

**The Sensitivity of Reinsurance Demand to Counterparty Risks:  
Evidence from US Property-Liability Insurance Industry**

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**Abstract**

This article investigates market discipline in the reinsurance market by examining the sensitivity of reinsurance demand to reinsurer counterparty risks for a sample of US property-liability insurance companies. Using the financial strength rating of reinsurers as a proxy for reinsurance counterparty risk, we find evidence of market discipline that reinsurance demand is sensitive to counterparty risk. Specifically, reinsurance demand reacts negatively to reinsurer rating downgrade, with the reduction being the largest when a “weak” reinsurer gets “weaker,” followed by a reinsurer being downgraded below a benchmark rating. The sensitivity is higher for authorized reinsurance than for unauthorized reinsurance. Reinsurance demand sensitivity to counterparty risk is found to be lower for ceding insurers with higher leverage. Ceding insurers with high reinsurer sustainability are less sensitive to the non-critical rating downgrade of reinsurers. In addition, reinsurance demand is found to be less sensitive to reinsurer upgrading than to reinsurer downgrading.

JEL classification: G22; G32

Keywords: counterparty risk, reinsurance demand, financial strength rating, market discipline, property-liability insurance

## **The Sensitivity of Reinsurance Demand to Counterparty Risks: Evidence from US Property-Liability Insurance Industry**

### **1. Introduction**

Reinsurance plays an important economic role in risk management. With the capacity of diversifying risks nationwide and globally, reinsurance is an important tool for primary insurance companies to manage underwriting risks, alleviate insolvency risks, satisfy stringent regulatory requirements, and deal with uncertainties caused by regulation changes or catastrophic losses. In addition, primary insurance companies can improve their balance sheet items by using reinsurance. By transferring or ceding risks to reinsurers, a ceding insurer may take a credit (e.g., reducing loss reserves and unearned premium reserves) in its financial statements, which provides surplus relief and increases the underwriting capacity of ceding insurers. The use of reinsurance, however, creates a new type of risk for ceding insurers: reinsurer counterparty risk. In the US, reinsurer counterparty risk is still a “grey area” of insurance regulation. Other than requiring unauthorized (alien) reinsurers to post collaterals for the coverage they provide, current regulations offer little incentive for primary insurers to distinguish between reinsurers with stronger financial strength and those with weaker ratings. With loose regulations on reinsurance credit risk, it is important to examine if the private market offers adequate discipline for ceding insurers to manage that risk, which is the theme of this paper.

Traditionally, research on reinsurance has focused on dealing with asymmetric information in the insurer-reinsurer relationship (e.g., Doherty and Smetters, 2005 and Garven, Hilliard, and Grace, 2014) and on exploring the optimal design for reinsurance contracts (e.g., Cai et al., 2013 and Tan and Weng, 2012). More recently, there has been more empirical research on the factors determining the demand for reinsurance by ceding insurers (e.g., Cole and McCullough, 2006 and Lin, Yu, and Peterson, 2014). Additionally, the most recent financial crisis of 2007-2010 has put the reinsurance industry into the public eye for its

close interconnectedness with the primary insurance industry and for the possibility of creating systemic risks for the economy. Therefore, reinsurer risk and financial solvency has become an important concern for regulators, ceding insurers, and researchers. Ceding insurers may take “credit” from their reinsurance transactions, but for regulators, that credit for reinsurance only makes sense when reinsurers are able to fulfill their obligations. Also, it is argued that even in the absence of regulations, ceding insurers should still have concerns regarding reinsurance credit quality. Poor reinsurance contracting may adversely affect the solvency ability of ceding insurers and lower their financial strength ratings (Park and Xie, 2014), which may ultimately lower the revenue of ceding insurers, as insurance buyers may opt to “pay for quality” (Cummins and Danzon, 1997).

Despite the credit risk imposed by reinsurance, little empirical research has been done to examine how credit risk from reinsurers may actually affect ceding insurers’ behaviors. Park and Xie (2014) analyze the impact of credit risk from reinsurers on ceding insurers’ financial strength and stock performance and find both that ceding insurers are more likely to be downgraded when their contracting reinsurers are downgraded and that ceding insurers’ stocks also react negatively to their reinsurers’ downgrades. The paper suggests that counterparty risk from reinsurers is important to ceding insurers and should be carefully managed.

The objective of this paper is to examine the relationship between reinsurance demand and the credit risk change of reinsurers by using the US property-liability insurance industry as an experiment. In particular, we investigate the sensitivity of reinsurance demand to the downgrading of reinsurers and likelihood that ceding insurers will revise a contract relationship with a reinsurance partner whose financial strength changes. We hypothesize that, if market discipline exists, a ceding insurer will recognize the impact of reinsurers’ credit risk change and adjust its contracts accordingly when a reinsurer’s rating changes. In particular,

ceding insurers would adjust trading terms with the downgraded counterparty reinsurers through changes in both price and quantity of reinsurance purchased, or, in extreme cases, terminate the relationship with the downgraded reinsurers. If this is the case, direct regulation on reinsurance may not be needed. On the other hand, if ceding insurers fail to adjust their reinsurance position in accordance with reinsurers' credit risks, it may suggest that such insurers simply use reinsurance for surplus relief and have neglected credit quality. Solvency risk to ceding insurers may therefore increase when the reinsurer downgrades, and such risk has to be taken seriously by the insurers, market, and regulators.

This paper contributes to the literature in several ways. First, it enriches the existing literature on counterparty risk in the financial services industries (Jarrow and Yu, 2001 and Jorion and Zhang, 2009) by extending the research into the insurance-reinsurance market. With the collapse of the subprime mortgage market in 2007, counterparty risk has received increasing attention from the financial services industry and regulators and has become a crucial issue in risk management. Managing counterparty risk is an important theme of the Dodd-Frank Act of 2010 and is also an important concern of rating agencies (Moody's Investors Services, 2015).

Second, the paper intends to provide implication of counterparty risk regulation in the insurance/reinsurance market. With the turmoil brought by the meltdown of insurance giant AIG and the financial difficulties experienced by some life insurers and global reinsurers during the crisis, counterparty risk in the insurance/reinsurance market has become an important issue in insurance regulation as well. Discussion continues as to how much regulation is needed in order to supervise reinsurance contracts/transactions and whether market discipline can serve as a substitute for regulation (Gatumel and Lemoyne De Forges, 2013). Our paper will provide further evidence for the effectiveness of market discipline.

Third, the reinsurance market in the United States provides a great opportunity to test

the question of customer-driven market discipline. Epermanis and Harrington (2006) examine market discipline in the primary insurance market by looking at policyholders' insurance demand changes following insurance companies' financial strength rating changes. One difficulty experienced by that research is that state guaranty funds will compensate part (or all) of policyholders' losses in case of insurers' insolvency, which may distort the incentive of policyholders to look for healthy insurers. Such contamination does not exist in the reinsurance market, as guaranty funds do not protect insurance companies. Therefore, the paper can provide a "cleaner" testing result of market discipline without the contamination of the guaranty fund.

The remainder of the article is structured as follows. The next section presents the literature review and hypotheses tested, followed by the discussion of the data and methodology. We then report empirical results and conclude the paper.

## **2. Literature Review and Hypotheses**

### ***Insurance, Reinsurance Credit Risk, and Market Discipline***

Ceding insurers transfer part of their underwriting risks to reinsurers to obtain surplus relief, hedge the risk of catastrophic losses, and stabilize underwriting performance. This act of risk management, however, gives rise to another type of risk: reinsurance credit risk; that is, ceding insurers may not be able to recover losses from their counterparty reinsurers. As a general practice, ceding insurers manage credit risk by taking into consideration the creditworthiness of the reinsurer counterparties and by monitoring their own accumulated risk exposures to any single contracted reinsurer (Bodoff, 2013). To assess the credit risk of reinsurers, most ceding insurance companies rely on rating agency models. In addition, in the US, it is a common practice for ceding insurers to require "collateral" from unauthorized (alien) reinsurers. Also, reinsurance contracts often contain a "special termination clause,"

which states that if the counterparty reinsurer's financial strength rating deteriorates below some crucial threshold, then the ceding company has the right to require the reinsurer to post collateral for unpaid reinsured claims.

The US statutory accounting principle (SAP) allows ceding insurers to take credit from reinsurance transactions by deducting from their loss reserves the losses ceded to authorized reinsurers.<sup>1</sup> However, current regulation provides little incentive for ceding insurers to manage reinsurance credit risk. As argued by Bodoff (2013), the balance sheet of ceding insurers has an item titled "provision for reinsurance," which is connected to Schedule F and reduces the surplus of ceding insurers, but this penalty does not reflect the varying credit risk of reinsurers and therefore offers no incentive for the ceding insurers to distinguish between reinsurers of stronger or weaker financial strength. With such loose regulation on reinsurance credit risk, it is important to determine whether or not the private market offers adequate discipline for ceding insurers to manage counterparty risk.

Literature on market discipline in insurance is somewhat limited. Harrington (2004) provides some general discussion of market discipline in the insurance and reinsurance market. Eling (2012) provides a literature review on market discipline in the banking and insurance industries. Empirical work on market discipline in insurance falls into two categories: customer-driven market discipline and investor-driven market discipline.

Studies on customer-driven market discipline examine the impact of an insurer's financial strength rating change on policyholders' demand for insurance, usually measured by premium growth or lapse of policies. Epermanis and Harrington (2006) analyze the relationship between insurance premium growth and changes in financial strength ratings for US property/casualty insurers and find significant premium declines in the year of and the year following rating downgrades, with insurers losing an A- rating suffering the most.

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<sup>1</sup> The Nonadmitted and Reinsurance Reform Act of 2010 released the collateral requirement for unauthorized reinsurers. Financially stronger (unauthorized) reinsurers are no longer required to post 100 percent collateral.

Premium declines were generally greater for firms with relatively low pre-downgrade ratings (A.M. Best's rating of either A - or B++ and below) and were also concentrated among commercial insurance, where little state fund guarantee is provided. They conclude that premiums surrounding rating changes are consistent with risk-sensitive demand. Similarly, Baranoff and Sager (2007) and Grace et al. (2015) also examine the issue in the US life insurance market, while Eling and Schmit (2012) look at the issue in the German insurance market.

Studies on investor-driven market discipline mainly focus on the impact of rating changes on insurance companies' stock prices, such as Halek and Eckles (2010) and Singh and Power (1992).

Research examining market discipline in the reinsurance market specifically and the impact of the creditworthiness of reinsurers is scarce. Park and Xie (2014) is the only paper providing empirical evidence on how a reinsurer's financial rating downgrade affects a ceding insurer's rating and stock prices. That paper finds that both financial ratings and stock prices of ceding insurers react negatively to the downgrading of counterparty reinsurers. However, the paper does not look into how ceding insurers change their reinsurance demand in regard to the downgraded counterparty reinsurers.

### ***Determinants of Reinsurance Demand***

Existing literature in general examines reinsurance demand at the firm aggregate level. Garven and Lamm-Tennant (2003) summarize the literature on theoretical motivations for and analytic approaches of studying the demand for reinsurance. The paper documents that some traditional literature focuses on the risk management aspect of the reinsurance decision (e.g., Borch, 1962 and Blazenko, 1986), and others analyze the issue from a capital structure perspective (Doherty and Tiniç, 1981; Mayers and Smith, 1981; and Garven, 1987). Mayers



and Smith (1990) and Garven and Lamm-Tennant (2003) provide empirical analyses on the factors that may affect an insurer's total reinsurance demand, using a sample of US property-liability insurers. Mayers and Smith (1990) find that ownership structure (in a more refined way) matters for reinsurance demand, and firm size, line-of-business concentration, and geographic concentration all have a significant (negative) impact on the demand for reinsurance. Garven and Lamm-Tennant (2003) additionally find that leverage, asset volatilities, equity risk (cash flow volatilities), and length of tail have a significant (positive) impact on the demand for reinsurance.

Recent literature on reinsurance demand considers more subtle relationships between ceding insurers and reinsurers. For example, Cole and McCullough (2006) examine whether the state of the reinsurance industry affects the demand for reinsurance by exploring the overall demand for reinsurance and the utilization of foreign reinsurance by U.S. insurers. Bernard and Ludkovski (2012) design a static model to examine the counterparty default risk on optimal reinsurance contracts. They argue that reinsurance becomes unreliable in the presence of counterparty risk and find that this risk both increases the reinsurance demand in the tail and decreases the overall optimal reinsurance premium level. Garven, Hilliard, and Grace (2014) specifically examine the tenure of the insurer-reinsurer relationship and its impact on reducing information asymmetry in reinsurance transactions. The paper provides empirical evidence that the amount of reinsurance, the ceding insurer's profitability, and the credit quality all increase with the tenure of the insurer-reinsurer relationship. Lin, Yu, and Peterson (2014) further enrich the literature on reinsurance demand by testing the impact of contracted numbers of reinsurers (network centrality) and the business linkage among the set of reinsurers used (network cohesion) on the reinsurance level.

Despite the fact that the insurer-reinsurer relationship and the counterparty risk imposed by reinsurers have both received more attention following the recent financial crisis,

there is no direct empirical work testing how ceding insurers' reinsurance strategy changes with the credit quality change of reinsurers, and this paper intends to fill that gap.

***Hypotheses:***

Reinsurance transactions are less regulated in the US insurance industry. The existing regulations focus on rules affecting the financial statements of the ceding insurers, i.e., whether the ceding insurers can take any credit to reduce their liabilities from reinsurance transactions. However, these regulations give little consideration to the credit risk imposed by reinsurers and basically rely on the market mechanism to control counterparty risk in the reinsurance market.

Theoretically, in a competitive market, ceding insurers will have incentive to reduce counterparty risk, because by successfully managing counterparty risk, ceding insurers can reduce the probability of insolvency and increase the possibility of securing a good financial rating, which in turn may have a positive impact on their contractual relationships with policyholders and other stakeholders, and protect firms' franchise value. This market-discipline mechanism can only work if ceding insurers have good information on the creditworthiness of reinsurers and can adjust their contractual relationship with the reinsurers accordingly. Epermanis and Harrington (2006) demonstrate the effect of market discipline in the primary insurance market, documenting that insurance premium revenue declines when an insurance company suffers a rating downgrade in the primary insurance market, with the insurers downgraded below certain benchmarks (A.M. Best's rating of A -, for example) suffering the greatest losses in premium income. In addition, the paper finds that premium revenue drops more when weaker insurers (A.M. Best's rating of either A - or B++ and below) get weaker. We therefore hypothesize that:

*H1-1: The reinsurance demand of ceding insurers is sensitive to the credit risk of*

*reinsurers. In particular, reinsurance ceded to a counterparty reinsurer will decrease if the counterparty reinsurer suffers a rating downgrade.*

*The demand sensitivity is heterogeneous depending on the pre-downgrading financial strength of the reinsurers and the level of rating changes. Specifically, if a reinsurer is downgraded below certain benchmark rating, the reinsurance ceded to it will be reduced more than the amount ceded to those reinsurers suffering a downgrading but still maintaining a rating above the benchmark.*

Harrington (2004) mentions that potentially high search costs and the opacity of insurance firms may make it difficult for policyholders to identify high-quality insurers and advisors, which in turn reduce the risk sensitivity of demand in the primary insurance market. The reduced risk sensitivity in primary insurance demand may have some impact on the reinsurance market, as it may reduce ceding insurers' risk sensitivity in reinsurance demand and may actually encourage ceding insurers to contract with low-quality reinsurers for cost-effectiveness. In addition, as pointed out by Bodoff (2013), there is a divergence in time and personnel in managing counterparty risk by ceding insurers in the current mechanism, which may make it hard for ceding insurers to respond to a reinsurer's creditworthiness change. If the current counterparty risk management system of ceding insurers is not effective or even provides an excuse for mismanagement of counterparty risk, the above hypothesis will not hold and no sensitivity will be observed.

The conjecture of H1-1 can also easily be applied to reinsurer rating upgrades. That is, reinsurance ceded to a counterparty reinsurer will increase if the counterparty reinsurer enjoys a rating upgrade that suggests the credit risk of the counterparty reinsurer is now reduced. A reinsurer rating upgrade may represent good news to the ceding insurer because the ceding insurer has already built certain relationships with the reinsurer. A ceding insurer can now enjoy a lower reinsurer credit risk, without incurring the extra costs of creating a

new reinsurance contract. However, stronger financial strength may also encourage the reinsurer to increase its price for reinsurance to reflect its better quality. The ceding insurer, in contrast, may have a target counterparty risk and price, and it may not be willing to pay extra for a lower reinsurer credit risk. In considering the tradeoff between price and risk, it is possible that the ceding insurer may reduce its demand for reinsurance from a counterparty reinsurer after the reinsurer's rating upgrade. Depending on the strength of these two effects, the reinsurance demand change due to reinsurer rating upgrade can be either positive or negative.

*H1-2: The impact of reinsurer rating upgrades on reinsurance demand is ambiguous; it may depend on the ceding insurer striking a balance between a reduced credit risk and an increased reinsurance price.*

In the United States, the Credit for Reinsurance Model law places collateral requirements for unauthorized reinsurance in place (Cole, McCullough, and Powell, 2010) to reduce reinsurer counterparty credit risk. Before 2010, unauthorized reinsurers were required to deposit 100% collateral for the risk they assumed from US ceding insurers; otherwise, ceding reinsurers could not take a credit against their loss reserve or unearned premium reserve if uncollateralized. These collaterals may help mitigate the impact of the credit risk of the reinsurers and make reinsurance demand less sensitive to reinsurers' financial rating. Hence, we hypothesize that:

*H2: Reinsurance demand sensitivity is heterogeneous depending on the type of reinsurance transaction. In particular, the demand for **unauthorized reinsurance** is less sensitive to the rating changes of counterparty reinsurers than the demand for **authorized reinsurance**.*

Epermanis and Harrington (2006) argue that the possible effect of rating changes on reinsurance demand is ambiguous if reinsurance is used simply to satisfy regulatory

scrutiny or action. If this is the primary purpose of a reinsurance transaction, the default risk of a reinsurer may not matter, as long as the regulations allow the ceding insurer to take credit from the reinsurance transaction. For ceding insurers with abundant capital and low leverage, the regulatory scrutiny may not be a strong binding condition; and regulatory scrutiny may matter more for ceding insurers with high leverage. In addition, the judgment proof hypothesis may also apply to high-leveraged ceding insurers. Such insurers have fewer assets to protect, and therefore have lower concern for insolvency risk, which may makes them to be less sensitive to reinsurance credit risk. We therefore predict that

*H3: Ceding insurers with high leverage are less sensitive to the downgrading of counterparty reinsurers because such insurers have fewer assets to protect, and they tend to buy reinsurance mainly for surplus relief to meet minimum regulatory requirements.*

As suggested by Garven, Hilliard, and Grace (2014), some ceding insurers tend to maintain a network with a group of reinsurers and may develop an implicit long-term contract relationship with specific reinsurers (contract sustainability). This long-term relationship may in turn give less incentive for ceding insurers to quickly adjust their placement of business with those reinsurers when they suffer credit quality problems. We then predict that

*H4: Reinsurance demand sensitivity is lower for downgraded/upgraded reinsurers that have maintained a long-term relationship with the ceding insurer.*

### **3. Data and Methodology**

#### ***Data source and sample description***

We study the sensitivity of reinsurance demand to credit risk of counterparty reinsurers in the US property-liability insurance industry. The data period used is 2002-2009. Financial data for individual ceding insurers is obtained from NAIC annual statements. The counterparty reinsurers' information about each ceding reinsurer is collected from the NAIC Schedule

F–part 3, from which we are able to collect information such as reinsurers’ names, domiciles, ceded reinsurance premiums, and recoverable amounts. The financial strength rating information for reinsurers is collected from A.M. Best, S&P, and Moody’s. We manually merge the rating data with the NAIC data by matching the reinsurer’s name, domicile, and NAIC code if available.

Our analysis is at the firm level. We keep in our sample unaffiliated single firms and affiliated firms of each group if a group contains multiple affiliates.<sup>2</sup> To be included in the sample, a ceding insurer must have positive direct and net premiums written in year  $t-1$ , year  $t$ , and year  $t+1$ , and have at least two annual observations for other variables used.

Table 1 tabulates the number of insurer-reinsurer observations, reinsurance rating changes by rating category, and rating changes by rating category and reinsurance type during the sample period. The table shows that there are more authorized reinsurance transactions than unauthorized reinsurance transactions, and more unaffiliated transactions than affiliated transactions. The majority of rated reinsurance transactions have benchmark (A- or equivalent) or above bench ratings. During the sample period, there were more reinsurer rating downgrades than upgrades overall, but for reinsurers that already had benchmark ratings, more upgrades were observed than downgrades. In addition, reinsurers with low ratings tend to experience more rating changes than other groups.

[Insert Table 1 Here]

## ***Methodology***

### *A. Univariate analysis*

We begin with univariate analysis to document the abnormal reinsurance demand change upon a reinsurer’s rating change. We measure reinsurance demand change,  $\Delta R\_demand_{i,j,t}$ , as a growth in the proportion of reinsurance premium ceded to a particular

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<sup>2</sup> Ceding insurers that are reinsurance specialists are excluded from the sample.

reinsurer  $j$  by ceding insurer  $i$ .  $\Delta R\_demand_{i,j,t}$  is defined as (reinsurance premiums ceded to reinsurer  $j$  in year  $t$  / total reinsurance premiums ceded of ceding insurer  $i$  in year  $t$ ) – (reinsurance premiums ceded to reinsurer  $j$  in year  $t-1$  / total reinsurance premiums ceded of ceding insurer  $i$  in year  $t-1$ ).<sup>3</sup> Instead of measuring reinsurance demand at the aggregate level for a ceding insurer, we calculate this reinsurance demand amount from each counterparty reinsurer of any one ceding insurer, which allows us to observe changes in reinsurance demand associated with an individual reinsurer over time.

Following a similar procedure used in Epermanis and Harrington (2006), we use a control-group practice to estimate abnormal growth in reinsurance demand for the univariate analysis. We first calculate the mean change in reinsurance demand ( $\Delta R\_demand_{i,j,t}$ ) for reinsurers experiencing no rating changes during the investigation periods, calculating separately for reinsurers with “above bench” ratings (A or higher), “bench” ratings (A- and equivalent), and “low” ratings (rating of B++ or lower) (at the beginning of year  $t$ ). Next, for sample reinsurers with rating changes, we deduct from their change in reinsurance demand the mean change of no-rating-change reinsurers in the same rating category (“above bench,” “bench,” or “low”). We then test whether the demeaned changes in reinsurance demand of the upgraded and downgraded reinsurers are significantly different from zero. We run analyses on the whole sample and various sub-samples in order to test the hypotheses presented in the previous section.

### *B. Regression analysis*

We adopted regression analyses to test our hypotheses. The general regression model used is as follows:

$$\Delta R\_demand_{i,j,t} = \alpha_t + \gamma_1 Downgrade_{i,j,t} + \gamma_2 Upgrade_{i,j,t} + \theta X_{i,t} + \varepsilon_{i,t} \quad (1),$$

<sup>3</sup> As a robustness check, we also measure reinsurance demand change using the difference in the logarithm of reinsurance premium ceded to a particular reinsurer  $j$  from year  $t-1$  to year  $t$ . Our main results still hold. We argue that the changes in the proportion of reinsurance premium ceded is a better measure because it is scaled by total reinsurance ceded of a ceding insurer, which helps control the impact brought by the strategic changes of a ceding insurer’s total reinsurance need.

where  $\Delta R\_demand_{i,j,t}$  is the reinsurance demand change of insurer  $i$  from reinsurer  $j$  from year  $t-1$  to year  $t$ .  $Downgrade_{i,j,t}$  and  $Upgrade_{i,j,t}$  are indicator variables equal to one if a reinsurer  $j$  is downgraded or upgraded in year  $t$  or  $t-1$ , respectively.  $X_{i,t}$  is a vector of control variables. Time effects and firm fixed effects are also controlled in the regression.

The downgrade and upgrade dummy variables count the changes in both year  $t$  and  $t-1$  because insurance companies report financial data, including reinsurance premium ceded, on a calendar-year basis without the reinsurance transaction date, but rating agencies update financial strength ratings throughout the year.<sup>4</sup> As a result, some reinsurance transactions reported in year  $t$  are made after a reinsurance credit rating change in year  $t$ , while other reinsurance transactions are made before the reinsurer credit rating assignment in year  $t$  and after the rating in year  $t-1$ . For the latter case, the rating change in year  $t-1$  may affect the reinsurance demand in year  $t$ . Therefore, we define the downgrade/upgrade variables to include rating changes in both  $t$  and  $t-1$ . This may capture some cases where ceding insurers adjust their reinsurance portfolio in a somewhat delayed way.

Our control variables in the model follow the existing literature on reinsurance demand (Mayers and Smith, 1990; Garven and Lamm-Tennant, 2003; Cole and McCullough, 2006; Garven, Hilliard, and Grace, 2014; and Lin, Yu, and Peterson, 2014) and key rating agency topic factors that may affect reinsurance demand (Aon Benfield, 2013). Variables measuring the characteristics of ceding insurers that may affect their reinsurance demand include the ceding insurers' size, financial leverage, lagged combined ratio, underwriting leverage that serves as a proxy for the capital adequacy of the ceding insurers, the ceding insurer's exposure to catastrophic risks, exposure to workers' compensation risks and other long-tail risks, the ceding insurer's diversification across business lines and geographical

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<sup>4</sup> It is known that the ratings of ceding insurers are mostly assigned in June, three months after the NAIC filing (Epermanis and Harrington, 2006). However, the months of reinsurance rating assignments do not follow this pattern but instead spread throughout the calendar year.



areas, cash flow volatility, and the number of contracted reinsurers. In addition, a ceding insurer's A.M. Best rating and return on asset at  $t-1$  is also controlled. We also control for the ceding insurer's existing exposure to the contracted reinsurer (percentage of reinsurance recoverable from the reinsurer at  $t-1$ ). The definitions of variables are provided in Table 2.

After we examine whether reinsurance demand is sensitive to the reinsurer's credit quality change, we modify this basic regression in order to test other hypotheses. We first create a new set of rating change dummy variables by a reinsurer's pre-change financial strength. We define a reinsurer's rating as "high" if its average rating from the three rating agencies – Moody's, S&P, and A.M. Best – is above or equal to A- (A3 for Moody's) ("above bench" or "bench"). Similarly, a reinsurer's rating is classified as "low" when its average rating is below A- or equivalent (below "bench"). Then we classify downgrades and upgrades into three groups each: changes within the "high" rating (Downgrade\_high, Upgrade\_high), benchmark rating changes (Downgrade\_bench, Upgrade\_bench), and changes within the "low" rating (Downgrade\_low, Upgrade\_low) (see Table 2 for detailed description). The lagged rating dummies of reinsurers (lag\_high and lag\_low) are also controlled in the regressions.

[Insert Table 2 Here]

To test if the demand sensitivity varies among different types of reinsurers, we split the sample into subsamples based on the type of reinsurers or other criteria to be tested, and perform Chow-tests for the sub-sample regressions to examine if the coefficients of the rating change variables are significantly different between the sub-samples. Three types of sub-sample regressions are conducted to test related hypotheses: authorized vs. unauthorized (H2), high leverage vs. low leverage (H3), and high sustainability vs. low sustainability (H4).

## **4. Empirical results**

### ***4.1. Sample statistics***

Table 3 presents the summary statistics of our dependent variable, key independent variables, and other control variables. Variables are winsorized at the 1% level in order to remove outliers.

[Insert Table 3 Here]

### ***4.2. Univariate analyses: control group test – risk sensitivity demand of reinsurance***

Table 4 presents the univariate analyses of abnormal changes in reinsurance ceded to counterparty reinsurers that are downgraded or upgraded. Overall, the results demonstrate that reinsurance demand is sensitive to reinsurer rating downgrades and upgrades, and the sensitivity varies with the types of downgrading or upgrading.

Panel A shows the results for downgraded reinsurers. The “All” sample result is consistent with our prediction that downgraded reinsurers experience a decrease in reinsurance ceded, and the amount of that decrease is the largest when “weak” reinsurers get “weaker” (Downgrade\_low), followed by a reinsurer being downgraded below the benchmark rating (Downgrade\_bench). The decrease is the smallest if a reinsurer is downgraded but still maintains a “high” rating (Downgrade\_high). The results suggest that ceding insurers view that the increase in counterparty risk is limited when a reinsurer is downgraded within the “high” rating category, but they are less tolerable when the already weak reinsurers become weaker. Similar conclusions can be drawn for unaffiliated reinsurers only. Both unauthorized and authorized reinsurance transactions are sensitive to the rating downgrades, but authorized reinsurance transactions are economically more sensitive in all downgrading categories. Affiliated reinsurance transactions are statistically insensitive to

rating downgrades overall.<sup>5</sup>

Panel B shows the results for upgraded reinsurers. In the case of rating upgrading, the overall reaction is negative but to a lesser degree than the reaction to downgrading. The overall negative reaction is driven by the negative reaction to further upgrade of already-strong reinsurers and “within low” upgrade of weak reinsurers. The reaction to a reinsurer’s upgrading from low to benchmark rating is significantly positive, suggesting that ceding insurers do value reduced credit risk for this set of reinsurers more than their possible price increase. The negative reaction to upgrading of strong reinsurers may be caused by increased pricing by stronger reinsurers, leading to reduced demand. The negative reaction to the upgrading of weaker reinsurers is somewhat puzzling. This might support the “judgment proof” argument that ceding insurers contracting with weak reinsurers care more about the cost of reinsurance than about the credit risk, or it simply could be because the reduced credit risk from these weak reinsurers cannot offset their increase in reinsurance price after upgrading. Similar conclusions hold for unaffiliated reinsurers and authorized reinsurers. Again, affiliated reinsurance transactions are statistically insensitive to rating upgrades overall.

[Insert Table 4 Here]

### ***4.3. Regression analyses***

Fixed effects estimates of the regression model in section 3 are shown in Table 5 to test H1-1 and H1-2. We present the regression results both with and without firm characteristic control variables. The estimation results for our key independent variables are similar in these regressions, results of which are also mostly consistent with our univariate findings. Model (1)

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<sup>5</sup> The issue of affiliated insurance demand is not the focus of this paper, as the relationship of ceding insurers and their affiliated reinsurers may be governed by many other factors in addition to credit risk management concerns. As a matter of interest, we do conduct regression analyses of demand sensitivity for affiliated reinsurance. We obtain negative coefficients for types of downgrade and upgrade dummies, but they are not statistically significant. The results are available from the authors upon request.

and Model (2) show the overall effect of downgrading and upgrading. Reinsurance demand is significantly reduced when a reinsurer is downgraded; it is also reduced when upgrading occurs, but to a lesser extent.

Model (3) and Model (4) examine if the reinsurance demand sensitivity varies by a reinsurer's rating and rating changes. We find that ceding insurers reduce the reinsurance ceded to the downgraded reinsurers the most when weak reinsurers become even weaker (Downgrade\_low), followed by benchmark downgrading (Downgrade\_bench), and the reduction is the smallest when strong reinsurers are downgraded but still maintain a strong rating (Downgrade\_high). In the case of upgrading, we find that ceding insurers increased reinsurance premium ceded when weak reinsurers become stronger – receiving a benchmark upgrade (Upgrade\_bench) or a within-weak upgrade (Upgrade\_low) – but when an already strong reinsurer becomes stronger (within-strong upgrade, Upgrade\_high), reinsurance ceded to this reinsurer is actually reduced. This supports the arguments that the cost of contracting with a super-strong reinsurer carries more weight than the benefit from the reduced credit risk.

[Insert Table 5 Here]

Table 6 tests the demand sensitivity between authorized and unauthorized reinsurance transactions (H2). Authorized reinsurance reacts significantly negatively in both downgrade and upgrade cases, but unauthorized reinsurance only reacts significantly negatively in the downgrade scenario. When examining demand sensitivity by types of rating changes, the p-values of the Chow-test show that authorized reinsurance transactions react more negatively to benchmark downgrading and within-low downgrading. Authorized reinsurance demand increases in the benchmark-upgrade cases and within-low upgrade cases, but it decreases when strong reinsurers get stronger (Upgrade\_high). Unauthorized reinsurance demand only increases in the within-low upgrade case, and no significant

changes are found in the other two types of upgrade. Overall, these results support our hypothesis 2, that authorized reinsurance demand is more sensitive to counterparty risk change.

[Insert Table 6 Here]

Table 7 compares the demand sensitivity of reinsurance for high-leverage ceding insurers and low-leverage ceding insurers. We divide ceding insurers into two groups based on their leverage in order to test H3, with the high-leverage group defined as being at the top 10<sup>th</sup> percentile by leverage value. The downgrade dummy is insignificant for high-leverage ceding insurers and significantly negative for low-leverage ceding insurers. High-leverage ceding insurers reduce their reinsurance demand when counterparty reinsurers are upgraded, but the demand change is insignificant for low-leverage ceding reinsurers. Analyses by types of rating changes show that, compared with low-leverage ceding insurers, high-leverage ceding insurers' reinsurance demand is less sensitive to benchmark downgrading of counterpart reinsurers (a lesser reduction in demand for reinsurance). These insurers do not increase their reinsurance demand when their counterpart reinsurers experience benchmark upgrading or "within-low" upgrading (as low-leverage insurers do), but they do reduce their demand when their contracted reinsurers become super-strong (Upgrade\_high). The results overall provide support for our hypothesis 3.

[Insert Table 7 Here]

In order to test H4, we define the insurer-reinsurer relationship sustainability following Garven, Hilliard, and Grace (2014). The 5-year Sustainability is defined as

Sustainability = mean of the reinsurer count distribution / (standard deviation of the reinsurer count distribution+1).

The highest possible value for this variable is 5, and it happens when a ceding insurer cedes to the same group of reinsurers during the 5-year period. Therefore, a higher value for

sustainability means persistent ceding insurers. Because we need five years of data to calculate this variable, we use 2002-2006 data to get the sustainability for 2007. As a result, we have the years 2007-2009 in the regression analysis sample. We split ceding insurers into “long-sustain” and “short sustain” samples using median sustainability as a cut.<sup>6</sup> The results are provided in Table 8. Our results suggest that sustainability does not affect the demand sensitivity in upgrading cases; the differences between the two groups are insignificant (Upgrade dummy), but reinsurance demand by persistent ceding insurers is slightly less sensitive to counterpart reinsurer downgrades (Chow-test of downgrade dummy is significant at the 5% level).

A further look at the sensitivity by types of rating changes show that the above finding is primarily driven by the fact that persistent ceding insurers are less sensitive to the “within strong” downgrading of counterpart reinsurers, which may suggest that persistent ceding reinsurers have a higher tolerance for non-critical rating changes. In contrast, the analyses also show that ceding insurers with long sustainability also increase reinsurance less when their counterpart reinsurers experience a benchmark upgrading. Overall, the results provide some support for hypothesis 4.

[Insert Table 8 Here]

## **5. Conclusions**

This article examines the sensitivity of reinsurance demand to counterparty risks in a sample of US property-liability insurance companies to test market discipline in the reinsurance market. We examine whether reinsurance premium growth is sensitive to a counterparty reinsurer’s rating change. We use the financial strength rating of reinsurers as a proxy for

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<sup>6</sup> We also test the hypotheses by comparing the top 25<sup>th</sup> percentile and bottom 25<sup>th</sup> percentile of the ceding insurers by sustainability and obtain similar results.

reinsurer counterparty risk, and use the change in the proportion of reinsurance premium ceded to a reinsurer over the total reinsurance premium ceded as a proxy for reinsurance demand change. The paper finds that the reinsurance demand of US ceding insurers is sensitive to reinsurer counterparty risk. In general, reinsurance demand changes negatively with reinsurer rating changes, and demand sensitivity is heterogeneous depending on the types of reinsurance contracts and the rating of reinsurers.

In particular, we find that when a reinsurer is downgraded, the reinsurance ceded to this downgraded reinsurer decreases overall, and the reduction was the most severe when an already weak reinsurer becomes weaker, followed by situations in which a reinsurer is downgraded below the benchmark rating. The reduction is the smallest when a strong reinsurer is downgraded but still maintains a strong rating. In the case of reinsurer upgrading, the reinsurance ceded to the upgraded reinsurer either increased or decreased depending on the rating of the reinsurer. When a weak reinsurer gets upgraded, the reinsurance demand associated with this upgraded reinsurer increases. However, when an already strong reinsurer (with A- or above financial strength rating) is upgraded, ceding insurers do not appreciate this credit improvement and reduce the reinsurance ceded to this reinsurer, possibly due to higher prices.

We also find that authorized reinsurance transactions are more sensitive to reinsurer rating changes. With collateral protections in place, it is reasonable to observe lower demand sensitivity in unauthorized reinsurance because credit risk has been partially mitigated by those collateral requirements.

The demand sensitivity of ceding insurers with high leverage is statistically different from the sensitivity of ceding insurers with low leverage. Low-leverage firms are found to reduce their reinsurance demand significantly in all downgrading cases, but the reduction is significant for high-leverage ceding insurers only when their weak counterparty reinsurers get

weaker. In addition, high-leverage insurers do not increase their reinsurance demand when their weak counterpart reinsurers experience rating upgrades, but they do reduce their demand when their contracted reinsurers become super-strong.

Ceding insurers that tend to maintain long-term relationships with reinsurers are found to be less sensitive to counterparty reinsurer downgrades, mainly driven by the phenomenon that they are less sensitive to noncritical rating downgrades. However, they do not possess more tolerance when the credit risk of their counterparty reinsurer increases dangerously to below benchmark or even lower ratings. Symmetrically, these insurers also increase their reinsurance demand less when their counterpart reinsurers experience a benchmark upgrading.

Our results show that overall reinsurance demand is sensitive to the counterparty risk, supporting the traditional arguments of market discipline in the reinsurance market. Without any protections of a guaranty fund, the results are expected. If ceding insurers mostly utilize reinsurance to deal with regulatory scrutiny, the reinsurance demand is not necessarily sensitive to the counterparty risk. This is partly supported by our results that highly-leveraged firms are less sensitive to reinsurer rating downgrades, which could call for some regulatory attention. However, the overall demand sensitivity shows that this type of moral hazard is not very severe, and ceding insurers do manage reinsurance counterparty risk as market discipline predicts.

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**Table 1. Reinsurance Transactions by Reinsurer Rating Changes, 2002-2009**

<b>Reinsurer Rating at t-1</b>	<b>Number of observations at t-1</b>	<b>No Change at t</b>	<b>Downgrade at t</b>	<b>Upgrade at t</b>
<b>All Types of Reinsurer</b>				
Above Bench	125,824	98,322	16,479	11,023
Bench	23,664	18,878	2,163	2,623
Low	8,546	3,642	2,939	1,965
Total Rated	158,034	120,842	21,581	15,611
Non-rated	181,482			
Total	339,516			
<b>Authorized Reinsurer</b>				
Above Bench	89,904	71,881	11,352	6,671
Bench	13,880	10,983	1,371	1,526
Low	6,579	2,829	2,190	1,560
Total Rated	110,363	85,693	14,913	9,757
Non-rated	110,755			
Total	221,118			
<b>Unauthorized Reinsurer</b>				
Above Bench	35,920	26,441	5,127	4,352
Bench	9,784	7,895	792	1,097
Low	1,967	813	749	405
Total Rated	47,671	35,149	6,668	5,854
Non-rated	70,727			
Total	118,398			
<b>Affiliated Reinsurer</b>				
Above Bench	10,709	9,255	1,093	361
Bench	1,871	1,724	60	87
Low	988	626	177	185
Total Rated	13,568	11,605	1,330	633
Non-rated	6,598			
Total	20,166			
<b>Unaffiliated Reinsurer</b>				
Above Bench	114,954	88,939	15,363	10,652
Bench	21,739	17,109	2,098	2,532
Low	7,546	3,012	2,761	1,773
Total Rated	144,239	109,060	20,222	14,957
Non-rated	163,810			
Total	308,049			

Note: The table shows the number of insurer-reinsurers-year transactions by reinsurer rating changes at t. "Above Bench" rating category includes A (A2 for Moody's) or Above; "Low" rating category includes B++ or lower (BBB+ for S&P, Baa1 for Moody's); "Bench" rating category includes A- (A3 for Moody's).

**Table 2. Variable Description and Definition**

Variable Name	Definition
<b>Dependent Variable</b>	
$\Delta R\_demand_{i,j,t}$ – Change in reinsurance demand of ceding insurer $i$ from reinsurer $j$	(reinsurance premiums ceded to reinsurer $j$ in year $t$ / total reinsurance premiums ceded of ceding insurer $i$ in year $t$ ) – (reinsurance premiums ceded to reinsurer $j$ in year $t-1$ / total reinsurance premiums ceded of ceding insurer $i$ in year $t-1$ )
<b>Key independent variables: reinsurer rating changes and reinsurer characteristics</b>	
Downgrade	Dummy variable equal to 1 if a reinsurer is downgraded in year $t$ or $t-1$ ; 0 otherwise
Downgrade_bench	Dummy variable equal to 1 if a reinsurer is downgraded from “high” rating (“above bench” or “bench”) to below benchmark rating; 0 otherwise
Downgrade_high	Dummy variable equal to 1 if an “above bench” rating reinsurer is downgraded but still maintains an “above bench” or “bench” rating; 0 otherwise
Downgrade_low	Dummy variable equal to 1 if a “low” rating reinsurer is downgraded to lower rating; 0 otherwise
Upgrade	Dummy variable equal to 1 if a reinsurer is upgraded in year $t$ or $t-1$ ; 0 otherwise
Upgrade_bench	Dummy variable equal to 1 if a reinsurer is upgraded from “low” rating to “bench” or “above bench” rating; 0 otherwise
Upgrade_high	Dummy variable equal to 1 if a “high” rating (“above bench” or “bench”) reinsurer is upgraded; 0 otherwise
Upgrade_low	Dummy variable equal to 1 if a “low” rating reinsurer is upgraded but still maintains a “low” rating 0 otherwise
Lag_high	Dummy variable equal to 1 if a reinsurer possesses a “high” rating (“bench” or “above bench”) prior to rating change; 0 otherwise
Lag_low	Dummy variable equal to 1 if a reinsurer possesses a “low” rating prior to rating change; 0 otherwise
Authorized	Dummy variable equal to 1 if a reinsurer is an authorized reinsurer; 0 otherwise
Unauthorized	Dummy variable equal to 1 if a reinsurer is an unauthorized reinsurer; 0 otherwise
Affiliated	Dummy variable equal to 1 if the reinsurer and the ceding insurer are affiliated; 0 otherwise
Unaffiliated	Dummy variable equal to 1 if the reinsurer and the ceding insurer are unaffiliated; 0 otherwise
<b>Control variables: Characteristics of ceding insurers that affect their reinsurance demand</b>	
Size	Log value of ceding insurer’s admitted assets
Leverage	Liability / policyholders’ surplus
Lag_combined	Combined ratio at $t-1$
Capitalization	Net premiums written / policyholders’ surplus
CAT risk	The proportion of catastrophic risk exposure: defined as direct premiums written in homeowners, farmowners, auto physical damage, commercial multiperil, or inland marine in AL, FL, MS, SC, or TX to total premiums written
Long_tail	Percentage of premiums in workers’ compensation and other long-tail lines
Geo_Herf	Herfindahl index by geographical areas
LOB_Herf	Herfindahl index by business lines
STD_CF	Standard deviation of ceding insurer's net cash flow over the previous four years

Pre_rating	Ceding insurer's financial strength rating by A.M. Best at $t-1$
Pre_ROA	Net income after dividend & before tax/total assets at $t-1$
Ln_Numrein	Log value of ceding insurer's numbers of contracted reinsurers at $t-1$
<b><i>Variables measuring relationship between ceding insurers and reinsurers</i></b>	
Rein_rec	Reinsurance recoverable from reinsurer $j$ / total reinsurance recoverable of ceding insurer $i$ at $t-1$
Contract sustainability	Sustainability of primary insurer, calculated following Grace et al. (2014)

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**Table 3. Summary Statistics of variables**

<b>Variable Name</b>	<b>N</b>	<b>Mean</b>	<b>STD</b>	<b>Min</b>	<b>Max</b>
<i>Dependent Variable</i>					
$\Delta R\_demand_{i,j,t}$	338251	-0.011	4.039	-22.629	21.150
<i>Key independent variables: reinsurer rating changes and reinsurer characteristics</i>					
Downgrade	339516	0.105	0.306	0	1
Downgrade_bench	339516	0.010	0.099	0	1
Downgrade_high	339516	0.081	0.273	0	1
Downgrade_low	339516	0.014	0.117	0	1
Upgrade	339516	0.081	0.272	0	1
Upgrade_bench	339516	0.006	0.079	0	1
Upgrade_high	339516	0.070	0.255	0	1
Upgrade_low	339516	0.004	0.065	0	1
Lag_high	339516	0.440	0.496	0	1
Lag_low	339516	0.025	0.157	0	1
Authorized	339516	0.651	0.477	0	1
Unauthorized	339516	0.349	0.477	0	1
Affiliated	339516	0.059	0.236	0	1
Unaffiliated	339516	0.907	0.290	0	1
<i>Control variables: Characteristics of ceding insurers that affect their reinsurance demand</i>					
Size	339516	13.127	2.187	8.307	17.359
Leverage	338443	2.042	1.523	0.000	12.887
Lag_combined	314804	101.01	27.91	38	271
Capitalization	339516	0.904	0.593	0	2.486
CAT risk	339516	0.063	0.177	0	0.994
Long_tail	338639	0.710	0.264	0	1
Geo_Herf	332518	0.344	0.358	0.034	1
LOB_Herf	338793	0.405	0.273	0.111	1
STD_CF	338254	0.076	0.108	0.002	0.784
Pre_rating	312931	10.895	1.500	0	13
Pre_ROA	337817	2.533	4.432	-15	16
Ln_Numrein	339516	4.542	1.623	0	7.499
<i>Variables measuring relationship between ceding insurers and reinsurers</i>					
Rein_rec	336989	0.038	0.155	0	1
Contract sustainability	146425	1.117	0.245	0.618	5

**Table 4. Univariate Analyses: Reinsurance Demand Change by Reinsurer Rating Change**

**Panel A: Impact of Reinsurer Downgrading on Reinsurance Demand Change**

Types of Reinsurers		All Downgrades	Downgrade_bench	Downgrade_high	Downgrade_low
All	Mean	-0.34	-0.65	-0.17	-1.19
	T-value	(-12.00)***	(-7.37)***	(-5.30)***	(-13.54)***
Affiliated	Mean	-0.23	-1.51	-0.05	-0.75
	T-value	(-1.13)	(-1.65)	(-0.26)	(-0.88)
Unaffiliated	Mean	-0.35	-0.61	-0.17	-1.22
	T-value	(-12.92)***	(-7.48)***	(-5.76)***	(-15.36)***
Authorized & Unaffiliated	Mean	-0.47	-0.87	-0.24	-1.47
	T-value	(-12.55)***	(-7.30)***	(-5.66)***	(-14.41)***
Unauthorized & Unaffiliated	Mean	-0.09	-0.15	-0.04	-0.45
	T-value	(-3.32)***	(-1.91)**	(-1.33)	(-6.01)***

**Panel B: Impact of Reinsurer Upgrading on Reinsurance Demand Change**

Types of Reinsurers		All Upgrades	Upgrade_bench	Upgrade_high	Upgrade_low
All	Mean	-0.14	0.29	-0.16	-0.44
	T-value	(-4.54)***	(2.17)**	(-5.20)***	(-2.70)***
Affiliated	Mean	-0.22	-0.58	-0.39	1.80
	T-value	(-0.68)	(-0.71)	(-1.10)	(1.35)
Unaffiliated	Mean	-0.14	0.39	-0.15	-0.65
	T-value	(-4.95)***	(3.43)***	(-5.33)***	(-5.02)***
Authorized & Unaffiliated	Mean	-0.25	0.49	-0.31	-0.78
	T-value	(-6.29)***	(3.74)***	(-7.00)***	(-4.80)***
Unauthorized & Unaffiliated	Mean	0.07	-0.15	0.08	-0.14
	T-value	(2.43)	(-0.92)	(2.80)***	(-4.25)***

Note: Significant at the \*\*\*1%, \*\*5%, and \*10% levels. Reinsurance demand change is defined as the change in proportion of a ceding insurer  $i$ 's reinsurance premium ceded to a reinsurer  $j$  over total reinsurance premiums ceded of the ceding insurer  $i$ . The variable is demeaned using the mean change in demand of control firms (reinsurers in the same rating category but experiencing no rating changes). A rating is defined as "high" ("low") when a reinsurer's average rating from the three rating agencies – Moody's, S&P, and A.M. Best – is above or equal to (below) A- or equivalent. When a rating change is within high (low) rating, we classify it as downgrade\_high or upgrade\_high (downgrade\_low or upgrade\_low). When a rating downgrades (upgrades) from high to low (low to high), it is classified as downgrade\_bench (upgrade\_bench).

**Table 5. Regression–Reinsurance Demand Change by Reinsurer Rating Change (Hypothesis 1)**

Variable	Model 1	Model 2	Variable	Model 3	Model 4
Downgrade	-0.3953*** [0.0206]	-0.1512*** [0.0209]	Downgrade_bench	-0.5354*** [0.0644]	-0.4123*** [0.0599]
Upgrade	-0.1213*** [0.0227]	-0.0281 [0.0225]	Downgrade_high	-0.2482*** [0.0243]	-0.0611*** [0.0226]
Lag_high		0.1145*** [0.0135]	Downgrade_low	-0.7757*** [0.0637]	-0.5736*** [0.0588]
Lag_low		-0.5741*** [0.0406]	Upgrade_bench	0.6596*** [0.0827]	0.6095*** [0.0778]
Size		0.2478*** [0.0372]	Upgrade_high	-0.1829*** [0.0252]	-0.1023*** [0.0237]
Leverage		-0.0867*** [0.0148]	Upgrade_low	0.1581 [0.1027]	0.3131*** [0.0964]
Lag_combined		0.0005 [0.0004]	Lag_high	0.0410*** [0.0145]	0.1091*** [0.0135]
Capitalization		0.3680*** [0.0290]	Lag_low	-0.5354*** [0.0549]	-0.4707*** [0.0511]
CAT risk		-0.3795* [0.2225]	Size		0.2449*** [0.0372]
Long_tail		-0.1086 [0.0949]	Leverage		-0.0858*** [0.0148]
Geo_Herf		0.2899*** [0.1013]	Lag_combined		0.0005 [0.0004]
LOB_Herf		0.1256 [0.0934]	Capitalization		0.3675*** [0.0290]
STD_CF		-0.4593*** [0.1540]	CAT risk		-0.3783* [0.2224]
Pre_rating		-0.0530*** [0.0121]	Long_tail		-0.1102 [0.0949]
Pre_ROA		0.0009 [0.0023]	Geo_Herf		0.2952*** [0.1013]
Ln_Numrein		-0.029 [0.0178]	LOB_Herf		0.1262 [0.0934]
Rein_rec		-12.4799*** [0.0868]	STD_CF		-0.4547*** [0.1539]
			Pre_rating		-0.0517*** [0.0121]
			Pre_ROA		0.0011 [0.0023]
			Ln_Numrein		-0.0293 [0.0178]
			Rein_rec		-12.4894*** [0.0867]
Year dummies	Yes	Yes		Yes	Yes
Firm fixed effects	Yes	Yes		Yes	Yes
Observations	318,739	264,794		318,739	264,794
r2-w	0.0013	0.0758		0.0028	0.0765

Note: Standard errors are in brackets. Significant at the \*\*\*1%, \*\*5%, and \*10% levels. Both firm and time fixed effects are included but not reported due to space. Dependent variable is the change in proportion of a ceding insurer  $i$ 's reinsurance premium ceded to a reinsurer  $j$  over total reinsurance premiums ceded of the ceding insurer  $i$ . Definitions of control variables are in Table 2.



**Table 6. Regression–Reinsurance Demand Sensitivity: Authorized vs. Unauthorized Reinsurers (Hypothesis 2)**

Variable	Authorized	Unauthorized	P-Chow	Variable	Authorized	Unauthorized	P-Chow
Downgrade	-0.1702*** [0.0295]	-0.0967*** [0.0240]	0.2646	Downgrade	-0.5009*** [0.0866]	-0.1826*** [0.0666]	0.0148
Upgrade	-0.0579* [0.0331]	0.0171 [0.0240]	0.1114	_bench	-0.0537* [0.0321]	-0.0704*** [0.0258]	0.3723
Lag_high	0.1515*** [0.0190]	0.0139 [0.0160]	<0.000	Downgrade	-0.6822*** [0.0810]	-0.2896*** [0.0733]	0.0057
Lag_low	-0.6917*** [0.0551]	-0.2190*** [0.0515]	<0.000	_low	0.7430*** [0.0991]	-0.0053 [0.1184]	0.0002
Size	0.3612*** [0.0522]	0.0281 [0.0447]	0.1273	Upgrade	-0.1793*** [0.0356]	0.0085 [0.0248]	0.0001
Leverage	-0.1219*** [0.0206]	-0.0104 [0.0180]	0.5143	_high	0.2681** [0.1274]	0.2966** [0.1318]	0.7589
Lag_combined	0.0001 [0.0006]	0.0015*** [0.0005]	0.4468	_low	0.1444*** [0.0191]	0.0124 [0.0160]	<0.000
Capitalization	0.4759*** [0.0401]	0.1276*** [0.0352]	0.0201	Lag_high	-0.5427*** [0.0712]	-0.1723*** [0.0614]	0.0009
CAT risk	-0.4856 [0.3125]	-0.0277 [0.2625]	0.1163	Lag_low	0.3595*** [0.0522]	0.0256 [0.0447]	0.1398
Long_tail	-0.1204 [0.1410]	-0.0791 [0.1016]	0.5508	Size	-0.1205*** [0.0206]	-0.0105 [0.0180]	0.563
Geo_Herf	0.3509** [0.1424]	0.1675 [0.1194]	0.1544	Leverage	0.0001 [0.0006]	0.0015*** [0.0005]	0.4559
LOB_Herf	0.2276 [0.1447]	-0.0113 [0.0943]	0.0671	Lag_combined	0.4743*** [0.0401]	0.1288*** [0.0352]	0.0201
STD_CF	-0.7578*** [0.2073]	0.2326 [0.2025]	0.1311	Capitalization	-0.4831 [0.3123]	-0.0237 [0.2625]	0.1044
Pre_rating	-0.0656*** [0.0180]	-0.0391*** [0.0136]	0.1057	CAT risk	-0.1251 [0.1409]	-0.0802 [0.1016]	0.5704
Pre_ROA	0.0007 [0.0033]	0 [0.0027]	0.5789	Long_tail	0.3530** [0.1423]	0.1695 [0.1194]	0.1505
Ln_Numrein	-0.0614** [0.0250]	0.0168 [0.0210]	0.7127	Geo_Herf	0.2336 [0.1446]	-0.013 [0.0943]	0.0645
Rein_rec	- [0.1047]	-19.4543*** [0.2300]	<0.000	LOB_Herf	-0.7516*** [0.2072]	0.2341 [0.2025]	0.1333
				STD_CF	-0.0643*** [0.0180]	-0.0385*** [0.0136]	0.1183
				Pre_rating	0.001 [0.0033]	0.0001 [0.0027]	0.5622
				Pre_ROA	-0.0617** [0.0250]	0.017 [0.0210]	0.6679
				Ln_Numrein	- [0.1047]	-19.4557*** [0.2300]	<0.000
				Rein_rec	Yes	Yes	
Year dummies	Yes	Yes		Yes	Yes		
Firm fixed	Yes	Yes		Yes	Yes		
Observations	168,529	96,265		168,529	96,265		
r2-w	0.0795	0.0715		0.0804	0.0717		

Note: Standard errors are in brackets. Significant at the \*\*\*1%, \*\*5%, and \*10% levels. Both firm and time fixed effects are included but not reported due to space. Dependent variable is the change in proportion of a ceding insurer  $i$ 's reinsurance premium ceded to a reinsurer  $j$  over total reinsurance premiums ceded of the ceding insurer  $i$ . Definitions of control variables are in Table 2.

**Table 7. Regression–Reinsurance Demand Sensitivity: High Leverage Ceding Insurers vs. Low Leverage Ceding Insurers (Hypothesis 3)**

Variable	High Lev	Low Lev	P-Chow	Variable	High Lev	Low Lev	P-Chow
Downgrade	-0.0471 [0.0555]	-0.1566*** [0.0222]	0.3369	Downgrade	-0.0293 [0.1520]	-0.4489*** [0.0642]	0.0483
Upgrade	-0.1341** [0.0655]	-0.0211 [0.0237]	0.1103	Downgrade _high	-0.0121 [0.0610]	-0.0602** [0.0241]	0.8982
Lag_high	0.0816** [0.0371]	0.1163*** [0.0143]	0.8055	Downgrade _low	-0.2838** [0.1440]	-0.6074*** [0.0633]	0.1689
Lag_low	-0.2626*** [0.1014]	-0.6083*** [0.0436]	0.0075	Upgrade _bench	-0.0251 [0.2036]	0.6718*** [0.0830]	0.0133
Size	0.2463 [0.1725]	0.1913*** [0.0397]	0.2118	Upgrade _high	-0.1416** [0.0705]	-0.1008*** [0.0250]	0.427
Lag_combined	0.0004 [0.0016]	0.0002 [0.0004]	0.17	Upgrade _low	-0.2001 [0.2522]	0.3605*** [0.1028]	0.0995
Capitalization	0.1089 [0.0854]	0.3470*** [0.0287]	0.0605	Lag_high	0.0741** [0.0374]	0.1111*** [0.0143]	0.8442
CAT risk	1.0943 [1.7057]	-0.3991* [0.2385]	0.0147	Lag_low	-0.1634 [0.1250]	-0.5017*** [0.0549]	0.0354
Long_tail	-0.0088 [0.6311]	-0.0031 [0.1014]	0.3676	Size	0.2488 [0.1725]	0.1884*** [0.0396]	0.1963
Geo_Herf	0.7062 [0.6775]	0.2636** [0.1069]	0.8781	Lag_combined	0.0004 [0.0016]	0.0002 [0.0004]	0.168
LOB_Herf	-0.4819 [0.7033]	0.1509 [0.0988]	0.3431	Capitalization	0.1088 [0.0854]	0.3476*** [0.0287]	0.0634
STD_CF	-0.4672 [0.6484]	-0.3975** [0.1667]	0.9759	CAT risk	1.0586 [1.7058]	-0.3986* [0.2384]	0.0143
Pre_rating	0.0364 [0.0412]	-0.0534*** [0.0135]	0.5923	Long_tail	-0.0183 [0.6312]	-0.0037 [0.1014]	0.3544
Pre_ROA	-0.0134 [0.0092]	0.0027 [0.0025]	0.8582	Geo_Herf	0.7037 [0.6776]	0.2698** [0.1069]	0.8567
Ln_Numrein	-0.3479*** [0.1059]	-0.0539*** [0.0190]	0.1123	LOB_Herf	-0.4754 [0.7033]	0.1526 [0.0987]	0.3545
Rein_rec	- [0.3651]	- [0.0899]	<0.000	STD_CF	-0.4673 [0.6484]	-0.3930** [0.1667]	0.9784
				Pre_rating	0.0359 [0.0412]	-0.0518*** [0.0135]	0.5538
				Pre_ROA	-0.0134 [0.0092]	0.0028 [0.0025]	0.8618
				Ln_Numrein	-0.3470*** [0.1059]	-0.0541*** [0.0190]	0.108
				Rein_rec	-18.0391*** [0.3652]	-12.3180*** [0.0899]	<0.000
Year dummies	Yes	Yes		Yes	Yes		
Firm fixed	Yes	Yes		Yes	Yes		
Observations	23,455	241,339		23,455	241,339		
r2-w	0.0965	0.0755		0.0966	0.0763		

Note: Standard errors are in brackets. Significant at the \*\*\*1%, \*\*5%, and \*10% levels. Both firm and time fixed effects are included but not reported due to space. Dependent variable is the change in proportion of a ceding insurer  $i$ 's reinsurance premium ceded to a reinsurer  $j$  over total reinsurance premiums ceded of the ceding insurer  $i$ . Ceding insurers with leverage value in the top 10th percentile are classified as high leverage firms (High Lev); others are classified as low leverage firms (Low Lev). Definitions of control variables are in Table 2.

**Table 8. Regression–Reinsurance Demand Sensitivity: Ceding Insurers with Long Sustainability vs. Short Sustainability (Hypothesis 4)**

Variable	Long	Short	P-Chow	Variable	Long	Short	P-Chow
Downgrade	-0.2405*** [0.0461]	-0.3781*** [0.0603]	0.0472	Downgrade	-0.3813 [0.4745]	-0.5709 [0.4828]	0.7515
Upgrade	-0.1565*** [0.0371]	-0.1561*** [0.0459]	0.9147	Downgrade _bench	-0.1836*** [0.0479]	-0.3350*** [0.0629]	0.0383
Lag_high	0.0658*** [0.0230]	0.0651** [0.0285]	0.9212	Downgrade _low	-1.0092*** [0.1765]	-0.7296*** [0.2261]	0.3556
Lag_low	-0.1527 [0.1038]	-0.048 [0.1411]	0.5486	Upgrade	0.2892** [0.1404]	0.7673*** [0.1708]	0.0298
Size	0.3206* [0.1709]	0.2781* [0.1509]	0.6339	Upgrade _bench	-0.2039*** [0.0385]	-0.2272*** [0.0477]	0.7668
Leverage	-0.1059* [0.0587]	-0.0711 [0.0483]	0.7092	Upgrade _low	0.6221*** [0.2247]	0.2811 [0.2743]	0.4045
Lag_combined	0.0013 [0.0014]	0.0014 [0.0012]	0.0785	Lag_high	0.0632*** [0.0232]	0.0630** [0.0287]	0.9396
Capitalization	0.4841*** [0.0931]	0.8560*** [0.0947]	0.2213	Lag_low	-0.069 [0.1383]	-0.193 [0.1831]	0.5698
CAT risk	1.5455** [0.7598]	-1.7803** [0.7749]	0.2811	Size	0.3175* [0.1709]	0.2819* [0.1509]	0.5899
Long_tail	0.1134 [0.4085]	0.5452* [0.3274]	0.7465	Leverage	-0.1043* [0.0587]	-0.0691 [0.0482]	0.7242
Geo_Herf	0.8041* [0.4255]	0.7249* [0.4067]	0.3804	Lag_combined	0.0013 [0.0014]	0.0015 [0.0012]	0.0797
LOB_Herf	-0.036 [0.3557]	-0.0358 [0.4020]	0.0015	Capitalization	0.4809*** [0.0931]	0.8521*** [0.0946]	0.233
STD_CF	-1.2942** [0.5913]	-0.4167 [0.5134]	0.0805	CAT risk	1.5370** [0.7595]	-1.7640** [0.7747]	0.2844
Pre_rating	-0.1103* [0.0599]	0.0623 [0.0462]	0.0304	Long_tail	0.1318 [0.4084]	0.5534* [0.3273]	0.7461
Pre_ROA	0.0095 [0.0062]	0.0179*** [0.0064]	0.0688	Geo_Herf	0.7991* [0.4253]	0.7374* [0.4066]	0.3921
Ln_Numrein	0.0735 [0.0544]	0.2250*** [0.0439]	0.9065	LOB_Herf	-0.0252 [0.3556]	-0.0436 [0.4019]	0.0018
Rein_rec	-9.5224*** [0.1744]	- [0.1917]	<0.000	STD_CF	-1.2846** [0.5911]	-0.4173 [0.5133]	0.0795
				Pre_rating	-0.1073* [0.0599]	0.0629 [0.0461]	0.0295
				Pre_ROA	0.0096 [0.0062]	0.0178*** [0.0064]	0.0786
				Ln_Numrein	0.0758 [0.0543]	0.2228*** [0.0439]	0.9573
Year dummies	Yes	Yes		Rein_rec	-9.5010*** [0.1744]	-12.8348*** [0.1917]	<0.000
Firm fixed	Yes	Yes			58,686	54,637	
Observations	58,686	54,637			0.0522	0.0822	
r2-w	0.0515	0.0815					

Note: Standard errors are in brackets. Significant at the \*\*\*1%, \*\*5%, and \*10% levels. Both firm and time fixed effects are included but not reported due to space. Dependent variable is the change in proportion of a ceding insurer  $i$ 's reinsurance premium ceded to a reinsurer  $j$  over total reinsurance premiums ceded of the ceding insurer  $i$ . A ceding insurer has a high sustainability score when the reinsurance portfolio did not change much during the past five years. Median sustainability score is used as a cutoff for division of long sustainability (Long) vs. short sustainability (Short). Definitions of control variables are in Table 2.