0.0087	0.0087	-0.0067	0.0146
Year dummies	Yes		Yes		Yes		Yes		Yes			
Chi-Square statistic	18.25***		15.02***		5.96***		12.62***		20.40***		8.58***	
Adjusted R-square	0.0935		0.0568		0.0655		0.0650		0.0770		0.0967	
Coefficient equality test (Wald test)	(1) vs (2)		(1) vs (3)		(2) vs (3)		(1) vs (2)		(1) vs (3)		(2) vs (3)	
	0.00		0.58		0.67		0.75		1.58		3.49*	

Notes:

1. The figures in parentheses are the standard errors of the coefficients.
2. ***, **, and * represent statistical significance levels of 1%, 5%, and 10% respectively.

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With respect to hypothesis 3a and 4a, none of the statistics regarding the coefficient equality tests are significant in table 3-8. Thus, we do not find the evidence implying significant difference among three subsamples in terms of the magnitude of the coefficients on target leverage deviation. Both hypothesis 3a and 4a are not supported.

With respect to other control variables, both firm size and RBC ratio exerts negative effects on external reinsurance usage for all the three groups, implying that the insurers with lower insolvency risk require less external reinsurance to improve their solvency positions. In regards to capital issuance, the coefficients on these two variables are negative and significant in some columns of Panel B, These results are generally consistent with those of external reinsurance. In addition to the aforementioned results, Table 3-8 shows that stock insurers are negatively associated with external reinsurance, whereas they are associated with more capital issuance. Based on these results, stock insurers tend to utilize greater access to capital markets to raise capital in their capital management practices.

4.5.3 Premiums Growth

The effects of target leverage deviation on direct and net premiums growth are presented in Table 3-9. In Panel A, the coefficients on target leverage deviation on direct premiums growth are generally not significant, only with the exception of the recipients. Contrary with our expectation, the coefficient is positive and significant for the

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recipients. The possible explanation is that the degree of target leverage deviation may indicate recipients' tendency to increase leverage and the capacity supplement from internal reinsurance transactions. When the recipients' actual leverage ratios exceed the target leverage ratios, they still receive additional capacity via internal reinsurance. Such capacity replenishment could further strengthen recipients' tendency to increase premiums written and leverage. In short, we do not find any supports for hypothesis 5.

The results regarding net premiums written are presented in Panel B of Table 3-9. The coefficients on target leverage deviation are negative for all the three subsamples. For providers, the coefficient is statistically significant. Hypothesis 5 receives partial supports based on the results in Panel B. On the other hand, the negative effect of target leverage deviation on net premiums growth is weaker for the recipients based on the absolute value of the coefficients reported in table 8. Moreover, the results of coefficient equality tests reveal a significant difference between providers and recipients. The negative effect of the deviation from target leverage ratio on net premiums written is significantly weaker for recipients. Based on these results, the capacity replenishment via internal reinsurance could mitigate the negative impact of undercapitalization on the recipients' premiums growth. Hypothesis 5a is partially supported in Panel B.

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Table 3- 9 The effect of capital structure deviation on premiums growth

Variable	Panel A: Dependent variable: direct premiums growth $_{t+1}$						Panel B: Dependent variable: net premiums growth $_{t+1}$					
	Column (1) Providers		Column (2) Recipients		Column (3) Non-participants		Column (1) Providers		Column (2) Recipients		Column (3) Non-participants	
	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev	Coef	St dev
Constant	0.2010	0.1438	0.5423***	0.0978	0.5827***	0.2074	0.4980***	0.1422	0.3034**	0.1240	1.6123***	0.5333
Deviation from target leverage	0.0142	0.0125	0.0368**	0.0156	-0.0179	0.0180	-0.1028***	0.0258	-0.0260	0.0168	-0.0418	0.0320
Firm size $_t$	-0.0008	0.0065	-0.0213***	0.0047	-0.0258**	0.0103	-0.0207	0.0061	-0.0135**	0.0059	-0.0729***	0.0217
RBC ratio	-0.0007	0.0010	0.0007***	0.0001	0.0023	0.0018	0.0060*	0.0036	0.0012***	0.0003	0.0018	0.0016
New York State	0.0353	0.0499	0.0001	0.0362	0.0945	0.0887	0.0615	0.0577	0.0234	0.0438	0.5194**	0.2456
Organization Form	0.0047	0.0163	0.0214	0.0150	0.0280	0.0294	0.0345***	0.0167	0.0213	0.0160	-0.0083	0.0740
Returns on equities	0.2402***	0.0774	0.1251**	0.0636	-0.0680	0.0726	-0.0810***	0.1004	-0.0596	0.0882	0.1727	0.1605
Hurricane exposure	0.0067	0.0250	0.0104	0.0241	0.0042	0.0394	0.0557*	0.0369	0.0247	0.0239	0.0211	0.0564
Geographic concentration	-0.0504**	0.0246	-0.0739***	0.0220	-0.0576	0.0431	-0.0046*	0.0272	-0.0532**	0.0245	-0.0654	0.0795
Line of business concentration	0.0556	0.0353	0.0424	0.0295	-0.0271	0.0544	0.0387	0.0348	0.0246	0.0349	-0.1004	0.0977
Long-tail lines $_t$	-0.1022**	0.0477	0.0206	0.0298	-0.0110	0.0563	0.0512	0.0426	0.0418	0.0367	-0.0039	0.0817
Commercial lines $_t$	0.0410	0.0315	0.0030	0.0244	-0.0173	0.0450	-0.0208	0.0306	0.0322	0.0283	-0.0628	0.0681
Year dummies	Yes		Yes		Yes		Yes		Yes			
Chi-Square statistic	2.83***		12.68***		1.96***		9.64***		16.21***		2.71***	
Adjusted R-square	0.0108		0.0478		0.0134		0.0491		0.0614		0.0236	
Coefficient equality test (Wald test)	(1) vs (2)		(1) vs (3)		(2) vs (3)		(1) vs (2)		(1) vs (3)		(2) vs (3)	
	1.28		2.19		5.29**		6.53**		2.30		0.19	

Notes:
1. The figures in parentheses are the standard errors of the coefficients.
2. ***, **, and * represent statistical significance levels of 1%, 5%, and 10% respectively.

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In addition to the aforementioned results, Table 3-9 reveals that several control variables exert significant effects on premiums growth. For instance, firm size negatively affects premiums growth variables in all the columns of Table 3-9. Such results may be attributed to the positive relation between firm size and age. Therefore, larger insurers could experience slower business growth. In contrast, we find that the coefficients on RBC ratio are positive and significant in several columns. The insurers with better solvency positions could be able to increase the amount of premiums written without the breach of regulatory requirements.

4.6 Further Analysis

In this section, we separate our samples into the following two categories: undercapitalized and overcapitalized insurers. Specifically, if the insurer' actual leverage exceeds target leverage, it will be classified as undercapitalized insurer. In contrast, the insurer whose actual leverage is below target leverage is defined as overcapitalized insurers. After such classification, we rerun the regressions in our second part analysis. As insurers may react to undercapitalization and overcapitalization in asymmetric manners, we conduct this additional analysis to address such concern. The results are summarized in Table 3-10 and the detailed reports on the regression results are available in Appendix C. In Table 3-10 and the results presented in Appendix C, we measure target leverage deviation as follows. For

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undercapitalized insurers, the deviation is calculated as the actual leverage ratio minus the target leverage ratio. Conversely, the deviation is measured as the target leverage ratio minus the real leverage ratio for overcapitalized insurers.

Table 3- 10 The coefficients on target leverage deviation in capital adjustment channel equations: split the samples by capitalization

Panel A: Undercapitalized insurers

1. The coefficient on target leverage deviation							
Dependent variable	Internal reinsurance provision	Internal reinsurance receipt	Internal capital transfer	External reinsurance use	Capital issuance	Direct premiums growth	Net premiums growth
(1) Providers (N=1,906)	-0.0319 **		0.0657 ***	0.0173 *	0.0760 ***	-0.0482 **	-0.0797 ***
	(0.0128)		(0.0171)	(0.0096)	(0.0185)	(0.0228)	(0.0238)
(2) Recipients (N=2,477)		0.0461 ***	0.0669 ***	0.0254 **	0.0871 ***	0.0241	-0.0050
		(0.0140)	(0.0138)	(0.0091)	(0.0159)	(0.0309)	(0.0298)
(3) Non-participants (N=718)			-0.0158	0.0149	0.0481 **	-0.0528 ***	-0.0854 ***
			(0.0107)	(0.0184)	(0.0219)	(0.0284)	(0.0213)
2. Coefficient equality tests							
(1) vs (2)			0.00	0.43	0.20	3.46 *	3.74 *
(1) vs (3)			16.27 ***	0.01	0.95	0.02	0.03
(2) vs (3)			22.30 ***	0.24	2.19	4.57 **	4.84 **

Panel B: Overcapitalized insurers

1. The coefficient on target leverage deviation							
Dependent variable	Internal reinsurance provision	Internal reinsurance receipt	Internal capital transfer	External reinsurance use	Capital issuance	Direct premiums growth	Net premiums growth
(1) Providers (N=2,441)	-0.0224		0.0101 *	-0.0128 *	0.0093	-0.0434	0.1560 ***
	(0.0168)		(0.0073)	(0.0097)	(0.0073)	(0.0288)	(0.0720)
(2) Recipients (N=3,573)		0.0077	0.0117 **	0.0295 **	0.0190 *	-0.0192	0.0403
		(0.0156)	(0.0057)	(0.0084)	(0.0115)	(0.0232)	(0.0297)
(3) Non-participants (N=1,124)			0.0403 **	0.0618 ***	0.0444 ***	-0.0098	0.0257
			(0.0162)	(0.0184)	(0.0170)	(0.0364)	(0.0788)
2. Coefficient equality tests							
(1) vs (2)			0.03	1.34	0.51	0.43 *	2.23 *
(1) vs (3)			2.86 *	4.95 ***	3.60 *	0.53	1.49
(2) vs (3)			2.75 *	2.27	1.53	0.05 **	0.03 **

Notes:
1. The figures in parentheses are the standard errors of the coefficients.
2. ***, **, and * represent statistical significance levels of 1%, 5%, and 10% respectively.
3. In panel A, the deviation from target leverage is calculated as the difference between actual leverage and target leverage, which represent the extent of undercapitalization.
4. In panel B, the deviation is calculated as the difference between target leverage and actual leverage, which measures the degree of overcapitalization.

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The results reported in Panel A of Table 3-10 are generally consistent with the aforementioned regression results, but with several exceptions. For instance, when we focus on undercapitalized subsample, the effect of target leverage deviation is negative and significant. With respect to external reinsurance usage, we find that the coefficients on target leverage deviation are positive and significant for providers and recipients in the analysis of undercapitalized subsample.

When we analyze undercapitalized subsamples, there is some evidence indicating the active role of external reinsurance in capital structure adjustment due to the statistically significant coefficients. Nevertheless, the values of the coefficients in external reinsurance equation are considerably smaller than those in internal capital transfer and capital issuance equations. These results may indicate that external reinsurance still plays a less important role in capital management. In regards to premiums growth, we find that target leverage deviation negatively affects direct premiums growth for both providers and non-participants in the analysis of undercapitalized subsample. Nevertheless, the coefficient on the deviation from target leverage is not significant for the subsample of recipients. When we use net premiums written as the proxy for premiums growth, we find similar results. In short, the above-mentioned evidence could confirm the conclusion that undercapitalized recipients

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experience less decline in premiums growth due to the capacity supplement via internal reinsurance transactions.

Turning to overcapitalized insurers, many of the coefficients in Panel B are statistically insignificant, only with some exceptions. For instance, the coefficients on the deviation from target leverage are positive and marginally significant in internal capital transfer equation. It implies that the extent of overcapitalization is positively associated with the amount of capital received via internal capital transfer in next year. Such direction of internal capital transfer is not consistent with the notion that financially weak affiliates tend to receive supports from other group members.

Moreover, we also find positive coefficients on target leverage deviation in both external reinsurance and capital issuance equation. With respect to external reinsurance, the possible explanation is the more financial resources available for insurers to purchase external reinsurance. The positive effect of target leverage deviation on capita issuance may be attributed to insurers' conservativeness regarding capital management. The insurers with larger extent of overcapitalization may be more conservative and exhibit greater tendency to raise capital. Turning to premiums growth, we find that target leverage deviation exerts a positive effect on the providers' net premiums growth, indicating that the degree of overcapitalization leads to higher growth of premiums.

5. Conclusion

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This research analyzes the channels through which group-affiliated insurers manage their capital structure toward target leverage ratios in the context of the U.S non-life insurance industry. Moreover, we further investigate whether insurers' roles in intra-group reinsurance arrangements affect how they make capital adjustment decisions. By analyzing the sample of group-affiliated insurers from 1999 to 2016, we find that internal reinsurance receipt, internal capital transfer, and capital issuance are used for reducing the deviation from target leverage ratios.

Furthermore, the coefficients on target leverage ratio in internal capital transfer equation are positive and significant for both providers and recipients. Nevertheless, such effect does not appear in the subsample of non-participants. These results could be caused by the economic connections created by intra-group reinsurance arrangements. Under these arrangements, the financial performance and solvency positions of providers and recipients are interconnected. The significant drop in the capital positions or insolvencies of these intra-group reinsurance participants could lead to more severe impact on the rest of group. Thus, they may have more chances to be supported when they are undercapitalized in comparison with the insurers without such economic linkages. With respect to premiums growth, some of our results indicate that recipients tend to experience less decline in premiums growth. Based on these results, the negative effect of undercapitalization on premiums growth could be offset by the

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effect of capacity replenishment via internal reinsurance. Our results suggest that intra-group reinsurance participation status affect the ways by which insurers adjust capital structure.

Appendix C

The detailed capital adjustment channels regression results for undercapitalized and overcapitalized insurers are presented in Table C1 to C4.

Table C- 1 The effects of target leverage deviation on internal reinsurance: split the samples by capitalization

Variable	Dependent variable: internal reinsurance $_{t+1}$			
	Undercapitalized subsample		Overcapitalized subsample	
	Column (1) Providers (N=1,906)	Column (2) Recipients (N=2,477)	Column (1) Providers (N=2,441)	Column (2) Recipients (N=3,573)
Constant	-0.2935 *	1.3022 **	-0.1337	1.5335 ***
	(0.1591)	(0.1729)	(0.1588)	(0.1530)
Deviation from target leverage	-0.0319 **	0.0461 **	-0.0224	0.0077
	(0.0128)	(0.0140)	(0.0168)	(0.0156)
Firm size	0.0195 ***	-0.0570 ***	0.0095	-0.0631 ***
	(0.0074)	(0.0079)	(0.0072)	(0.0073)
RBC ratio	-0.0002	0.0000	0.0002	0.0010 **
	(0.0005)	(0.0001)	(0.0008)	(0.0004)
New York State	-0.0520	0.0714 *	-0.0549	0.0797 **
	(0.0382)	(0.0420)	(0.0364)	(0.0392)
Organization Form	0.1026 ***	0.0439	0.1504 ***	0.0713 **
	(0.0253)	(0.0354)	(0.0217)	(0.0280)
Returns on equities	0.0785	0.1490 **	-0.0005	-0.1509 **
	(0.0595)	(0.0608)	(0.0857)	(0.0730)
Hurricane exposure	0.0264	0.0542	-0.0066	0.0152
	(0.0440)	(0.0430)	(0.0368)	(0.0344)
Geographic concentration	0.1717 ***	-0.0543	0.1300 ***	-0.1133 ***
	(0.0318)	(0.0384)	(0.0323)	(0.0342)
Line of business concentration	0.0402	-0.0662	0.0614	-0.1136 ***
	(0.0441)	(0.0417)	(0.0395)	(0.0438)
Long-tail lines	-0.0146	0.1816	-0.0177	0.1281 ***
	(0.0474)	(0.0443)	(0.0438)	(0.0441)
Commercial lines	0.0637 *	-0.0681	0.0918 ***	-0.0543
	(0.0363)	(0.0376)	(0.0335)	(0.0354)
Year fixed effects	Yes	Yes	Yes	Yes
F-test	6.97***	10.24***	9.96***	26.98***
R Square	0.0753	0.0884	0.0871	0.1590

Notes:
1. The figures in parentheses are the standard errors of the coefficients. ***, **, and * represent statistical significance levels of 1%, 5%, and 10% respectively.
2. For providers (recipients), the dependent variable is the ratio of net internal reinsurance assumed (net internal reinsurance ceded) to gross premiums written.

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Table C- 2 The effects of target leverage deviation on internal capital transfer: split the samples by capitalization

Variable	Dependent variable: internal capital transfer $_{t+1}$					
	Undercapitalized subsample			Overcapitalized subsample		
	Column (1) Providers (N=1,906)	Column (2) Recipients (N=2,477)	Column (3) Non-participants (N=718)	Column (1) Providers (N=2,441)	Column (2) Recipients (N=3,573)	Column (3) Non-participants (N=1,124)
Constant	0.1036 *	0.2277 ***	-0.0934	0.0644 **	0.0340	0.0493
	(0.0554)	(0.0645)	(0.0844)	(0.0308)	(0.0333)	(0.0525)
Deviation from target leverage	0.0657 ***	0.0669 ***	-0.0158	0.0101	0.0117 **	0.0403 **
	(0.0171)	(0.0138)	(0.0107)	(0.0073)	(0.0057)	(0.0362)
Firm size	-0.0025 **	-0.0108 ***	0.0034	-0.0029 **	-0.0007	-0.0031
	(0.0023)	(0.0031)	(0.0041)	(0.0014)	(0.0015)	(0.0026)
RBC ratio	-0.0002 *	-0.0000	-0.0004 **	0.0002	-0.0000	0.0002
	(0.0003)	(0.0000)	(0.0002)	(0.0002)	(0.0000)	(0.0003)
New York State	0.0023	-0.0079	-0.0084	0.0047	0.0048	0.0218
	(0.0188)	(0.0153)	(0.0173)	(0.0123)	(0.0103)	(0.0288)
Organization Form	0.0240 ***	0.0268 **	0.0521 ***	0.0063	0.0104 *	0.0188 ***
	(0.0059)	(0.0109)	(0.0133)	(0.0047)	(0.0063)	(0.0071)
Returns on equities	-0.1266 ***	-0.1718 ***	-0.2091 ***	-0.0938 ***	-0.0969 ***	-0.1637 ***
	(0.0429)	(0.0494)	(0.0649)	(0.0359)	(0.0318)	(0.0485)
Hurricane exposure	-0.0014	0.0133	0.0374 **	0.0036	0.0121 *	0.0150
	(0.0112)	(0.0142)	(0.0190)	(0.0088)	(0.0071)	(0.0128)
Geographic concentration	-0.0118	-0.0373 **	-0.0142	-0.0014	0.0033	-0.0097
	(0.0109)	(0.0145)	(0.0175)	(0.0069)	(0.0075)	(0.0112)
Line of business concentration	0.0005	0.0278	0.0436 *	0.0055	-0.0054	-0.0214
	(0.0122)	(0.0189)	(0.0239)	(0.0089)	(0.0080)	(0.0181)
Long-tail lines	-0.0116	-0.0029	-0.0453 *	0.0052	0.0072	0.0090
	(0.0130)	(0.0210)	(0.0248)	(0.0085)	(0.0075)	(0.0163)
Commercial lines	-0.0069	0.0080	0.0035	-0.0080	-0.0016	0.0022
	(0.0113)	(0.0148)	(0.0196)	(0.0065)	(0.0059)	(0.0132)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
F-test	19.26***	27.38***	6.93***	3.54***	4.17***	2.84***
R Square	0.0954	0.0941	0.0833	0.0113	0.0226	0.0409

Notes:

1. The figures in parentheses are the standard errors of the coefficients. ***, **, and * represent statistical significance levels of 1%, 5%, and 10% respectively.
2. For providers (recipients), the dependent variable is the ratio of net internal reinsurance assumed (net internal reinsurance ceded) to gross premiums written.

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Table C- 3 The effects of target leverage deviation on external reinsurance and capital issuance: split by capitalization

Variable	Dependent variable: external reinsurance $_{t+1}$						Dependent variable: capital issuance $_{t+1}$					
	Undercapitalized subsample			Overcapitalized subsample			Undercapitalized subsample			Overcapitalized subsample		
	Column (1) Providers (N=1,906)	Column (2) Recipients (N=2,477)	Column (3) Non-participants (N=718)	Column (1) Providers (N=2,441)	Column (2) Recipients (N=3,573)	Column (3) Non-participants (N=1,124)	Column (1) Providers (N=1,906)	Column (2) Recipients (N=2,477)	Column (3) Non-participants (N=718)	Column (1) Providers (N=2,441)	Column (2) Recipients (N=3,573)	Column (3) Non-participants (N=1,124)
Constant	0.4169 ***	0.2831 ***	0.7235 ***	0.4011 ***	0.1257 ***	0.5841 ***	0.0804	0.1788 **	0.1184	0.0348	0.0722 *	0.0613
	(0.0948)	(0.0698)	(0.2313)	(0.0499)	(0.0331)	(0.1188)	(0.0556)	(0.0730)	(0.1264)	(0.0309)	(0.0400)	(0.0611)
Deviation from target leverage	0.0173 *	0.0254 ***	0.0149	0.0128	0.0295 ***	0.0618 ***	0.0760 ***	0.0871 ***	0.0481 **	0.0093	0.0190 *	0.0444 ***
	(0.0096)	(0.0091)	(0.0184)	(0.0097)	(0.0084)	(0.0184)	(0.0185)	(0.0159)	(0.0219)	(0.0073)	(0.0115)	(0.0170)
Firm size	-0.0142 ***	-0.0109 ***	-0.0204 *	-0.0130	-0.0041 ***	-0.0168 ***	-0.0026	-0.0090 ***	-0.0047	-0.0012	-0.0025	-0.0036
	(0.0044)	(0.0032)	(0.0111)	(0.0022)	(0.0015)	(0.0056)	(0.0025)	(0.0034)	(0.0054)	(0.0014)	(0.0019)	(0.0030)
RBC ratio	-0.0021 ***	-0.0000 ***	-0.0013 ***	-0.0014 ***	-0.0001 **	-0.0006	-0.0002	-0.0000	-0.0004 **	0.0001	-0.0000	0.0002
	(0.0004)	(0.0000)	(0.0003)	(0.0004)	(0.0000)	(0.0007)	(0.0005)	(0.0000)	(0.0002)	(0.0003)	(0.0000)	(0.0003)
New York State	0.0294	-0.0439 **	-0.0557	0.0209 **	0.0018	0.0653	-0.0141	-0.0155	-0.0078	0.0112	0.0018	0.0173 **
	(0.0266)	(0.0184)	(0.0940)	(0.0097)	(0.0115)	(0.0751)	(0.0201)	(0.0172)	(0.0211)	(0.0139)	(0.0111)	(0.0293)
Organization Form	-0.0303 **	0.0088	-0.0689	-0.0319 ***	0.0209 ***	-0.0270	0.0335 ***	0.0244 *	0.0431 *	0.0102 **	0.0108	0.0237 ***
	(0.0140)	(0.0164)	(0.0435)	(0.0067)	(0.0057)	(0.0184)	(0.0058)	(0.0135)	(0.0236)	(0.0048)	(0.0066)	(0.0076)
Returns on equities	-0.0437	-0.0474	-0.1190 *	-0.0541	-0.0027	-0.1221	-0.1070 **	-0.2342 ***	-0.2252 ***	-0.0684 **	-0.1082 ***	-0.1839 ***
	(0.0494)	(0.0369)	(0.0671)	(0.0456)	(0.0322)	(0.0775)	(0.0417)	(0.0547)	(0.0736)	(0.0410)	(0.0339)	(0.0610)
Hurricane exposure	0.1302 ***	0.0801 ***	0.0495	0.0880 ***	0.0620 ***	0.0499 **	0.0184	0.0236	0.0746 ***	0.0137	0.0151 *	0.0139
	(0.0258)	(0.0199)	(0.0375)	(0.0129)	(0.0084)	(0.0196)	(0.0130)	(0.0153)	(0.0236)	(0.0100)	(0.0083)	(0.0138)
Geographic concentration	-0.0319 *	-0.0139	-0.0442	-0.0101	0.0014	-0.0070	-0.0247 **	-0.0357 **	0.0083	-0.0041	-0.0063	-0.0108
	(0.0190)	(0.0163)	(0.0472)	(0.0100)	(0.0076)	(0.0226)	(0.0120)	(0.0172)	(0.0217)	(0.0079)	(0.0087)	(0.0130)
Line of business concentration	-0.0566 **	-0.0244	-0.0316	-0.0481 ***	-0.0135	-0.0870 ***	0.0068	0.0441 **	-0.0447	0.0151 *	-0.0043	-0.0276
	(0.0281)	(0.0207)	(0.0607)	(0.0133)	(0.0109)	(0.0269)	(0.0134)	(0.0203)	(0.0369)	(0.0090)	(0.0098)	(0.0196)
Long-tail lines	-0.0266	-0.0712 ***	-0.1515 ***	-0.0353 **	-0.0961 ***	-0.0477 *	0.0001	-0.0010	-0.0297	-0.0045	0.0163 *	0.0201
	(0.0327)	(0.0236)	(0.0519)	(0.0159)	(0.0125)	(0.0251)	(0.0152)	(0.0225)	(0.0293)	(0.0098)	(0.0086)	(0.0178)
Commercial lines	0.0169	0.0235	0.0554	0.0424 ***	0.0348 ***	-0.0129	-0.0016	0.0193	-0.0199	-0.0021	0.0032	-0.0043
	(0.0204)	(0.0148)	(0.0452)	(0.0094)	(0.0081)	(0.0188)	(0.0124)	(0.0170)	(0.0219)	(0.0070)	(0.0074)	(0.0150)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test	9.98***	8.76***	4.29***	9.56***	9.52***	3.67***	10.67***	14.73***	6.02***	3.00***	3.65***	2.89***
R Square	0.1092	0.0753	0.1064	0.0836	0.0584	0.0583	0.1166	0.1260	0.1540	0.0208	0.0189	0.0419

Notes:
1. The figures in parentheses are the standard errors of the coefficients.
2. ***, **, and * represent statistical significance levels of 1%, 5%, and 10% respectively.

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Table C- 4 The effect of target leverage deviation on premiums growth: split by capitalization

Variable	Dependent variable: direct premiums growth $_{t+1}$						Dependent variable: net premiums growth $_{t+1}$					
	Undercapitalized subsample			Overcapitalized subsample			Undercapitalized subsample			Overcapitalized subsample		
	Column (1) Providers (N=1,906)	Column (2) Recipients (N=2,477)	Column (3) Non-participants (N=718)	Column (1) Providers (N=2,441)	Column (2) Recipients (N=3,573)	Column (3) Non-participants (N=1,124)	Column (1) Providers (N=1,906)	Column (2) Recipients (N=2,477)	Column (3) Non-participants (N=718)	Column (1) Providers (N=2,441)	Column (2) Recipients (N=3,573)	Column (3) Non-participants (N=1,124)
Constant	0.3541	0.8442 ***	0.6476 **	0.1038	0.3837 ***	0.4498 *	0.4250 **	0.5699 ***	1.4919 **	0.5480 ***	0.0419	1.5399 **
	(0.2267)	(0.1600)	(0.2616)	(0.1532)	(0.1225)	(0.2624)	(0.1814)	(0.1727)	(0.6286)	(0.1988)	(0.1538)	(0.7501)
Deviation from target leverage	-0.0482 **	0.0241	-0.0528 ***	-0.0434	-0.0192	-0.0098	-0.0797 ***	-0.0050	-0.0854 ***	0.1560 **	0.0403	0.0257
	(0.0228)	(0.0309)	(0.0186)	(0.0288)	(0.0232)	(0.0364)	(0.0238)	(0.0298)	(0.0213)	(0.0720)	(0.0297)	(0.0788)
Firm size	-0.0046	-0.0402	-0.0253 **	0.0020	-0.0117 **	-0.0199	-0.0172 **	-0.0264 ***	-0.0703 **	-0.0231 ***	-0.0002	-0.0689 **
	(0.0096)	(0.0079)	(0.0123)	(0.0070)	(0.0057)	(0.0128)	(0.0079)	(0.0083)	(0.0291)	(0.0086)	(0.0071)	(0.0292)
RBC ratio	0.0002	0.0007 ***	0.0014	-0.0008	0.0007 *	0.0037	0.0045	0.0009 ***	-0.0007	0.0066 *	0.0024 ***	0.0077
	(0.0014)	(0.0000)	(0.0022)	(0.0011)	(0.0004)	(0.0036)	(0.0044)	(0.0000)	(0.0010)	(0.0038)	(0.0004)	(0.0055)
New York State	0.0437	-0.0619	-0.0048	0.0380	0.0398	0.2120 **	0.0283	-0.0371	0.4140	0.0907	0.0281	0.6548
	(0.0822)	(0.0411)	(0.0422)	(0.0547)	(0.0449)	(0.1549)	(0.0663)	(0.0554)	(0.4099)	(0.0844)	(0.0552)	(0.4167)
Organization Form	0.0069	0.0268	0.0481	0.0152	0.0257	0.0309	0.0044	0.0063	-0.0350	0.0445 *	0.0280	0.0004
	(0.0276)	(0.0250)	(0.0422)	(0.0168)	(0.0177)	(0.0355)	(0.0224)	(0.0290)	(0.1165)	(0.0232)	(0.0205)	(0.0923)
Returns on equities	0.1278	0.2517 ***	-0.0207	0.3828 ***	-0.0679	-0.2890 *	0.0696	0.0858	0.2474	-0.2193	-0.2318 **	0.0500
	(0.1013)	(0.0915)	(0.0826)	(0.1258)	(0.0938)	(0.1666)	(0.1145)	(0.1254)	(0.1869)	(0.1965)	(0.1137)	(0.3704)
Hurricane exposure	-0.0256	0.0746 *	0.0792 *	0.0329	-0.0238	-0.0219	0.0635	0.0564 *	0.1012	0.0451	0.0001	0.0101
	(0.0325)	(0.0390)	(0.0432)	(0.0352)	(0.0287)	(0.0514)	(0.0434)	(0.0308)	(0.0716)	(0.0542)	(0.0335)	(0.0833)
Geographic concentration	-0.0921 **	-0.1441 ***	-0.1300 **	-0.0195	-0.0292	-0.0140	-0.0319	-0.0748 **	-0.0544	0.0213	-0.0363	-0.0780
	(0.0387)	(0.0321)	(0.0569)	(0.0282)	(0.0279)	(0.0513)	(0.0373)	(0.0344)	(0.0762)	(0.0368)	(0.0333)	(0.1146)
Line of business concentration	0.0912 *	0.0850 **	0.0800	0.0287	0.0155	-0.0694	0.0653	0.0195	0.0908	0.0020	0.0032	-0.1953
	(0.0549)	(0.0419)	(0.0679)	(0.0440)	(0.0359)	(0.0727)	(0.0335)	(0.0364)	(0.1259)	(0.0567)	(0.0491)	(0.1393)
Long-tail lines	-0.0898	0.0247	-0.0551	-0.1075 *	0.0217	0.0133	0.0318	0.0496	-0.0408	0.0814	0.0469	0.0343
	(0.0678)	(0.0474)	(0.0876)	(0.0638)	(0.0366)	(0.0571)	(0.0474)	(0.0406)	(0.1089)	(0.0667)	(0.0537)	(0.1097)
Commercial lines	0.0194	-0.0428	0.0155	0.0550	0.0272	-0.0382	0.0022	-0.0315	-0.0656	-0.0448	0.0653	-0.0754
	(0.0470)	(0.0383)	(0.0561)	(0.0404)	(0.0281)	(0.0547)	(0.0345)	(0.0344)	(0.0702)	(0.0441)	(0.0401)	(0.0927)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test	1.68**	9.61***	1.64**	2.24***	5.44***	1.66**	2.71***	9.52***	1.67**	7.01***	10.69***	2.00***
R Square	0.0092	0.0829	0.0226	0.0130	0.0313	0.0151	0.0228	0.0822	0.0201	0.0602	0.0659	0.0227

Notes:
1. The figures in parentheses are the standard errors of the coefficients.
2. ***, **, and * represent statistical significance levels of 1%, 5%, and 10% respectively.

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