Reinsurance and Systemic Risk:
The Impact of Reinsurer Downgrading on Property-Casualty Insurers

Sojung Carol Park

Assistant Professor of Finance
Mihaylo College of Business and Economics
California State University, Fullerton
Fullerton, CA 92834-6848, USA
Email: sopark@fullerton.edu
Phone: (657) 278-3754

and

Xiaoying Xie

Assistant Professor of Finance
Mihaylo College of Business and Economics
California State University, Fullerton
Fullerton, CA 92834-6848, USA
Email: xxie@fullerton.edu
Phone: (657) 278-5389

Reinsurance and Systemic Risk:
The Impact of Reinsurer Downgrading on Property-Casualty Insurers

Abstract

This paper analyzes the interconnectedness between reinsurers and US property-casualty insurers and presents the first detailed examination on the likely impact of major global reinsurer insolvency on the US property-casualty insurance industry in order to illustrate the potential systemic risk caused by the interconnectedness of the insurance sector through reinsurance. We find that the likelihood of a primary insurer's downgrade increases with its reinsurance default risk exposure from downgraded reinsurers. Counterparty primary insurers' stocks also react negatively to their reinsurers' downgrades. The negative effects also spill over to insurers that are not directly exposed to the credit risk of downgraded reinsurers. Despite the close interconnectedness, worst-case scenario analyses show that the likelihood of systemic risk caused by reinsurance transactions is relatively small for the US property-casualty insurance industry.

Keywords: Reinsurance; systemic risk; property-casualty insurers; rating; event study; scenario analysis

1. Introduction

The danger of systemic risk to the financial services industry and the world economy as a whole, triggered by the potential failure of the reinsurance industry, has drawn much attention from industry practitioners, regulators, and academic scholars since the early 2000s (Swiss Re, 2003; Rossi and Lowe, 2002; The Group of Thirty, 2006). Earlier research in general finds the risk is small and inconsequential. Such a view was challenged in the wake of the recent financial crisis, as the meltdown of insurance giant AIG (American International Group) severely deepened the crisis. As a result, a new round of research has emerged to examine the financial stability of the insurance industry and its potential to pose systemic risks to the whole financial system and to national/international economies (Geneva Association, 2010; Cummins and Weiss, 2010; Grace, 2010; Bell and Keller, 2009; Acharya, et al., 2009; Harrington , 2009; Billio, et al., 2011).

Literature generally uses three primary indicators to assess the degree of systemic risk posed by an institution / industry: size, interconnectedness, and substitutability. It is argued that the property-casualty insurance industry may be subject to systemic risk because of its heavy dependence on reinsurance and the complexity of the reinsurance market (Cummins and Weiss, 2010). As argued in Acharya, et al. (2009), "The reinsurance market increases the interconnectedness of the system exponentially and therefore might increase the systemic risk in the overall market" because of the "bilateral [relationship] in nature and [the lack of] adequate risk controls due to the opacity of bilateral markets." Despite the broad discussion on reinsurance and systemic risk in existing literature, little empirical work has been done to examine the actual interconnectedness of the insurance and reinsurance systems and test how significant the risk could be. Our research intends to fill this gap to some extent by investigating this interconnectedness through examining the reaction of property-casualty insurers to reinsurer

downgrading and conducting scenario analyses to show hypothetical impacts of major reinsurance groups' insolvency on the US P/C insurance industry.

Reinsurance companies are at the top of the insurance sector network. The failure of reinsurance companies may create financial instability within the broader insurance sector, which could cause a spillover effect into the whole economy. In addition, this risk could be aggravated if the increased default risk of primary insurers due to the failure of reinsurers cannot be conceived transparently in the market, as we have seen in the recent financial crisis. In fact, to outside investors, reinsurance arrangements between primary insurers and reinsurers often seem quite complicated, given the complexity of the contract terms and the number of parties involved in the cession and retrocession arrangements. Therefore, it is important to understand the connectedness of the insurance and reinsurance industries and whether the market can evaluate the reinsurance risk exposure of primary insurers. In this research, we analyze the impact of reinsurance company credit rating downgrades on counterparty primary insurance companies' credit ratings and their stock returns in order to illustrate the interconnectedness of the insurance sector and to investigate whether the reinsurance credit risk information is transparently delivered to the capital market.

Understanding the interconnectedness is an important step in the context of evaluating the potential systemic risk caused by reinsurance companies. However, this does not provide us information on how serious the potential problem could be. We cannot assess systemic risk brought by reinsurers using historical data because there was no major reinsurance company collapse in history (Swiss Re, 2003). To get some sense on the magnitude of systemic risk, we conduct multiple scenario analyses where major global reinsurer(s) collapse.

By providing empirical evidence of interconnectedness, the market's ability to evaluate this risk, and the potential impact on the US P/C industry caused by major reinsurance

insolvency, we hope the paper can shed light on the systemic risks that the reinsurance sector may pose to the entire financial system and overall economy. The remainder of the article proceeds as follows. After the discussion of relevant literature on insurance industry interconnectedness, we move to discuss the data, samples, and methodology, then present empirical results and discussion.

2. Reinsurance and Insurance Industry Interconnectedness

The functions of reinsurance have been widely documented and acknowledged in insurance operations. Reinsurance companies have traditionally provided the global risk diversification mechanism by pooling the risks of local insurance companies at a global level. Thus, primary insurers can stabilize their loss experiences and limit catastrophic losses by transferring risks to reinsurance companies. In addition, reinsurance transactions can increase the underwriting capacity of primary insurers and provide surplus relief. Other functions of reinsurance include providing underwriting guidance and facilitating a market segment withdrawal for primary insurers.

Reinsurance companies are essential to the global insurance industry and have functioned smoothly in the past. However, some concerns in relation to the possibility of systemic risk posed by reinsurance companies have been raised recently, and these concerns can be summarized as follows. First, the top five reinsurance groups[1] provided approximately 60% of reinsurance worldwide in 2009 (A. M. Best, 2010). The US P/C insurance market also depends heavily on the top reinsurance groups. Based on data reported to the NAIC, the top five global reinsurance groups provide about 30% of unaffiliated reinsurance to US P/C insurers. In terms of number, 1,315 companies out of a total 2,492 P/C insurers in US had unaffiliated reinsurance

[1] Munich Re, Swiss Re, Berkshire Hathaway Reinsurance, Hannover Re, and XL Capital.

with Swiss Re, Munich Re, and Berkshire in 2009. Therefore, these reinsurance companies are at the top of the insurance sector's interconnectedness (Swiss Re, 2003; Cummins, 2007; Cummins and Weiss, 2010). Reinsurance company failure would have a significant impact on primary insurers because those reinsurers may no longer be able to pay the primary insurers' losses. Unfortunately, little is known about the pattern and degree of damages caused by reinsurer failure on primary insurers throughout the world and, consequently, the systemic risk to the real economy (Swiss Re, 2003).

Second, it will be hard to isolate the impact of major reinsurer failure from primary insurers and the economy due to the complexity and opacity of reinsurance. There is a serious lack of transparency associated with the risk of reinsurance transactions due to the international nature of reinsurance companies and lack of standardized prudential supervision (Cole and McCullough, 2006; Rossi and Lowe, 2002; Acharya, et al., 2009). To some extent, rating agencies may help reduce some information asymmetry and perhaps may serve as the "de facto" regulator in the insurance industry (IMF Global Financial Stability Report, 2004). However, they still cannot eradicate the lack of transparency and supervision problems and the credibility of ratings of complex and opaque risks was challenged during the 2007-2009 financial crisis.

Third, there are risks of retrocession spirals or reinsurance spirals of the kind that once spread out during the period 1988 to 1992 in the London Market Excess (Schwartzman, 2008; Cummins and Weiss, 2010). The retrocession spirals may trigger failures of multiple reinsurers all at once through the retrocession channel, and this shock may cause a ripple effect in a broad range of primary insurers.

There have been a few studies examining the systemic risk posed by the reinsurance industry; many were done by research institutions sponsored by insurance companies. Swiss Re (2003) examines the systemic risk posed by reinsurance companies and concludes that the risk is

insignificant because reinsurance company defaults have been a very rare event in history and reinsurance companies generally have very high credit ratings. Even if a reinsurance company were to become insolvent, the risk of a ripple effect to other industries through primary insurers seems to be minimal because a bank run on reinsurance companies is unlikely, given the sticky nature of reinsurance liability (withdrawal is only allowed when loss is actually realized). In addition, total reinsurance premiums are relatively small, accounting for only 6 percent of total direct premiums.

The Group of Thirty (2006) also investigates the systemic risk of reinsurance. It runs a simple "stress test" under an assumption that 20% of global reinsurance capacity fails and reaches, as in Swiss Re (2003), a similar conclusion: even major reinsurer failure will have only a limited short-term effect because 20% of global reinsurance capacity is still only about 2-2.5% of gross total premiums; additionally, the reinsurance sectors' linkage to the banking sector and capital market is rather limited.

Although research by Swiss Re (2003) and the Group of Thirty (2006) demonstrates that the systemic risk posed by the failure of reinsurance companies is low, the interests and concerns of financial institution supervisors and academic researchers have not abated since the financial crisis of 2007-2008. Bell and Keller (2009) and the Geneva Association (2010) revisited this issue and draw similar conclusions: the insurance sector is fundamentally different from the banking sector, and thus the systemic risk posed by reinsurance companies seems to be insignificant. The only possible source of systemic risk posed by the insurance and reinsurance industries is through their non-core activities, such as derivative transactions, including Credit Default Swaps (CDS), financial derivative trading, short-term funding, and security lending, all of which were major factors behind the AIG crisis. Cummins and Weiss (2010) examine various dimensions of systemic risk posed by the insurance sector. They also conclude that the

possibility of systemic risk caused by core insurance activities is very limited. However, there could be a significant systemic vulnerability within the insurance sector through reinsurance spirals and the interconnectedness of the insurance sector, which calls for further empirical studies.

Previous studies argue that reinsurers pose a low systemic risk because of the very low default probability of major reinsurance companies. For example, Swiss Re (2003) identifies 24 reinsurer bankruptcies during the 1980-2002 period, and none of them involved major reinsurance companies. Due to the limited number of bankruptcies and the relatively small size of bankrupt reinsurers, counterparty credit risks regarding reinsurance companies were considered to be insignificant. Several empirical studies on primary insurer failures also find that, historically, reinsurer bankruptcy accounts for only about 2-5% of primary insurers' failure cases (McDonnell, 2002; Sharma et. al., 2002; Cummins and Weiss, 2010). However, as we learned from the 2007-2008 financial crisis, there is no such thing as "too big to fail" in the financial world. In recent years, the ratings of reinsurers' financial strength have deteriorated. As shown by S&P and Moody's, the percentage of reinsurers with AAA and AA ratings decreased significantly between 2002 and 2010, as more firms now fall into the A and BBB rating categories. Table 1 shows the number of ratings upgrades and downgrades for reinsurers during the 2002-2010 period. In total, there are 173 downgrades; there are far fewer upgrades in that period. It seems that the declined investment income in the 2000s and the recent financial crisis have deteriorated the asset quality of reinsurers, and the impact of the terrorist attacks and intensified natural disasters, such as the 2004-2005 hurricane seasons, have exposed reinsurers to greater risks. Meanwhile, the global reinsurance industry has become more concentrated than ever. Cummins and Weiss (2000) report that the top ten reinsurers accounted for 35 percent of the world reinsurance market in 1991, but that percentage increased to 52 percent in 1998 after

the merger and acquisition waves during the 1990s. The number further increased to 79 percent by net premiums earned in 2009 in the property-casualty market (A.M. Best Company, 2010). The increased concentration of the reinsurance market, combined with the seemingly deteriorating quality of reinsurers and the possibility of failure of the major reinsurance companies, magnify concerns over potential reinsurer failure and the possible spillover effect into the whole insurance industry and beyond.

Credit risk from reinsurance counterparties has been a concern of ceding companies, as reflected in regulation and contracting terms. For example, for US property-casualty insurers, the NAIC specifies that the risk-based capital of P/C firms will include a risk charge equal to 10 percent of reinsurance recoverable to guard against the risk of uncollectability of reinsurance recoverable. Additionally, ceding companies have been increasingly using the special termination clause (STC) with rating triggers in their reinsurance contracts (Reynolds Porter Chamberlain LLP, 2007) to reduce their credit risk. However, such practices may actually exacerbate the problem of retrocession spirals because the clause would allow the primary company to cancel the reinsurance policy if the reinsurer's rating was downgraded below a certain threshold, making already weak reinsurers even weaker (Cummins and Weiss, 2010), thus leading to a greater potential for systemic risks.

Given the increasing concern over interconnectedness in the insurance market, this paper will empirically investigate the dependency of US P/C insurers on reinsurance and the ability of rating agencies and the capital market in assessing the reinsurance risk by examining how the downgrading of reinsurers affects the credit risk of primary insurers (and, therefore, their ratings) and the stock price of publicly traded insurance groups. We also provide scenario analyses of the impact of reinsurer failure(s) by examining how many rating downgrades and insolvencies could be triggered if leading world reinsurers were to collapse.

3. Data

We study the interconnectedness of insurers and reinsurers in the US property-casualty insurance industry by using a sample from the 2002 to 2009 period. Financial data for ceding insurers is obtained from NAIC annual statements. In particular, reinsurance premiums ceded and reinsurance recoverable data is extracted from the NAIC Schedule F− part 3. Ratings information for ceding insurers and domestic reinsurers is extracted from A. M. Best's Key Rating Guide, and ratings information for global reinsurers is obtained from S&P, Moody's and A. M. Best. Since the NAIC Schedule F− part 3 data may involve some reporting errors, especially regarding the names of reinsurers (Cummins, 2007), we clean the raw data to correct the errors with our best discretion.[2] We manually merge the ratings data and NAIC data by matching the reinsurer's name and domicile.

4. The Dependency of Primary Insurers on Reinsurers

4.1. Summary statistics: reinsurance usage by the US P/C industry

This section discusses the dependency of primary insurers on reinsurers. Insurance companies can choose to cede their business to affiliated companies within the same insurance group for the benefits of intra-group portfolio diversification. They can also choose to cede business to unaffiliated insurers for the benefits of inter-company diversification of risks. These affiliates and non-affiliates could domicile in the United States and be subject to US regulation, but they could also be alien companies that are not subject to US regulations. Both types of reinsurance can pose an insolvency threat to insurers, as pointed out by Cummins and Weiss (2010), though

[2] For example, the database reports each Lloyd's of London syndicate (or managing agent) as an individual entity. We systematize the reporting of names (e.g., by checking the Lloyd's of London's website and using the FEIN number of the entity) and put them into one category: Lloyd's of London.

non-affiliated reinsurance is generally considered to pose more counterparty risk than affiliated reinsurance.

Reinsurance could pose significant credit risks to ceding insurers. Reinsurance recoverable may have a significant impact on balance sheets of ceding insurers. In Schedule F– part 3, the reinsurance recoverable on paid losses and loss adjustment expenses represents the reinsurance receivable item on an insurer's balance sheet, and the reinsurance recoverable on unpaid losses and loss adjustment expenses represents the contra-liability item to loss reserves of primary insurers. As a result, the net reinsurance recoverable item in schedule F– part 3 is the total effect that reinsurance could have on ceding insurers' surplus levels (Feldblum, 2002). The recoverable item helps reduce the ceding company's leverage ratio and expand its capacity to write insurance.

Table 2 shows the dependence of US P/C insurers on reinsurance at the industry level. Because professional reinsurers differ from non-reinsurers in reinsurance activities,[3] we perform separate analyses for them. The results for professional reinsurers are not reported in the paper but discussed in the footnote in pursuit of brevity. We adopt A. M. Best's definition in defining professional reinsurers; that is, if a firm's reinsurance assumed from unaffiliated firms is more than 75 percent of the sum of reinsurance assumed from affiliates and its direct premiums written, then it is classified as a professional reinsurer (Cole and McCullough, 2008).

Panel A of Table 2 shows the percentage of total ceded premiums to total direct premiums written and the percentage of total net reinsurance recoverable to policyholder surplus for US P/C industry (excluding professional reinsurers). There is an obvious upward trend in the premiums ceded percentage and a downward trend in recoverable percentage, suggesting that US P/C insurers use more reinsurance services over time but become less "dependent" on

[3] Professional reinsurers underwrite little to no direct business and tend to contract with other reinsurance firms.

reinsurance because of their strong capital position. However, percentage-wise, reinsurance could still pose significant risks to primary insurers. For example, the percentage of net reinsurance recoverable over surplus ratio was 131.3% in 2009.

When breaking down reinsurance activities by contracted reinsurers' type, we find that the industry cedes more premiums to and has more recoverable from affiliated reinsurers (Panel B and Panel C), while using significantly fewer reinsurance services from unaffiliated reinsurers over time (Panel D and Panel E). This trend may be the result of mergers and acquisitions in the US domestic insurance market and global insurance markets, where more unaffiliated firms have become affiliated (Cummins and Xie, 2010; Cummins and Weis, 2004). The percentages show that US primary insurers depend the most on affiliated reinsurers domiciled in the United States (e.g., 77.3% ceded premiums are to the US affiliated reinsurers, and 72.8% net recoverable are from US affiliated reinsurers in 2009, see panel B). The second largest category is composed of US unaffiliated reinsurers (8.0% ceded premiums and 10.9% net recoverable in 2009, see panel D), followed by alien affiliated reinsurers (Panel C) and alien unaffiliated reinsurers (Panel E).[4]

4.2. Diversification of reinsurance portfolios (at firm level)

[4] The analyses for professional reinsurers show that, unlike non-reinsurers, professional reinsurers cede their premiums mostly to alien affiliated reinsurers (e.g., 58.5% in 2009) and spread the rest almost equally to the other three types of reinsurers. A similar pattern is observed for net recoverable, with the percentage of alien affiliated reinsurers increasing over time. Major reinsurance groups usually operate globally, and many professional reinsurers in the US are subsidiaries of these groups. As a result, it is not surprising that these reinsurers cede their business to their non-US affiliates to seek intra-group risk diversification.

Compared to non-reinsurer ceding insurers, professional reinsurers have less aggregated reinsurance (retrocession) exposure. For example, the net reinsurance recoverable over surplus ratio for this group of firms is only 63.26% in 2009, suggesting US professional reinsurers in aggregate maintain a strong capital ability. However, these professional reinsurers are exposed to higher credit risks from unaffiliated reinsurers than the non-reinsurer ceding companies. For example, in non-reinsurer ceding companies' portfolios, about 15.6 percent of net reinsurance recoverable is from unaffiliated reinsurers, whereas the percentage for the professional reinsurer was 30.7 percent. It is also worth noting that the credit risk for professional reinsurers is sensitive to catastrophic losses. The net reinsurance recoverable over surplus ratio was as high as 105% in 2002 and 195.49% in 2005 following the huge losses from the September 11th terrorist attacks and Hurricane Katrina, respectively, which depleted reinsurers' capital significantly.

Table 3 shows the diversification of reinsurance portfolios for US P/C insurers (professional reinsurers excluded). Five types of Herfindahl indices are calculated based on ceded premiums and net reinsurance recoverable, respectively: (1) Herfindahl index for all reinsurers, regardless of their affiliation and domicile; (2) Herfindahl index for US affiliated reinsurers only; (3) Herfindahl index for alien affiliated reinsurers only; (4) Herfindahl index for US unaffiliated reinsurers only; and (5) Herfindahl index for alien unaffiliated reinsurers only. Both mean and median values of Herfindahl index are reported, along with the number of ceding firms that use those types of reinsurers. Since the level and trend of Herfindahl indices are similar for both ceded premiums-based and recoverable-based, we proceed with the recoverable-based Herfindahl.

The results indicate that US insurers overall are not diversified enough in their reinsurance portfolios (with a mean Herfindahl index higher than 0.6). The situation improves slightly over time (from 0.657 in 2002 to 0.639 in 2009). The concentration in reinsurance portfolios is mainly attributable to firms that cede premiums to their US affiliates. About 60 percent of ceding firms (out of more than 2,000 ceding firms with positive reinsurance recoverable) have reinsurance recoverable from their US affiliates. This affiliated reinsurance portfolio is extremely concentrated (with a mean Herfindahl index higher than 0.9) and shows no sign of changing over time. This result supports the view of Cummins and Weiss (2010) that affiliates could be a significant source of credit risk to US insurers. There are also a growing number of US insurers using alien affiliated reinsurer services (from 10% in 2002 to 13% in 2009, calculated from the number of ceding firms, recoverable-based). This reinsurance portfolio is concentrated as well (with a mean Herfindahl index higher than 0.8).

More than 70% of US insurers have reinsurance transactions with US non-affiliates, and this set of reinsurance portfolios is more diversified (with a mean Herfindahl index 0.543 in 2002

and 0.532 in 2009) than the affiliated reinsurance portfolio. Still, the credit risk could be high; a Herfindahl index higher than 0.5 indicates that ceding insurers depend very much on the top one or two reinsurance companies. A significant percentage of US insurers (40% in 2002, 52% in 2009) use alien unaffiliated reinsurance services; this set of reinsurance portfolios is the most diversified, and the diversification level increases over time (mean Herfindahl index 0.484 in 2002 and 0.449 in 2009), suggesting that credit risk exposure from these types of reinsurance services is relatively small.[5]

In summary, the reinsurance portfolios of US insurers are highly concentrated. The industry cedes business heavily to affiliated reinsurers, and the portfolio is extremely concentrated. Though the industry depends less on unaffiliated reinsurers, significant credit risks still exist because of the relatively high concentration of the unaffiliated reinsurance portfolio and the significance in size of this portfolio to ceding insurers' surplus.

5. The Impact of Reinsurer Downgrades on Primary Insurers' Risk

This section analyzes the impact of reinsurer downgrades on primary insurers' risk. A downgrade of a reinsurer's financial rating may lead to an increase in the risk of its counterparty primary insurers because of the increased default risk of reinsurance recoverable. Therefore, through reinsurance transactions, the risk of reinsurers is connected to the primary insurers' risk. If rating agencies and capital market can assess the extent of the connection, rating downgrades

[5] We also analyze the diversification of reinsurance portfolios for US professional reinsurers only. This mostly reflects the retrocession activities of these companies, since such firms have little direct business. Overall, professional reinsurers' retrocession portfolios are more diversified (with a mean Herfindahl index 0.533 in 2009) than those of ceding insurers that are not professional reinsurers. Only a small proportion of professional reinsurers (about 35%) retrocede to their affiliates (domestic or alien) and do not diversify their portfolio with affiliates (mean Herfindahl index close to 0.9, with an upward trend from 2002 to 2009). More than 90 percent of professional reinsurers retrocede to US unaffiliated reinsurers, and that portfolio is quite diversified, with a downward trending Herfindahl index (0.506 in 2002, and 0.448 in 2009). Percentage-wise, an increasing number of US professional reinsurers (63% in 2002 and 77% in 2009) retrocede to alien unaffiliated reinsurers, and this type of reinsurance portfolio is the most diversified (mean Herfindahl index 0.426 in 2009). Overall, professional reinsurers tend to be more diversified in unaffiliated reinsurance but very concentrated in affiliated reinsurance usage.

of counterparty reinsurers should negatively affect primary insurers' financial strength ratings and stock prices. The objective of this section is to conduct joint tests examining the extent of risk transition from reinsurers to primary insurers and the ability of the market to conceive of these risks.

5.1. The impact of reinsurer rating downgrades on counterparty primary insurers' rating

To examine the interconnectedness in the insurance-reinsurance market, we first analyze the rating changes of primary insurers following the downgrades of their reinsurer counterparties. We expect that reinsurers' ratings downgrades will negatively impact the ratings of their primary insurers. Specifically, we run the following logit regression model:

$$\mathrm{PDown_{it}} = \alpha + \beta \times \mathrm{RDown_{it}} + \gamma \times \mathrm{RDownRec_{it}} + \delta \times \mathrm{X_{it}} + \theta \times \mathrm{Year_t} + \varepsilon_{it}, \qquad (1)$$

where $\mathrm{PDown_{it}}$ is a dummy variable with the value of 1 when a primary insurer is downgraded. $\mathrm{RDown_{it}}$ is a dummy variable with the value of 1 when any of the reinsurers of the insurer *i* has been downgraded between the prior rating date and current rating date of the insurer *i*. $\mathrm{RDownRec_{it}}$ is the proportion of reinsurance recoverable from the downgraded reinsurer(s) to the surplus of the insurer *i*. $\mathrm{X_{it}}$ is a set of control variables of primary insurer characteristics which may affect the rating change of the insurer *i*. Finally, $\mathrm{Year_t}$ represents year-fixed effect dummy variables that allow us to control both the macroeconomic conditions and insurance industry-specific conditions that affect the ratings of primary insurers.[6] We expect $\beta > 0$ *and* $\gamma > 0$.

[6] We did not include firm-fixed effects in the model because that operation will lose about 75% of insurer-year observations where an insurer has no rating downgrades during the sample period. In addition, we believe the control of previous ratings information in the regression can capture most firm-specific effects.

To construct the insurer-year panel data about ratings downgrades for primary insurers and reinsurers, we start with all US P/C insurers that file with NAIC and have Financial Strength ratings from A.M. Best. For PDown_{it}, we assign a dummy variable equal to 1 when there is a rating downgrade in year *t*. For each insurer, we collect their unaffiliated reinsurance transaction data from NAIC Schedule F and obtain the ratings information for these reinsurers from A.M. Best, Moody's, and S&P reinsurer ratings. If any of the reinsurers of insurer *i* are downgraded by any of the rating agencies between the previous rated date and the current rated date of insurer *i*, we assign the value of 1 to RDown_{it}.

In regard to the spread of credit risk from downgraded reinsurers to primary insurers, it is logical that a higher percentage of reinsurance recoverable from downgraded reinsurers will have a greater negative effect on a primary insurer's rating. To test this hypothesis, we include $\mathrm{RDownRec}_{it}$ in the regression. This variable is constructed as follows. For insurer *i* at year *t*, we calculate its sum of reinsurance recoverable at *t-1* from all downgraded reinsurers, then scale this by insurer *i*'s surplus at *t-1* to measure the relative size of the default risk from downgraded reinsurers. We restrict our focus only to the unaffiliated reinsurance transactions out of the concern that subsidiary insurers within the same insurance group often receive the same rating, and affiliated insurers' risks are interconnected in much more complicated ways than simply through the explicit reinsurance transactions.

In addition to reinsurance arrangements, a primary insurer's rating may be downgraded because of a host of other factors that affect the default risk and the firm's financial strength. We follow the insurance rating literature to select control variables X_{it}. We first conduct an ordered probit regression model, with the dependent variable being the numerical conversion of A.M.

Best rating categories.[7] The explanatory variables include all Financial Analysis and Surveillance Tracking (FAST) scores, Best's Capital Adequacy Ratio (BCAR), and a few other variables mentioned in Best's Credit Rating Methodology (2009) and other insurer insolvency and rating studies (Cummins et al., 1995; Doherty and Phillips, 2002; Doherty et al., 2011; Kartasheva and Park, 2011). The first round results show that not all variables are significant in the model, and many variables show high correlation with each other and create possible multicollinearity problems. Hence, we keep only significant variables from this probit regression model and use them as control variables in our main regression model (1).

The selected set of control variables from the probit regression model and their definitions are presented in Table 4. These variables include investment yield, net premiums written to surplus ratio, reinsurance recoverable to surplus ratio, reserve to surplus ratio, junk bond investment to surplus ratio, BCAR (Best's Capital Adequacy Ratio), log(Asset), proportion of catastrophic risk exposure, combined ratio, a dummy variable indicating whether the insurer (or its parent) is publicly traded, a dummy variable for single unaffiliated company, and firm age. Because the dependent variable of the regression model (1) is not the rating itself but the change in rating (downgrade), we include the difference between year *t-1* and year *t* of these selected variables as control variables. Therefore, the two dummy variables and the firm age variable are dropped from the model. Lastly, we include the previous A.M. Best Rating in X_{it} to control possible heterogeneity in rating changes for the different rating categories. For example, the stronger ratings, such as A++ and A+, could be more sensitive to any risk changes than B or C ratings because rating agencies could be more stringent in the awarding of the strongest ratings. On the other hand, it is also possible that firms with strong ratings tend to put more efforts into

[7] We converted the A.M. Best rating as follows: A++=13, A+=12, A=11, … and D=1.

maintaining their current ratings, so these firms may have persistent ratings than firms with weak ratings.

Table 5 shows the summary statistics of variables used in model (1). During the study period, 3.3 percent of primary insurers have been downgraded. The average ratio of reinsurance recoverable from downgraded unaffiliated reinsurers to policyholders' surplus is 2.9 percent.

The regression results of model (1) are shown in Table 6.[8] The key variables of interest are RDown and RDownRec. The signs of both coefficients are positive, but only the RDownRec is significant. This result suggests that a primary insurer is more likely to be downgraded when its contracted reinsurer(s) is(are) downgraded, and the increased reinsurance risk is precisely captured because the likelihood of downgrade is positively correlated with the magnitude of increased default risk from downgraded reinsurers, which is measured by RDownRec.

In this analysis, we only analyze unaffiliated reinsurance transactions because the ratings of affiliated companies within a group are usually the same, and even if they are different, the risk of interconnectedness between subsidiaries cannot be summarized solely through reinsurance transactions. However, we acknowledge that the primary insurers that have access to affiliated reinsurance transactions may be less impacted by downgrading of unaffiliated reinsurer counterparties because they can diversify risk among affiliated and unaffiliated reinsurers. In contrast, unaffiliated single companies that only have access to unaffiliated reinsurance transactions will be more adversely impacted by the downgrading of unaffiliated reinsurers. To test this hypothesis, we conduct one more regression by including an interaction term of a single company dummy variable and RDownRec. The result is presented in the last column of Table 6. Once we include this interaction term, the RDownRec becomes insignificant and the interaction

[8] The number of observations used in the regression of table 6 is smaller than the one in Table 4 because we lose all observations of year 2002 due to the use of lagged one period variables in the regression, and we lose some observations in other years due to the use of first difference in explanatory variables.

term is positive and significant, which suggests that the increased reinsurance risk has more impact on single unaffiliated insurers than on the subsidiaries of an insurance group.

The coefficients of the control variables all carry the expected signs: a primary insurer's downgrading is negatively associated with an increase in BCAR ratio and firm size, and positively associated with an increase in premium over surplus ratio, reinsurance recoverable over surplus ratio, combined ratio and reserve over surplus ratio. Although not significant, an increase in catastrophic risk exposure and junk bonds to surplus ratio is positively associated with downgrades, and an increase in investment yield is negatively associated with downgrades. Lastly, the previous Best's Rating carries a significant negative coefficient, suggesting that stronger insurers are less likely to be downgraded than weaker insurers.

The results in this section provide evidence on the interconnectedness between primary insurers and reinsurers and rating agencies' ability to properly incorporate the increased risk from reinsurance recoverable. Since this result also holds after controlling for the changes in combined ratio, it reasonably excludes contamination of the reverse causality effect, where the loss suffered by a primary insurer may affect the reinsurers' risk.

5.2. The impact of reinsurer rating downgrades on primary insurers' stock price

Since systemic risks and adverse shocks to an industry are usually first captured by the stock market, in this section we examine the link between the reinsurer ratings downgrades and primary insurers' stock price in the event study framework. We have shown in the previous section that counterparty reinsurers' risk adversely affects primary insurers' financial ratings. Similar adverse effects should also appear in the stock market, should market participants perceive the interconnectedness between reinsurers and primary insurers. Here, stock market analyses provide an additional advantage over the ratings downgrade analyses, since impacts of

adverse events are usually more directly reflected in short-term stock price movements. Since reinsurance downgrades can be triggered by unexpected losses from primary insurers, one might argue that negative stock movements of primary insurers may not be the result of reinsurance downgrades but the cause. The event study method can actually address the problem rather nicely. Given that there is lag time between primary insurers' loss events and reinsurers' downgrades, the large loss event of primary insurers which triggered a reinsurer's downgrade should have already been absorbed in the primary insurer's stock price by the time of the downgrade event. Therefore, changes in value of stocks of primary insurers following a reinsurer's downgrade are most likely attributable to the reinsurer's downgrade.

We assess the market reaction of primary insurers to the news of reinsurers' downgrading. The first analyses (Table 7, Panel A) present the stock reaction of counterparty primary insurers of the downgraded reinsurer(s), which measures the direct impact of reinsurer downgrades. The second analyses (Table 7, Panel B) present the negative spillover effects of reinsurer downgrades, i.e., the reaction of non-counterparty primary insurers (insurers that do not have reinsurance arrangements with the downgraded reinsurers). We conduct a standard event study utilizing the market model (MacKinlay, 1997) to measure abnormal returns.[9]

Table 7 shows that reinsurer downgrade events have a strong, statistically significant negative impact on the stock prices of counterparty primary insurers, with an average CAR -1.50% for the (-15, +15) days window (Panel A). This suggests that increases in reinsurance risk brings additional risk to the primary insurers and therefore reduces stock value.

[9] See Boehmer, Musumeci, and Poulsen (1991) and Cowan (1992) for the explanation of event study methodology and statistical significance tests. To address the concern of the cross-sectional correlation caused by clustering of firms around single event date, we also report the Portfolio Time-series CDA t-test in the table (Brown and Warner, 1980; Chandra, Moriarity, and Willinger, 1990).

In addition to the direct effects on counterparty primary insurers, we are aware of the possibility that the lack of transparency in the reinsurance market may create a contagion effect in the primary insurer market in the case of reinsurance company failures. That is, a reinsurer's failure could have negative effects even on primary insurers with no direct business relationships with the problematic reinsurers. To test this layer of risk, we investigate whether the reinsurance credit risk information is transparently delivered to the capital market by examining the stock reactions of primary insurers with no direct credit risk exposure to the downgraded reinsurers. The result shows that reinsurer downgrade announcements also have significant externalities, or spillover effects, on the stocks of non-counterparty primary insurers, with a negative CAR -0.48% for the (-15, +15) days window (Panel B), the magnitude of which is smaller compared to these events' impact on counterparty primary insurers.

There are two possible interpretations on the negative reaction of non-counterparty primary insurers. One is that the negative reaction could represent pure contagion effects caused by opacity: the market irrationally re-prices all insurers regardless of their relationship with the downgraded reinsurers. Alternatively, it could be information-based: the market worries about the indirect impact of downgraded reinsurers through retrocession spirals. Because we do not have access to the reinsurance and retrocession transactions between global reinsurance companies, testing these two alternative hypotheses are out of the scope of this study. However, the fact that the contagion effect is only about 30% of direct effect suggests that the reinsurance transaction is not a complete black box to capital market, but is reasonably transparent.

5.3. Robustness Check

We conducted a robustness check regarding whether the above results hold or become stronger for "threshold rating downgrades." Following Halek and Eckles (2010), we define a threshold

rating downgrade as losing an A- (A.M. Best), an Aa3 (Moody's), or an AA- (S&P). For ratings downgrade analyses, we find no significant result for this particular set of threshold downgrading.[10] In regard to the stock market reaction, for counterparty primary insurers, the announcing effect of threshold downgrading is similar to the overall sample, but we do find a stronger contagion effect for threshold downgrading announcements.

To address the issue of potential high correlation of firm returns when the event day and industry are the same, we run an event study by forming a portfolio of firms for each downgrade announcement and use portfolio returns instead of individual stock returns.[11] A similar conclusion is drawn for contagion effects (with a little stronger result), but we find a little weaker negative result for direct effects on counterparty primary insurers.

6. Scenario Analysis of Large Reinsurance Companies' Insolvency

In this section, we examine how bad things could get in case of large reinsurer insolvency. Although there was no major reinsurer insolvency historically, in the wake of the collapse of insurance giant AIG and other giant financial institutions, it is imperative that we improve our understanding of the dynamics and anticipate the scenarios of large reinsurer insolvency in the future.

Although the previously mentioned Group of Thirty's "stress test" concludes that the impact of reinsurance risk would be limited because 20% of global reinsurance capacity only

[10] If we further apply a lower threshold, i.e., for A.M. Best and S&P, the rating moves below A- (to B++ or lower, or to BBB or lower), and for Moody's, rating moves to Baa1 or lower, then an increase in reinsurance recoverable from counterparty reinsurers with threshold downgrading increases a primary insurer's likelihood of being downgraded. Meanwhile, the coefficient of reinsurance recoverable from threshold downgrading is higher than if it is from non-threshold downgrading, suggesting that the default risk of primary insurance companies increases more when the counterparty reinsurance company's financial condition is seriously impaired.

[11] See Ghosh and Hilliard (2010) for more discussions on cross-dependency issues caused by clustering of firms around single event date.

corresponds to about 2-2.5% of gross total premiums, the high concentration of reinsurance portfolios (as shown in Table 3) suggests that the failure of one major reinsurer could still pose serious risks to some primary insurers. In addition, the impact of top global reinsurers is not negligible due to the highly concentrated reinsurance market. The dependence on unaffiliated reinsurance could appear to be small as is argued in the Group of Thirty (2006) and Swiss Re (2003), but the high affiliated reinsurance dependency found in Table 2 suggests that if a company within a group assuming significant portions of affiliated reinsurance gets hit by the insolvency of unaffiliated reinsurers, broader impacts could be felt throughout the insurance industry through the affiliated reinsurance chain.

In this section, we run scenario analyses by allowing one of the top three reinsurers (Swiss Re, Munich Re, and Berkshire Hathaway) to become insolvent, which causes counterparty primary insurers to be unable to fully recover from this reinsurer failure. Because part of the recoverable can be paid off even with complete liquidation of reinsurers, we run multiple scenario analyses where the recoverable are defaulted by 100%, 50%, 30%, or 10%. We examine the effects of this recoverable default on the primary insurers' ratings downgrades and insolvencies using 2009 data. We use Swiss Re as an example to describe our scenario analyses.

To examine the impact of the insolvency of Swiss Re on primary insurers' ratings, we use the same rating probit regression model in Table 4 of section 5.1. First, we run the rating regression with the original surplus level and get the ratings estimate for each insurer. Second, we calculate the hypothetical surplus of primary insurers by assuming that 100%, 50%, 30%, or 10% of their reinsurance recoverable from Swiss Re will default. Next, we calculate all explanatory variables using the hypothetical surplus. Fourth, we estimate the hypothetical rating of the primary insurer by plugging new hypothetical explanatory variables into the fitted model

presented in Table 4. We then compare the original estimated ratings with the estimated hypothetical ratings to draw a conclusion on ratings downgrades.[12]

Table 8 presents the scenario analysis of the fall of major reinsurers and the likely impacts on primary insurers' ratings. The number of downgraded insurers as a result of the reinsurance recoverable default is presented. Since we can only include those insurers with an A.M. Best rating and no missing explanatory variables in the ratings regressions, the total number of insurers used in this analysis is 1,367. The result shows that the impact of major reinsurers' insolvency on US property-casualty insurers is not serious. Even under the extreme and unlikely assumption of 100% recoverable default, fewer than 35 insurers would be downgraded. The impact of Swiss Re's insolvency on US insurers is the strongest; 32 insurers out of 1,367 insurers (2.41%) would be downgraded if assuming 100% default from Swiss Re. Under the more realistic assumption of a 30% default rate, less than 1% of insurers will be downgraded when one of the top three reinsurers is insolvent. If the default rate is set to 10%, only one insurer would be downgraded if Munich Re or Swiss Re becomes insolvent, and no insurer would be affected by Berkshire Hathaway's insolvency.

To assess how many primary insurers would become insolvent as a result of reinsurer insolvency, we conduct a scenario analysis similar to the downgrade analysis. Using Swiss Re as an example again (see Figure 1), we first calculate the hypothetical surplus of primary insurers (insurer A-1, insurer A-2, insurer C, and insurer D) if their unaffiliated reinsurer−Swiss Re– becomes insolvent. If the new surplus of any insurer is negative, we treat this firm as insolvent.

[12] We compare the hypothetical ratings with the original estimated ratings instead of the actual ratings because the difference between actual and hypothetical estimated ratings contains both the increased risk and unavoidable modeling error. A comparison of estimated ratings both before and after the reinsurer insolvency event will return a more consistent result.

However, this criterion is too strict for insolvency because many firms declare bankruptcy before they reach a negative surplus. Insurance regulators in the US start to monitor an insurer closely if its surplus drops below 200 percent of risk-based capital (RBC). Therefore, we use the 200 percent RBC level as a conservative criterion of insolvency. That is, once a firm's hypothetical surplus goes below 200 percent of its RBC, we record the firm as an insolvent company.

Tracking the direct impact of Swiss Re's insolvency on its counterparty primary insurers is not sufficient to assess its overall impact on the insurance industry, because the insolvent primary insurers may also have assumed reinsurance, i.e., a chain effect may exist. Therefore, a primary insurer's insolvency as a result of Swiss Re's insolvency may make more insurers become insolvent through affiliated and unaffiliated reinsurance transactions.

To examine this chain effect, we estimate the total reinsurance recoverable that may be subject to default for a primary insurer by adding (1) its unaffiliated reinsurance recoverable from Swiss Re, and (2) its reinsurance recoverable from other contracted affiliated and unaffiliated reinsurers that are hypothetically insolvent as a result of Swiss Re's insolvency. For example, as shown in Figure 1, if insurer A-1 becomes insolvent due to collapse of Swiss Re (direct effect), and it has assumed reinsurance from its affiliated insurer A-2 and unaffiliated insurer C, then the total effect of Swiss Re on Insurer A-2 becomes b+c, and the total effect on insurer C is f+e. If Insurer C becomes insolvent as a result of the first round chain effect, and if it had assumed reinsurance from insurer D, then the final effect on insurer D is g+h.

For simplicity, we assume that the same proportion of recoverable can be collected from all insolvent reinsurers. For example, under the 30% recovery scenario, we assume that insurer A-1 can only recover 30% of recoverable from Swiss Re when Swiss Re becomes insolvent. If, unfortunately, this puts insurer A-1 into insolvency, then insurer A-2 and insurer C, which had

ceded business to Insurer A-1, can now only collect 30% of reinsurance recoverable from insurer A-1. If this also puts insurer C into insolvency, then we assume insurer D can only collect 30% from insurance C. We repeat this process until we reach a point where the number of insolvent insurers does not increase any more.

In each analysis, we did not count the downgrades or insolvency of the subsidiaries of Munich Re, Swiss Re, and Berkshire Hathaway under Munich Re's, Swiss Re's, and Berkshire Hathaway's insolvency scenarios, respectively.

Table 9 presents the number of insolvent insurers as a result of reinsurance recoverable default. The study sample of Panel A includes all US property-casualty insurers that have a surplus greater than 200% RBC in 2009. If using negative surplus to define insolvency, fewer than 10 insurers out of 2,492 will become insolvent even under the extreme assumption of 100% reinsurance loss. The chain effect was also minimal. Only one more insurer would become insolvent when they lose 100% recoverable from both Swiss Re and the nine additional insolvent insurers resulting from Swiss Re's insolvency. The number of insolvent insurers doubles if we apply a more conservative criterion − 200% RBC, but this number is still small relative to the size of the sample. Fewer than 30 insurers would become insolvent with and without the chain effect considered in all three cases, even with the assumption of 100% loss of recoverable from insolvent reinsurers. The number drops quickly as we reduce the default rate to 50%, 30%, and 10%. Only two insurers would become insolvent if Munich Re goes bankrupt and the primary insurers suffer a 10% loss in recoverable. The number is one and three, respectively, for Swiss Re and Berkshire Hathaway. In an unreported analysis, we also track the sum of total assets of the insolvent insurers. In any one of the major reinsurers insolvency scenario, the total assets of the resulting insolvent firms are smaller than one percent of total industry assets.

We provide one more analysis in Panel B of Table 9 to make the insolvency analysis results comparable to the downgrading analysis in Table 8. Here we conduct the analysis for the same 1,367 insurers used in the downgrade scenario analysis. Since the sample is restricted to rated insurers, the average size of insurers in Panel B is larger than that of insurers in Panel A. Once we limit our interest to only those rated insurers, the number of firms that will hypothetically go bankrupt drops dramatically. Under the negative surplus criterion of insolvency, no insurer will become insolvent if Munich Re were to become insolvent. When Swiss Re defaults on 50% of any of its reinsurance obligation, one insurer would become insolvent. The number would be two when Berkshire defaults on 100% of its reinsurance obligation. The number of insolvent insurers slightly increases if we apply the 200% RBC criterion, but it is still minor, with fewer than 15 insurers becoming insolvent in each case.

One major concern we have before we can conclude that the systemic risk caused by reinsurer collapse seems to be minor is that we have not considered reinsurance spiral cases in which multiple reinsurers' financial conditions deteriorate simultaneously due to the complex retrocession transactions among reinsurers. The risk of reinsurance spiral has been pointed out as a possible source of systemic risk (Cummins and Weiss, 2010). We consider two extreme cases: all three big reinsurers, Swiss Re, Munich Re, and Berkshire become insolvent altogether, and the most extreme case where all unaffiliated reinsurers become insolvent at the same time. The last two rows of Table 8 and Table 9 show the number of downgraded and insolvent insurers when they can only collect part of their unaffiliated reinsurance from insolvent reinsurers.

If all three reinsurers were to collapse at the same time, 70 out of the 1,367 insurers with ratings (5.12% of the sample) would be downgraded with 100% loss assumption, 9 insurers (0.1% of the sample) would delete capital, and 48 (3.6% of the sample) insurers' surplus over RBC

ratio would fall below 200%. Under the most extreme crisis scenario with 100% loss of all unaffiliated reinsurance assumption, out of the 1,367 firms with ratings, 248 insurers (18.15% of the sample) would be downgraded, 164 (11.99% of the sample) would delete capital, and 307 (22.45% of the sample) insurers' surplus over RBC ratio would fall below 200%. This can be quite a large shock to the economy but is only an apocalypse scenario. With a more realistic assumption of either a 30% or 10% default rate, less than 5 percent of insurers would become insolvent. The impact on the economy as a whole would be manageable. Results from Panel A of Table 9 when using the whole sample of 2,492 firms are comparable to that of panel B.

7. Conclusion and Discussion

In this paper, we examine systemic risks posed by the interconnectedness of the insurance sector through global reinsurance companies. Our goal is two-fold. The first is to provide empirical evidence of the interconnectedness between reinsurers and US property-casualty insurers. The second is to present the first detailed examination on the likely impact of major global reinsurer insolvency on the US property-casualty insurance industry.

There have been concerns about the complexity of the reinsurance transaction network and its resulting opacity, but our results suggest that the risk transitions from reinsurers to primary insurers are fairly well-recognized both by rating agencies and capital market participants. We document that the downgrade of reinsurers increases the likelihood of downgrading for counterparty primary insurers. We also find that primary insurers' stock prices react negatively to the downgrade of reinsurers in the event study framework. These results provide evidence that there is a close interconnectedness between the insurance sector and the reinsurance sector, and the market has well recognized it.

The next question we address is how bad things could get if major global reinsurer(s) collapse. We consider multiple scenarios where top global reinsurers become insolvent. The results suggest that it is reasonable to conclude that the systemic risk caused by reinsurance transactions is relatively small. Even under an extreme assumption of a 100% reinsurance recoverable default by one of the top three global reinsurers, only about two percent of insurers would be downgraded, and one percent of insurers would become insolvent.

Our study of interconnectedness and worst scenario analyses only serves as the first step in analyzing possible systemic risk imposed by the reinsurance sector. There are many other factors that should be considered and addressed when reaching final conclusions. The first is macroeconomic conditions and major loss shocks that may affect both primary insurers and reinsurers. If certain macroeconomic conditions or major loss shocks are the cause of reinsurer insolvency, it is very likely that primary insurers will also be affected. Second, the negative effects detected from past downgrading events may only serve as a lower limit of major reinsurer solvency cases. The market in the past has only experienced the insolvency of several small reinsurers. Shocking news such as major global reinsurer(s) failure could panic the market, magnifying the contagion effect even further as we have seen in the recent financial crisis. Third, the impact of affiliated insurer insolvency on other affiliated insurers within the same group is not fully addressed in this paper. Although we include affiliated reinsurance transactions in our scenario analysis, firms within the same group are connected through many channels other than reinsurance transactions. Collapse of affiliated reinsurers may have a more significant impact on a primary insurer than unaffiliated reinsurers because of the concentration of intra-group reinsurance arrangements and the sharing of the same corporate culture, risk preferences, and corporate governance mechanisms.

References

Acharya, Viral V., John Biggs, Matthew Richardson, and Stephen Ryan. 2009. On the Financial Regulation of Insurance Companies. *NYU Stern School of Business, working paper.*

A.M. Best Company. 2010. Global Reinsurance: 2009 Financial Review, Best's Special Report, April 12 (Oldwick, NJ).

Best's Credit Rating Methodology. 2009. Global Life and Non-Life Edition. *A. M. Best Company*.

Billio, Monica, Mila Getmansky, Andrew W. Lo, and Loriana Pelizzon. 2011. Econometric Measures of Systemic Risk in the Finance and Insurance Sectors. *MIT Sloan Research Paper No. 4774-10; NBER Working Paper No. 16223; AFA 2011 Denver Meetings Paper; CAREFIN Research Paper, No. 12/2010. Available at SSRN: http://ssrn.com/abstract=1571277.*

Bell, Marian, and Benno Keller. 2009. Insurance and Stability: The Reform of Insurance Regulation. *Zurich Financial Services Group (Zurich, Switzerland).*

Boehmer, E., J. Musumeci and A. Poulsen, 1991. Event-Study Methodology under Conditions of Event-induced Variance. *Journal of Financial Economics*, 30(2): 253-272.

Brown, Stephen J., and Jerold B. Warner. 1980. Measuring Security Price Performance. *Journal of Financial Economics* 8 (3):205-258.

Chandra, Ramesh, Shane Moriarity, and G. Lee Willinger. 1990. A Reexamination of the Power of Alternative Return-Generating Models and the Effect of Accounting for Cross-Sectional Dependencies in Event Studies. *Journal of Accounting Research* 28 (2):398-408.

Cole, Cassandra R., and Kathleen A. McCullough. 2006. A Reexamination of the Corporate Demand for Reinsurance. *The Journal of Risk and Insurance* 73 (1):169-192.

———. 2008. A Comparative Analysis of US Property and Casualty Reinsurers and Insurers. *Risk Management and Insurance Review* 11 (1):179-207.

Cowan, A., 1992. Nonparametric Event Study Tests. *Review of Quantitative Finance and Accounting*, 2: 343-358.

Cummins, J. 2007. Reinsurance for Natural and Man-Made Catastrophes in the United States: Current State of the Market and Regulatory Reforms. *Risk Management and Insurance Review* 10 (2):179.

Cummins, J.David, Scott E. Harrington, and Robert Klein. 1995. Insolvency experience, risk-based capital, and prompt corrective action in property-liability insurance. *Journal of Banking and Finance* 19 (3-4): 511-527.

Cummins, J. David, and Mary A. Weiss. 2000. The Global Market for Reinsurance: Consolidation, Capacity, and Efficiency. *Brookings-Wharton Papers on Financial Services* 2000:159-222.

———. 2004. Consolidation in the European Insurance Industry: Do Mergers and Acquisitions Create Value for Shareholders? The Brookings/Wharton Conference: Public Policy Issues Confronting the Insurance Industry.

———. 2010. Systemic Risk and the US Insurance Sector. *Temple University, Working Paper, Available at SSRN: http://ssrn.com/abstract=1725512*.

Cummins, J. David, and Xiaoying Xie. 2008. Mergers and Acquisitions in the US Property-Liability Insurance Industry: Productivity and Efficiency Effects. *Journal of Banking & Finance* 32 (1):30-55.

Doherty, Neil A., Anastasia V. Kartasheva, and Richard D. Phillips. 2011. Information effect of entry into credit ratings market: The case of insurers' ratings. *Journal of Financial Economics* Forthcoming.

Doherty, Neil A., and Richard D. Phillips. 2002. Keeping up with the Joneses: Changing Rating Standards and the Buildup of Capital by U.S. Property-Liability Insurers. *Journal of Financial Services Research* 21:55-78.

Feldblum, Sholom. 2002. Reinsurance Accounting: Schedule F. *Casualty Actuarial Society Forum,* Sixth Edition.

Geneva Association, Special Report of the Geneva Association Systemic Risk Working Group. 2010. Systemic Risk in Insurance: An Analysis of Insurance and Financial Stability. (Geneva, Switzerland, March 2010.

Ghosh, Chinmoy, and James I. Hilliard. 2010. The Value of Contingent Commissions in the Property-Casualty Insurance Industry: Evidence from Stock Market Returns. *Journal of Risk and Insurance*: forthcoming.

Grace, Martin F. 2010. The Insurance Industry and Systemic Risk: Evidence and Discussion. *Networks Financial Institute Policy Brief No. 2010-PB-02.*

Halek, M., and D. Eckles. 2010. Effects of Analysts' Ratings on Insurer Stock Returns: Evidence of Asymmetric Responses. *Journal of Risk and Insurance* 77 (4): 801-827.

Harrington, Scott E. 2009. The Financial Crisis, Systemic Risk, and the Future of Insurance Regulation. *Journal of Risk and Insurance* 76 (4):785-819.

IMF. 2004. Global Financial Stability Report, World Economic and Financial Surveys: Market Developments and Issues. *(Washington: International Monetary Fund, April).*

Kartasheva, Anastasia V., and Sojung Park. 2011. Real Effects of Changing Rating Standards for Catastrophic Risks. *Working paper, the Wharton School, University of Pennsylvania.*

MacKinlay, A. Craig (1997), Event studies in economics and finance," Journal of Economic Literature 35, 13-39.

McDonnell, William. 2002. Why Some Insurers Fail: Practical Lessons from Recent Cases in Europe. *FSA Occasional Paper December 2002 (London, U.K.).*

Reynolds Porter Chamberlain LLP. 2007. "Hasta la vista baby" - Special Termination Clauses. *Reinsurance Update*:1-6.

Rossi, Marie-Louise, and Nicholas Lowe. 2002. Regulating Reinsurance in the Global Market. *Geneva Papers on Risk & Insurance - Issues & Practice* 27 (1):122--133.

Schwartzman, Joy A. 2008. The Game of 'Pass the Risk': Then and Now. in Risk Management: The Current Financial Crisis, Lessons Learned and Future Implications (Schaumburg, IL: The Society of Actuaries).

Sharma, Paul, et al. 2002 Report: . Prudential Supervision of Insurance Undertakings. *Conference of the Insurance Supervisory Services of the Member States of the European Union (London, U.K.).*

Swiss Re. 2003. Reinsurance - A Systemic Risk? *Sigma No. 5/2003 (Zurich, Switzerland).*

The Group of Thirty. 2006. Reinsurance and International Financial Markets (Washington, D.C.).

Table 1 Frequency of Reinsurer Ratings Upgrades and Downgrades, 2002-2010

	S&P			Moody's		
	N	**Upgrades**	**Downgrades**	**N**	**Upgrades**	**Downgrades**
2002	101	0	39	118	0	62
2003	112	2	56	112	0	31
2004	114	2	9	118	4	27
2005	120	17	15	119	14	7
2006	121	19	17	121	18	2
2007	129	25	3	117	7	0
2008	133	3	5	113	26	6
2009	130	23	22	101	0	37
2010	138	9	7	94	1	1
Total		100	173		70	173

Table 2 Dependence of US Property-Casualty Insurers on Reinsurance by Reinsurer Type

Panel A. Ceding Insurers, All Types of Reinsurers

Year	Total Ceded Premiums	Total Net Recoverable	Direct Premiums Written (DPW)	Surplus	Total Ceded Premiums /DPW	Total Net Recoverable / Surplus
2002	320,464	561,798	402,471	304,803	79.62%	184.32%
2003	349,209	610,754	443,484	365,349	78.74%	167.17%
2004	364,980	640,440	463,514	413,152	78.74%	155.01%
2005	388,210	729,528	476,461	481,048	81.48%	151.65%
2006	395,824	716,290	494,105	516,245	80.11%	138.75%
2007	402,798	717,355	496,606	554,372	81.11%	129.40%
2008	405,683	739,650	486,857	506,222	83.33%	146.11%
2009	400,790	735,134	473,167	559,895	84.70%	131.30%

Panel B. US Affiliated Reinsurer

Year	Ceded Premiums	Net Recoverable	% Total Ceded Premiums	% Total Net Recoverable	Ceded Premiums /DPW	Net Recoverable / Surplus
2002	236,331	372,242	73.7%	66.3%	58.72%	122.13%
2003	257,192	405,367	73.6%	66.4%	57.99%	110.95%
2004	276,220	430,375	75.7%	67.2%	59.59%	104.17%
2005	300,778	501,696	77.5%	68.8%	63.13%	104.29%
2006	307,760	508,772	77.8%	71.0%	62.29%	98.55%
2007	313,543	519,032	77.8%	72.4%	63.14%	93.63%
2008	313,967	531,621	77.4%	71.9%	64.49%	105.02%
2009	309,899	535,319	77.3%	72.8%	65.49%	95.61%

Panel C. Alien Affiliated Reinsurer

Year	Ceded Premiums	Net Recoverable	% Total Ceded Premiums	% Total Net Recoverable	Ceded Premiums /DPW	Net Recoverable / Surplus
2002	16,031	24,499	5.0%	4.4%	3.98%	8.04%
2003	20,688	31,578	5.9%	5.2%	4.66%	8.64%
2004	22,518	36,492	6.2%	5.7%	4.86%	8.83%
2005	25,198	44,670	6.5%	6.1%	5.29%	9.29%
2006	26,247	46,405	6.6%	6.5%	5.31%	8.99%
2007	26,261	47,534	6.5%	6.6%	5.29%	8.57%
2008	26,606	54,464	6.6%	7.4%	5.46%	10.76%
2009	27,941	53,867	7.0%	7.3%	5.91%	9.62%

Panel D. US Unaffiliated Reinsurer

Year	Ceded Premiums	Net Recoverable	% Total Ceded Premiums	% Total Net Recoverable	Ceded Premiums /DPW	Net Recoverable / Surplus
2002	40,519	92,469	12.6%	16.5%	10.07%	30.34%
2003	40,887	97,311	11.7%	15.9%	9.22%	26.64%
2004	36,519	95,243	10.0%	14.9%	7.88%	23.05%
2005	32,062	96,503	8.3%	13.2%	6.73%	20.06%
2006	31,755	90,075	8.0%	12.6%	6.43%	17.45%
2007	30,504	82,647	7.6%	11.5%	6.14%	14.91%
2008	32,272	82,258	8.0%	11.1%	6.63%	16.25%
2009	31,896	79,970	8.0%	10.9%	6.74%	14.28%

Panel E. Alien Unaffiliated Reinsurer

Year	Ceded Premiums	Net Recoverable	% Total Ceded Premiums	% Total Net Recoverable	Ceded Premiums /DPW	Net Recoverable / Surplus
2002	18,985	47,240	5.9%	8.4%	4.72%	15.50%
2003	22,338	49,310	6.4%	8.1%	5.04%	13.50%
2004	21,409	47,677	5.9%	7.4%	4.62%	11.54%
2005	21,956	49,738	5.7%	6.8%	4.61%	10.34%
2006	21,520	40,617	5.4%	5.7%	4.36%	7.87%
2007	23,962	38,525	5.9%	5.4%	4.83%	6.95%
2008	24,750	40,637	6.1%	5.5%	5.08%	8.03%
2009	23,312	34,395	5.8%	4.7%	4.93%	6.14%

Note: Based on industry aggregates, but professional property-casualty reinsurers are excluded from the analysis. We define "professional reinsurer" using A.M. Best's definition. That is, if a firm's reinsurance assumed from unaffiliated firms is more than 75 percent of the sum of the reinsurance assumed from affiliates and its direct premiums written, then it is defined as a professional reinsurer (Cole and McCullough, 2008).

Table 3 Diversification of Reinsurance Portfolios- Herfindahl Index by Type of Reinsurer for US P/C Firms (Professional Reinsurers Excluded)

Year	By Reinsurance Premiums Ceded					By Net Reinsurance Recoverable				
Mean										
Year	All Reinsurers	US Affiliated Reinsurer	Alien Affiliated Reinsurer	US Unaffiliated Reinsurer	Alien Unaffiliated Reinsurer	All Reinsurers	US Affiliated Reinsurer	Alien Affiliated Reinsurer	US Unaffiliated Reinsurer	Alien Unaffiliated Reinsurer
2002	0.679	0.924	0.893	0.569	0.426	0.657	0.925	0.880	0.543	0.484
2003	0.670	0.928	0.870	0.571	0.409	0.653	0.924	0.889	0.533	0.486
2004	0.662	0.930	0.880	0.564	0.384	0.643	0.924	0.888	0.529	0.468
2005	0.650	0.928	0.872	0.551	0.387	0.635	0.926	0.868	0.524	0.440
2006	0.641	0.922	0.888	0.543	0.371	0.636	0.923	0.882	0.525	0.462
2007	0.637	0.924	0.894	0.543	0.361	0.639	0.921	0.877	0.528	0.466
2008	0.636	0.927	0.897	0.536	0.359	0.637	0.923	0.879	0.529	0.442
2009	0.636	0.929	0.877	0.548	0.352	0.639	0.925	0.872	0.532	0.449
Median										
2002	0.814	1	1	0.506	0.311	0.729	1	1	0.490	0.395
2003	0.778	1	1	0.502	0.280	0.719	1	1	0.471	0.405
2004	0.771	1	1	0.496	0.256	0.696	1	1	0.461	0.359
2005	0.737	1	1	0.473	0.252	0.683	1	1	0.444	0.333
2006	0.731	1	1	0.463	0.226	0.687	1	1	0.448	0.348
2007	0.725	1	1	0.461	0.219	0.685	1	1	0.457	0.350
2008	0.707	1	1	0.467	0.215	0.680	1	1	0.446	0.315
2009	0.718	1	1	0.483	0.216	0.686	1	1	0.440	0.349
Number of Ceding Firms										
2002	2163	1264	203	1571	967	2168	1298	221	1571	861
2003	2159	1235	197	1544	1021	2178	1284	231	1563	920
2004	2180	1227	215	1520	1095	2212	1291	249	1567	988
2005	2202	1235	239	1499	1164	2263	1298	264	1597	1087
2006	2233	1235	250	1532	1233	2298	1304	279	1623	1174
2007	2259	1257	248	1558	1257	2303	1321	279	1618	1162
2008	2301	1267	293	1564	1298	2353	1335	311	1661	1259
2009	2313	1299	297	1566	1272	2357	1360	312	1645	1215

Table 4 Rating Determinants – Ordered Probit Regression Model, 2002-2009

Variables	Definition	Expected Sign	Estimates
Investment Yield	Annualized investments return based on average invested assets	+	0.0271***
			[0.005]
NPW/PHS	Net premiums written to surplus ratio	-	-0.0018***
			[0.000]
Reinsurance Recoverable/PHS	Reinsurance recoverable to surplus ratio	-	-0.0023***
			[0.000]
Reserve/PHS	Reserve to surplus ratio	-	-0.0033***
			[0.000]
Junk Bond/PHS	Total junk bonds in asset to surplus ratio	-	-0.0068***
			[0.002]
BCAR	Best's capital adequacy ratio	+	0.0009***
			[0.000]
Log(Asset)	Log value of insurer's admitted assets	+	0.3624***
			[0.007]
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	-	-0.4113***
			[0.068]
Combined Ratio	Underwriting expense/ net premiums written + loss and loss adjustment expenses incurred/ premiums earned	-	-0.0008***
			[0.000]
Public	Dummy variable equal to 1 if the insurer (or its parent) is publicly traded, 0 otherwise	+	0.5758***
			[0.023]
Single	A dummy variable equal to 1 for single unaffiliated company, 0 otherwise	-	-0.2779***
			[0.031]
Age	Firm age	+	0.001***
			[0.000]
Intercept			0.15
			[0.142]
Number of Observations			11,808
Likelihood Ratio			5,673.4

Note: standard errors are in brackets. ***, significant at the 1% level; **, significant at the 5% level; *, significant at the 10% level.

Table 5 Summary Statistics of Variables Affecting Rating Downgrades

Variable	Definitions	Mean	STD	Min	Max	1%	99%
PDown	1 if primary insurer's A.M. Best rating downgrades in year t. 0 otherwise.	0.033	0.179	0	1	0	1
Δ Investment Yield (%)	Change in Investment Yield from year t-1 to year t.	-0.111	2.005	-39.7	52.8	-3.2	3.3
Δ CAT risk	Change in the proportion of catastrophic risk exposed lines of business from year t-1 to t.	0.000	0.038	-1	1	-0.067	0.070
Δ NPW/PHS (%)	Net premiums written to surplus ratio change from year t-1 to year t.	-6.733	41.35	-727	686	-127	108
Δ Reinsurance Recoverable/PHS (%)	Reinsurance recoverable to surplus ratio change from year t-1 to year t.	-2.004	42.60	-659.9	604.9	-134.6	126.5
Δ Reserve/PHS (%)	Reserve to surplus ratio change from year t-1 to year t.	-1.632	33.72	-637	1285	-79	77
Δ Junk Bond/PHS (%)	Total junk bonds in asset to surplus ratio change from year t-1 to year t.	-0.062	3.718	-75.68	134.0	-8.97	9.41
Δ BCAR	Best's Capital Adequacy Ratio change from year t-1 to year t.	7.082	75.56	-842.9	872	-203.4	204.3
Δ Log Asset	Log (Asset) change from year t-1 to year t.	0.075	0.182	-2.828	2.768	-0.353	0.697
Δ Combined Ratio (%)	Combined ratio change from year t-1 to year t.	0.515	76.92	-114	120	-114	120
Best Rating(t-1)	Numerical conversion of Best's rating in year t-1.	10.22	1.556	2	13	6	13
RDown	1 if reinsurer rating downgrades between the primary insurer's previous rating date and the current rating date. 0 otherwise.	0.049	0.217	0	1	0	1
RDownRec	The proportion of reinsurance recoverable from the downgraded reinsurers to the surplus of the primary insurer.	0.029	0.124	0	3.939	0	0.533
Single	1 if a primary insurer is an unaffiliated single insurer. 0 otherwise.	0.157	0.364	0	1	0	1
Single * RDownRec	Interaction term of RDownRec and Single.	0.003	0.045	0	2.611	0	0.082

Table 6 The Impact of Reinsurer Rating Downgrades on Primary Insurer Rating Downgrades, 2003-2009

Variables	Expected Sign	(1)	(2)
RDown	+	0.033	-0.010
		[0.321]	[0.327]
RDownRec	+	0.660**	0.353
		[0.290]	[0.372]
Single			0.061
			[0.184]
Single * RDownRec	+		1.681**
			[0.810]
Δ Investment Yield	-	-0.027	-0.027
		[0.027]	[0.027]
Δ CAT risk	+	1.514	1.532
		[1.461]	[1.465]
Δ NPW/PHS	+	0.006***	0.006***
		[0.002]	[0.002]
Δ Reinsurance Recoverable/PHS	+	0.002	0.002
		[0.001]	[0.001]
Δ Reserve/PHS	+	0.013***	0.013***
		[0.002]	[0.002]
Δ Junk Bond/PHS	+	-0.021	-0.023
		[0.018]	[0.018]
Δ BCAR	-	-0.002**	-0.002**
		[0.001]	[0.001]
Δ Log Asset	-	-1.212***	-1.209***
		[0.339]	[0.342]
Δ Combined Ratio	+	0.009***	0.009***
		[0.002]	[0.002]
Best Rating(t-1)	-	-0.111***	-0.109***
		[0.040]	[0.041]
Constant		-2.169***	-2.190***
		[0.426]	[0.441]
Number of Observations		7,739	7,739
Likelihood Ratio		219.24	225.27

Note: Standard errors are in brackets. ***, significant at the 1% level; **, significant at the 5% level; *, significant at the 10% level.

Table 7 The Impact of Reinsurer Rating Downgrades on Primary Insurer Stocks

Panel A. Counterparty Primary Insurers

Days	N	Mean CAR	Median CAR	Variance adjusted z-stat		Generalized sign z-test		Portfolio Time-series CDA t-test	
(0,0)	5038	-0.13%	-0.11%	-2.261	*	-1.821	*	-1.585	$
(-1,+1)	5038	-0.14%	-0.21%	-1.786	*	-2.356	**	-0.969	
(-5,+5)	5038	-0.46%	-0.18%	-0.595		0.858		-1.649	*
(-10,+10)	5038	-0.83%	-0.35%	-2.054	*	0.238		-2.156	*
(-15,+15)	5038	-1.50%	-0.73%	-4.343	***	-1.905	*	-3.199	***
(-10,-1)	5038	-0.32%	-0.14%	-0.168		0.914		-1.204	
(-15,-1)	5038	-0.73%	-0.33%	-2.444	**	-1.567	$	-2.221	*
(-1,+5)	5038	-0.37%	-0.23%	-2.092	*	-1.623	$	-1.648	*
(-1,+10)	5038	-0.35%	-0.17%	-1.592	$	0.604		-1.186	
(-1,+15)	5038	-0.61%	-0.45%	-2.974	**	-1.708	*	-1.758	*

Panel B. Contagion Effects – Non-counterparty Primary Insurers

Days	N	Mean CAR	Median CAR	Variance adjusted z-stat		Generalized sign z-test		Portfolio Time-series CDA t-test	
(0,0)	25930	-0.05%	-0.08%	-2.189	*	-1.431	$	-1.459	$
(-1,+1)	25930	-0.13%	-0.14%	-2.194	*	-1.357	$	-1.963	*
(-5,+5)	25930	-0.15%	-0.20%	0.026		0.296		-1.175	
(-10,+10)	25930	-0.18%	-0.05%	2.83	**	5.43	***	-1.042	
(-15,+15)	25930	-0.48%	-0.19%	-0.921		3.814	***	-2.29	*
(-10,-1)	25930	0.07%	-0.06%	4.087	***	4.435	***	0.584	
(-15,-1)	25930	0.02%	-0.13%	3.024	**	3.416	***	0.139	
(-1,+5)	25930	-0.16%	-0.22%	-1.19		-1.543	$	-1.665	*
(-1,+10)	25930	-0.27%	-0.26%	-0.258		-0.375		-2.072	*
(-1,+15)	25930	-0.52%	-0.33%	-4.393	***	-0.984		-3.358	***

Note: This table shows market model mean and median cumulative abnormal returns (CAR) of primary insurers in response to reinsurer downgrade announcements. The impact of reinsurers' downgrades on their counterpart primary insurers is shown in Panel A. The impact of reinsurers' downgrades on non-counterparty primary insurers is shown in Panel B. Day 0 is the day a reinsurer downgrade is announced by a ratings agency. Abnormal returns are calculated as the difference between realized returns and expected returns obtained from the market model estimated over a 250-day pre-event period ending 30 days before the announcement day. Three significance tests are reported: the variance adjusted z-statistic (Boehmer, Musumeci, and Poulsen, 1991), the non-parametric generalized sign z-test (Cowan, 1992), and the Portfolio Time-series CDA t-test which corrects for cross-sectional correlation caused by clustering of firms around event date (Brown and Warner, 1980; Chandra, Moriarity, and Willinger, 1990). Statistical significance is indicated by ***, significant at the 0.1% level; **, significant at the 1% level; *, significant at the 5% level; and $, significant at 10% level.

Table 8 Scenario Analysis: Number of Hypothetically Downgraded Insurers

	100% Loss	50% Loss	30% Loss	10% Loss
Munich Re	19	11	8	1
Swiss Re	32	12	4	1
Berkshire	17	9	7	0
All three	70	36	19	3
Any-unaffiliated	248	153	95	37

Note: Total number of insurers is 1,367.

Table 9 Scenario Analysis: Number of Hypothetically Insolvent Insurers

Panel A. Whole Sample

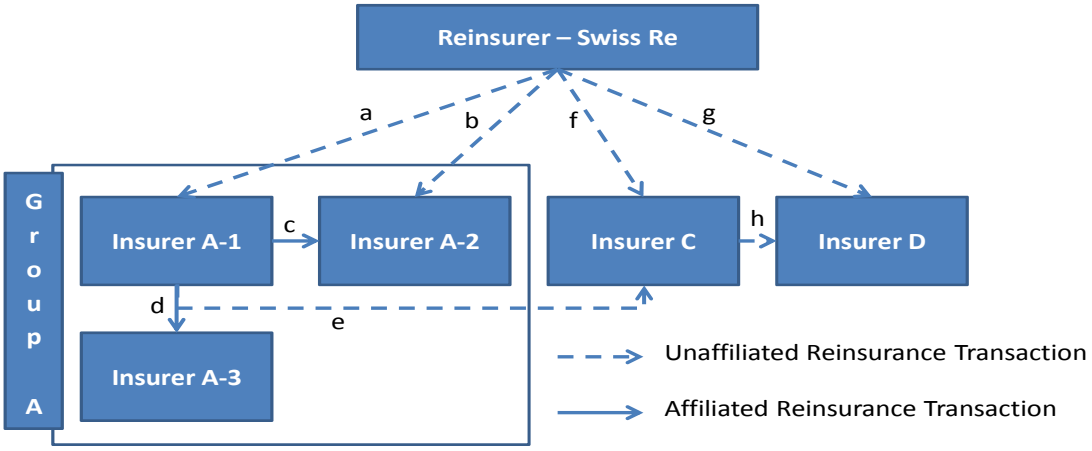
		100% Loss		50% Loss		30% Loss		10% Loss	
		Direct Effect	Chain Effect	Direct Effect	Chain Effect	Direct Effect	Chain Effect	Direct Effect	Chain Effect
Munich Re	Negative Surplus	5	5	3	3	3	3	1	1
	RBC 200%	17	20	8	8	5	5	2	2
Swiss Re	Negative Surplus	9	10	4	4	0	0	0	0
	RBC 200%	25	28	17	19	6	7	1	1
Berkshire	Negative Surplus	5	7	1	1	1	1	0	0
	RBC 200%	17	22	7	8	5	6	2	3
All three	Negative Surplus	28	31	8	8	6	6	1	1
	RBC 200%	57	98	29	31	18	19	6	7
All-unaffiliated	Negative Surplus	199	261	83	94	36	36	6	6
	RBC 200%	290	451	170	205	101	115	33	34

Panel B. Ratings Downgrade Analysis Sample

		100% Loss		50% Loss		30% Loss		10% Loss	
		Direct Effect	Chain Effect	Direct Effect	Chain Effect	Direct Effect	Chain Effect	Direct Effect	Chain Effect
Munich Re	Negative Surplus	0	0	0	0	0	0	0	0
	RBC 200%	3	6	1	1	0	0	0	0
Swiss Re	Negative Surplus	1	2	1	1	0	0	0	0
	RBC 200%	6	9	4	6	2	3	0	0
Berkshire	Negative Surplus	2	2	0	0	0	0	0	0
	RBC 200%	8	12	1	2	1	2	1	2
All three	Negative Surplus	7	9	1	1	1	1	1	1
	RBC 200%	21	48	7	8	3	4	1	2
All-unaffiliated	Negative Surplus	80	164	26	45	8	8	0	0
	RBC 200%	127	307	57	96	26	40	6	7

Note: Total number of insurers in Panel A is 2,492; total number of insurers in Panel B is 1,367.

Figure 1 Illustration of the Chain Effect



Direct Effect: Unaffiliated reinsurance with the insolvent reinsurer (Swiss Re here) − a, b, f, g.

Chain Effect: Unaffiliated reinsurance with the insolvent reinsurer (Swiss Re) + Unaffiliated and affiliated reinsurance with any insolvent insurer resulting from the insolvency of Swiss Re. For example, if A-1 becomes insolvent due to Swiss Re (direct effect), the chain effect on Insurer A-2 is b+c, and the chain effect on insurer C is f+e. If Insurer C becomes insolvent as a result of the first round chain effect, the final effect on insurer D is g+h.