Reinsurance Network and the Performance of U.S. Property-Liability Insurers

Abstract

Reinsurance plays a fundamental role in the insurance market to connect insurers and diversify risks. Prior studies have examined the impact of reinsurance counterparty relationships, such as reinsurance exposure, concentration, and tenure, on firm performance. However, no extant research investigates the relationship between an insurer's network position in a reinsurance network and its performance. In this paper, we utilize network analysis to construct the reinsurance networks from 2000 to 2011 and then evaluate an insurer's market position using various centrality measures. We find that there is an inverted U-shaped relationship between an insurer's underwriting performance (measured by combined ratio) and its network position, whereas there is a U-shaped relationship between its profitability (measured by risk adjusted ROA or risk adjusted ROE) and its network position. We also investigate the impact of an insurer's network position on its operational efficiency, including cost efficiency, revenue efficiency and profit efficiency.

1. Introduction

As the insurance for insurers, reinsurance plays a fundamental role in the insurance industry. On the one hand, it allows insurers to transfer risk among each other, thereby enhancing risk sharing and risk diversification. On the other hand, reinsurance can be costly as it exposes insurers and reinsurers to counterparty risks, contagion risks and potentially systemic risks. The use of reinsurance, therefore, has significantly economic impacts and implications to an insurer's performance and decision making. Prior studies (see, e.g., Cummins, Feng, and Weiss, 2012; Garven, Hilliard, and Grace 2014) mainly focus on analyzing the impact of reinsurance counterparty relationships on firm performance. Caution is needed when interpreting their results as their measures of reinsurance counterparty relationships are rather restricted - they either consider reinsurance between professional reinsurers and primary insurers only or direct linkages from an insurer to another. In this paper, we use network analysis to construct reinsurance networks via reinsurance transactions, both affiliated and non-affiliated. We develop more accurate network-based measures for an insurer's position in the reinsurance market and investigate how an insurer's network position affects its performance, including its underwriting performance, profitability and operational efficiency.

Firm performance can be affected by numerous factors. Traditionally, firm performance is examined using an individual firm's own characteristics. However, firms are not isolated but rather connected with each other through various economic relationships. A growing body of the literature has shown that external linkages formed among individual firms can affect firms' decisions and performance (Ahern and Harford, 2014; Li and Schürhoff 2012; Cohen-Cole, Kirilenko, and Patacchini 2014).

In the insurance market, reinsurance transactions connect insurers in a complex network. Therefore, reinsurance has been recognized as the primary source of interconnectedness in the US property-liability (P/L) insurance industry (Cummins and Weiss, 2014). As such, reinsurance interconnectedness can serve as a transmission mechanism for financial shocks and may exacerbate insurers' exposure to contagion and/or systemic risk.

There is a fast growing literature investigating the role of reinsurance in financial stability and systemic risk (see, e.g., Swiss Re, 2003; Geneva Association, 2010; International Association of Insurance Supervisors (IAIS) 2011, 2012, 2013; Park and Xie, 2014; Cummins and Weiss, 2014). Several limitations exist in these studies. First of all, most of the prior studies focus on the conventional "primary insurer - professional reinsurer" relationship, where "professional reinsurers" are identified as the key players in the reinsurance market. This identification could be arbitrary because there is no clear definition of "professional reinsurers" in the insurance literature (Cole and McCullough, 2008). Second, reinsurance transactions can occur not only between primary insurers and professional reinsurers, but also among primary insurers themselves. Without taking into account all types of reinsurance transactions, we might underestimate the complexity and interconnectedness of the reinsurance market. Third, previous studies rest on a simplified reinsurance market structure. IAIS (2012) concludes that the dominant connections are between primary insurers and reinsurers; connections among reinsurers (i.e., retrocession) are usually ignored; and in general connections among primary insurers are not assumed to be important. Little empirical evidence has been provided to support these assumptions.

To better understand the microstructure of the U.S. P/L reinsurance market, Chen et al. (2015) construct reinsurance networks from 2000 to 2011 and investigate the possible contagion effect due to the failure(s) of one or a few top (re)insurers. By using network analysis, they take into account both affiliated and non-affiliated reinsurance transactions, and consider both direct and indirect linkages among insurers. They find the U.S. P/L reinsurance market has a core-periphery structure, which is far more complicated than previous studies assumed. Following their approach, we construct reinsurance networks for the U.S. P/L insurance market and compute several centrality measures that capture the degree of interconnectedness of an insurer in the reinsurance market. We then examine the relationship between an insurer's network position and its performance.

Our paper is closely related to Cummins, Feng, and Weiss (2012) and Garven, Hilliard, and Grace (2014). Cummins, Feng, and Weiss (2012) analyze insurer characteristics that determine reinsurance utilization, exposure, and counterparty concentration. They also analyze the relationship between firm performance and reinsurance utilization. They find that firm performance is positively related to reinsurance utilization, especially with foreign reinsurers, but performance is negatively related to concentration in reinsurance counterparties. Garven, Hilliard, and Grace (2014) argue that stable reinsurance relationships help to reduce information asymmetry and thus contribute to firm performance. Their results indicate that an insurer's demand for reinsurance and its profitability increase with the tenure of reinsurance relationships. They, however, only consider the direct links among the primary insurer and reinsurer. In contrast, certain network-based statistics used in this study allow us to take into account both direct and indirect links among insurers and reinsurers, and thus better describe an insurer's relative position in the reinsurance market.

Our paper is also related to but different from Lin, Yu, and Peterson (2014). They utilize network theory to investigate the relationship between a primary insurer's network position and its demand for reinsurance, measured by premiums ceded. Consistent with their theoretical model, they find an inverted U-shaped relationship between an insurer's optimal percentage of reinsurance ceded and the number of reinsurance counterparties. In this paper, we aim at studying the relationship between an insurer's network position and its performance. We find an insurer's network position might be endogenous because firm performance can affect an insurer's strategy to use reinsurance and thus its relative position in the network. We construct the reinsurance network at the individual firm level, including both affiliated and non-affiliated transactions. This is important because affiliate reinsurance have been shown to be a solvency threat for insurance firms and thus can affect their performance (Cummins and Weiss, 2014; A.M. Best, 2014). Our reinsurance network includes both primary insurers and reinsurers rather than primary insurers alone. We find that there is an inverted U-shaped relationship between an insurer's underwriting performance (measured by combined ratio) and its network position, whereas there is a U-shaped relationship between its profitability (measured by risk adjusted ROA or risk adjusted ROE) and its network position.

This study contributes to the extant literature in several ways. First, we view the reinsurance market as a whole and use network analysis to develop more accurate measures to capture the complexity of reinsurance counterparty relationships. Second, to the best of our knowledge, this is the first empirical study to investigate the impact of an insurer's network position on its performance, including its underwriting performance, profitability and operational efficiency. Third, we find a non-linear relationship between centrality and performance, which helps us better understand the role of reinsurance in an insurer's decision making and adds new evidence to a large body of literature on how external linkages affect firm performance.

The rest of the paper is organized as follows. Section 2 briefly review the literatures in financial network and reinsurance. Section 3 develops our hypotheses. Section 4 discusses the sample data and empirical methodology. Section 5 presents the empirical results. Concluding remarks are given in section 6.

2. Literature Review

In this section, we first briefly review the literature related to financial network. We then discuss related studies in the insurance literature.

2.1. Literature in Financial Network

Network theory can provide a conceptual framework within which the intricate structure of linkages and various patterns of connections formed among financial institutions can be described and analyzed in a meaningful way (Allen and Babus, 2009). With a broad range of statistical measures provided by network theory, researchers are able to characterize a network and the role of each financial institution within it (Newman, 2010).

A large body of the literature on financial network focuses on network characteristics, financial integration and stability. In an early economic study, Allen and Gale (2001) examine the inter-linkages in the credit market and show that increasing connectivity monotonically increases financial stability through risk sharing. They argue that a more equal distribution of interbank claims increases the resilience of the system against the insolvency of any individual bank. However, this view has been challenged after the recent financial crisis.

Currently, the consensus seems to be that there exists a nonlinear relationship between interconnectedness and the stability of the financial market, which can be termed as the “robust-yet-fragile” property of a connected network (Haldane, 2009) or “phase transition” (Acemoglu, Ozdaglar and Tahbaz-Salehi, 2013). Below a certain threshold, connectivity among financial institutions serves as a shock-absorber, allowing the system to function as a mutual insurance device and disperse exogenous shocks. Connectivity therefore improves the robustness of the system through risk sharing and diversification. Above the threshold, however, interconnections can serve as shock-amplifiers that channel and enhance the propagation of losses through the system and lead to more fragility.

With the financial crisis and increasing concerns about financial stability, there is a fast growing literature that exploit the network of mutual exposures among financial institutions to examine financial contagion, spillovers and financial network stability. Among these studies the banking system has been extensively analyzed (European Central Bank, 2010; also see Hasman (2013) for a recent survey). This strand of literature has extended from banking to other financial systems, such as the credit default swaps (CDS) market (Kaushik and Battiston, 2012; Markose, Giansate and Shaghaghi, 2012), the global banking market (Minoiu and Reyes, 2012), and the global derivatives market (Markose, 2012). Empirically, Upper (2011) reviews network analysis and systemic risk with an emphasis on simulation-based methods. Hasman (2013) provides a recent survey in the area of contagion risk and the banking system. On the theoretical side, Chinazzi and Fagiolo (2013) compare various economic models in the network structure and financial stability. One important message from these studies is that the microstructure of a particular financial market has important economic implications for financial stability.

Another stand of financial network literature investigates the impact of network position on merger and acquisition, stock returns and firm performance. Ahern and Harford (2014) develop a network of industries via consumers and suppliers trade flows. They find that mergers propagate in waves across the network through customer-supplier links and those merger waves are driven by merger activity in industries centrally located in the product market network. Ahern (2013) examines the effect of industry connections on stock returns under an input-output network setting. He finds that industries that are more central in the input-output network earn higher stock returns than industries that are less central. Wu and Birge (2014) investigates the effects of supply chain connections on firm performance as reflected in stock returns. They find that supply chain structure is closely related to firm returns at two levels, a first-order effect from direct connections and a second-order impact from systemic exposures through the network.

Cohen-Cole, Kirilenko, and Patacchini (2014) examine the profitability of traders in Dow and Standard & Poor's 500 e-mini futures markets using network analysis. They find a significantly positive relationship between traders' network position and profitability. They argue that traders with similar trading strategies (e.g., providing liquidities through intermediation transactions between traders with needs) to exploit profitability opportunities tend to connect with each other, resulting in similarity in returns. Li and Schürhoff (2014) investigate the broker-dealer network in the over-the-counter U.S. municipal bond market. They find that dealer centrality is negatively related to the complexity of intermediation chains and positively related to dealer inventories and trade charges, because central dealers have superior ability to match transactions and are more willing to provide liquidity.

2.2 Literature in reinsurance & insurers' performance

One strand of literature regarding reinsurance focuses on the role of risk taking and risk diversification, i.e., what factors determine the demand and utilization of reinsurance. Mayers and Smith (1990) find that ownership structure, firm size, geographic and business concentration have significant effects on an insurer's reinsurance demand. Cole and McCullough (2006) find similar results. Cole, Lee and McCullough (2007) and Cole et al. (2012) explore the internationalization of the U.S. reinsurance market. Cole, Lee and McCullough (2007) find that traditional factors impacting globalization such as host market size, loss experience, and competitiveness as well as reinsurers' ability to expand based on available capacity can affect U.S. reinsurers' internationalization decisions. Using network analysis, Lin, Yu, and Peterson (2015) build a theoretical model in which an insurer's reinsurance purchase is determined by its reinsurance network position. They argue that there are both costs (e.g., contagion risk among counterparties) and benefits (e.g., deceasing transaction cost) associated with a central reinsurance network position, so the relationship between the reinsurance network position and reinsurance utilization could be non-linear due to the tradeoff between costs and benefits. They find supporting evidence using a sample of U.S. P/L insurers between 1993 and 2005.

Viewing the reinsurance utilization as a capital structure decision, another strand of literature explores the relationship between reinsurance, capital, risk taking and internal capital market activities. Powell and Sommer (2007) analyze reinsurance activities between affiliated and unaffiliated insurers. They argue that though the demand for affiliated and unaffiliated reinsurance has certain common determinants, the use of affiliated reinsurance is motived by some cost-based incentives, such as reducing information asymmetry and structural barriers that prevent insurers from external capital markets. Powell, Sommer, and Eckles (2008) investigate the activity and efficiency of the internal capital markets within insurance groups. They find evidence consistent with internal capital market efficiency, i.e., capital is allocated through the affiliated reinsurance transactions to subsidiaries with the best expected performance. Fier, McCullough, and Carson (2013) also examine the role of affiliated reinsurance transactions in capital decisions using a sample of US P/L insurers. They find that subsidiaries of insurance groups adjust their leverage to a target level using affiliated reinsurance. Mankaï and Belgacem (2015) jointly examine the interactions between insurers' capital, risk taking, and reinsurance in the U.S. P/L insurance industry. They find that insurers' risk taking is positively related to capital which is consistent with the capital buffer hypothesis, and that reinsurance is negatively associated with capital suggesting a substitutive effect.

As a common risk diversification strategy, reinsurance can also serve as the major driving factor for the interconnectedness in the reinsurance industry, and therefore contribute to systemic risk. Early literature (i.e., Swiss Re 2003) suggests that reinsurance transactions will not impose systemic risk to the insurance industry. This topic has gained a significant amount of attentions from both academia (Cummins and Weiss, 2014; Park and Xie, 2014; Chen et al., 2015) and regulatory authorities (e.g. Geneva Association, 2010; IAIS, 2011, 2012, 22013) after the recent 2007-2008 U.S. financial crisis. In particular, Cummins and Weiss (2014) conclude that the core insurance activities do not pose systemic risk. However, they suggest that both life and P/L insurers are vulnerable to reinsurance crises. Park and Xie (2014) find that a top reinsurer's downgrade could negatively affect the stocks of both its direct reinsurance counterparties and those not directly exposed to it. Moreover, their worst-case scenario analysis suggests that the likelihood of systemic risk caused by the failure of global reinsurers is relatively small for the U.S. P/L insurance industry.

The impact of reinsurance on insurers' performance is also well documented in the literature. Cummins et al. (2008) empirically examine the costs and benefits of reinsurance in the U.S. P/L insurance industry. They find that purchasing reinsurance significantly reduce the volatility of the loss ratio at the price of increasing production costs due to high reinsurance premiums. Cummins, Feng, and Weiss (2012) examine the effect of reinsurance counterparty relationships on U.S. P/L insurers' performance measured by efficiency scores and ROA/ROE. They find that insurer's performance is positively related to reinsurance utilization, but negatively related to concentration in reinsurance counterparties. Garven, Hilliard, and Grace (2014) empirically examine adverse selection between primary insurers and reinsurers. They argue that the stable tenure of reinsurance counterparty relationships could reduce information asymmetry between the ceding insurer and the reinsurer. Their results show that the amount of reinsurance, insurers' profitability, and credit quality increase with the tenure of reinsurance relationships.

3. Hypotheses Development

We next turn our attention to the economic implications of an insurer's network position to its performance. A central reinsurance network position comes with both benefits and costs. Burt (1992) argues that firms can obtain significant performance advantages, such as heterogeneous sources of information and diverse business opportunities, when exploiting relationships with their partners in an industrial network. In line with this view, a central reinsurance network position might provide insurers with several benefits that might potentially enhance their performance. First, it can facilitate insurers exploring business opportunities that are not viable in the primary insurance market, such as participation in global risk-diversification. Second, insurers with a central network position have easy access to information in the reinsurance market, such as reinsurance price, quality of services, and financial status of reinsurance counterparties. These information advantages, in turn, can help insurers increase bargaining powers in the reinsurance market and obtain coverages and rates that otherwise would not be available. Third, a central reinsurance network position might allow insurers to develop knowledge and expertise in their reinsurance operations, which may further improve their performance in the primary insurance market. Fourth, centrality can help insurers improve operational efficiency in the reinsurance market and benefit from economies of scale.

On the cost side, there are at least three types of costs associated with an insurer's reinsurance network position: coordination costs, costs related to counterparty risk, and costs associated with contagion risk. Coordination costs include the direct costs for managing an insurer's reinsurance counterparty relationships, such as search and monitoring costs. Costs may also arise due to the need to effectively allocate an insurer's internal resources between the primary insurance and reinsurance markets. As an insurer becomes more central, its coordination costs inevitably increase because of the increasing complexity of its reinsurance operations. In the meantime, costs from counterparty risk increase with an insurer's network centrality. The level of counterparty risk may depend on the extent of information asymmetries in the reinsurance market. Garven, Hilliard, and Grace (2014) find that a long-term and focused cedant-reinsurer relationship reduces information asymmetry between reinsurance counterparties. As a result, a ceding insurer's reinsurance utilization, profitability, and credit quality will increase as the reinsurance tenure increases. Lastly, we should take into account costs associated with contagion risk. Park and Xie (2014) have provided evidence that reinsurer downgrading can have a spillover effect to the stock prices for insurers even if they do not have direct transactions with downgraded reinsurers.

Lin, Yu and Peterson (2014) have found that the tradeoff between these benefits and costs leads to a non-linear relationship between reinsurance utilization and reinsurance network position. To the best of our knowledge, there is no prior research investigating the impact of an insurer's reinsurance network position on its performance. As an insurer plays a more central role in the reinsurance network, both the costs and benefits increase. Up to a certain point, the costs from coordination, counterparty risk and contagion risk may dominate the benefits from risk-diversification, information advantages, reinsurance expertise and economies of scale, resulting in a deterioration in an insurer's loss experience, profitability and firm efficiency. Beyond this threshold, the benefits may outweigh the costs, leading to an improvement in firm performance in terms of its loss experience, profitability and efficiency. Therefore, we postulate the following three hypotheses:

H1: An insurer's reinsurance network position is non-linearly related to its underwriting performance, measured by its combined ratio.

H2: An insurer's reinsurance network position is non-linearly related to its profitability, measured by risk-adjusted ROA or risk-adjusted ROE.

H3: An insurer's reinsurance network position is non-linearly related to its efficiency, including cost efficiency, revenue efficiency and profit efficiency.

4. Data and Methodology

In this section, we discuss the data and empirical methodology. We first discuss the data and the construction of reinsurance networks. We then present performance measures with a focus on the measures related to an insurer's efficiency.

4.1 Reinsurance Network Construction

Our main analysis is conducted at the individual firm level, i.e., including all affiliated and non-affiliated insurers, for several reasons. First, by recognizing both the intra- and inter- group reinsurance transactions, we gain a better understanding of interconnectedness among insurers. Second, network analysis at the individual firm level can generate a more accurate measure of an insurer's position in the reinsurance network. Third, it is meaningful and necessary for each insurer to understand its network position in order to achieve a better performance.

Our data used to construct the reinsurance networks is from the National Association of Insurance Commissioners (NAIC) annual statements for U.S. P/L insurers during the period of 2000-2011. We require the insurers included in our sample have positive total assets, surplus, and net premiums written in each sample year. The linkages among our sample insurers are identified using their reinsurance transactions extracted from Schedule F, Part 3 of the NAIC annual statement. In order to uniquely identify and trace each insurer and its reinsurance counterparties, we use the NAIC assigned company code and Federal employer identification number (FEIN) for US P/L insurers and their reinsurance counterparties, respectively. We manually clean the firm-level reinsurance transactions by excluding reinsurance transactions with negative reinsurance premium ceded or negative net reinsurance recoverable and transactions without enough information for us to identify the counterparties. In this way, we can measure all types of reinsurance transactions, especially those between U.S. P/L insurers and non-U.S. domiciled reinsurance counterparties. The final sample represents more than 98% of net premiums written in the U.S. P/L insurance industry.

For each sample year, we construct three reinsurance networks: (1) an equally-weighted network, i.e., each existing edge is weighted by 1; (2) a value-weighted network by reinsurance premiums ceded; and (3) a value-weighted network by net reinsurance recoverable. In total, we trace 2,901 US P/L insurers and 6,737 non-NAIC regulated reinsurance counterparties with 419,524 reinsurance transaction relationships. On average, our reinsurance network has 4,505 nodes with 1,952 US P/L (re)insurers and 34,960 edges per year.

4.2 Firm Performance Measures

We utilize a set of variables to measure an insurer's performance. First, the insurer's loss experience is measured by the combined ratio. Second, an insurer's profitability is measured by risk adjusted return on assets (RAROA) and risk adjusted return on equity (RAROE). Lastly, we estimate an insurer's operational efficiency using modern frontier efficiency analysis. The performance measures are then regressed on a set of independent variables representing an insurer's characteristics.

Specifically, the combined ratio is defined as the sum of the loss ratio and the expense ratio, where the loss ratio is the sum of loss incurred and loss adjustment expenses divided by net premium earned and the expenses ratio is expenses divided by net premium written. We define an insurer's return as the net income before dividends to policyholders and federal/foreign income taxes. An insurer' *RAROA* (*RAROE*) is then defined as the ratio of the return on total admitted assets (total surplus) to its standard deviation in previous three years.

We follow Cummins and Weiss (2012) to compute the efficiency measures. We define inputs, input prices, outputs, and output prices for P/L insurers as follows.

Inputs: we define four types of inputs, i.e., administrative labor, agent labor, materials and business services, and financial capital. The financial capital is measured as the average real value of policyholders' surplus during the year, where real values are obtained by deflating by the Consumer Price Index (CPI).

Input prices: the price for administrative labor is defined as the average weekly wage for direct property and casualty insurers in the state where the insurer's home office resides. The price for agent labor is defined as the premium weighted average of average weekly wage for employees of insurance agencies and brokerages across the states where an insurer writes business. The price for materials and business services is the weighted average of the national production price indices for materials and service items from the expense exhibit of the NAIC statement. The wages and price indices are collected from the U.S. Department of Labor and deflated to the year 2000 using the Consumer Price Index (CPI). The price of financial capital is the cost of equity capital based on the size adjusted capital asset pricing model (CAPM).

Output: we use the present value of real losses incurred as the proxy for risk-pooling outputs. In particular, we classify an insurer's lines of business into four groups, i.e., personal short-tail, personal long-tail, commercial short-tail, and commercial long-tail business. We use the average real invested asset as proxies for financial intermediation output.

Output prices: the prices for the risk-pooing outputs are defined as $p_i = \left[premium_i - PV(\mathrm{L}_i) \right] / PV(\mathrm{L}_i)$, where p_i is the price of output *i*, premium$_i$ is the net premium written for output *i*, and $PV(\mathrm{L}_i)$ is the present value of the loss incurred for output *i*. Cash flow patterns are estimated from data in Schedule P using the Taylor separation method (Taylor, 2000). Discounting is conducted using U.S. Treasury yield curves. The price of the financial intermediation output is measured by the expected rate of return on an insurer's assets. We use the ratio of actual investment income (minus dividends on stocks) to insurer holdings of debt instruments to represent the rate of return on that component of the portfolio. For stocks, we compute the expected return for a specified year as the 30-day Treasury bill rate at the end of the preceding year plus the long-term (1926 to the end of the preceding year) average market risk premium on large company stocks from Ibbotson Associates (2011). The expected portfolio rate of return for each insurer is a weighted average of the debt and equity returns, weighted by the proportion of the portfolio invested in debt securities and stocks.

After defining inputs and outputs, input prices and output prices, we then estimate cost, revenue, and profit efficiency for all U.S. P/L insurers with valid data. In particular, the decision making units (DMUs) is defined as individual insurers, because reinsurance networks are constructed at the individual insurer level.

4.3 Network Position Measures

Several measures of centrality are widely used in network analysis. The following provides a brief description of each measure.

Degree centrality measures the connectivity of an insurer in the network (a local property) by computing the number of counterparties to which an insurer is directly connected through reinsurance transactions.

Eigenvector centrality measures the importance of an insurer in the network (a global property) by assigning relative scores to all insurers in the network based on the principle that connections to high-scoring insurers contribute more to the score of the insurer than equal connections to low-scoring insurers.

Betweenness centrality measures a node's absolute position (a global property) by taking into account the connections beyond the immediate neighbors. Betweenness is computed by counting the number of shortest paths linking any two insurers in the network that pass through the insurer. Like eigenvector centrality, betweenness captures an insurer's overall importance.

Local clustering coefficient measures the average probability that two neighbors of a node are themselves neighbors. It is defined as the number of connected pairs of neighbors divided by the total number of pairs of neighbors. It is very common in many real world networks (for instance, social networks) that there is a high probability that nodes having the same neighbors are connected with each other.

4.4 Specification of Multivariate Regression Models

In order to test Hypotheses H1- H3, we specify a two-way fixed effect regression model as follows [1]

$$\text{Performance}_{i,t} = \alpha_0 + \theta_1 \text{Centrality}_{i,t} + \theta_2 \text{Centrality}^2_{i.t} + X_{i,t}\beta + \nu_i + \eta_t + \varepsilon_{i,t},$$

where ν_i represents the firm fixed effect for insurer *i* and η_t is the time fixed effect for year *t*.

The key variable of interest, $\text{Centrality}_{i,t}$, measures insurer *i*'s reinsurance network

[1] Two way fixed effects models are chosen after conducting the Hausman test to determine whether fixed or random effects should be used.

position in year *t*. We include its square term, $\text{Centrality}_{i.t}^{2}$ to test whether a non-linear effect exists.

For simplicity, we choose two measures of the reinsurance network position in our regression analysis: $Degree_{i,t}$, defined as insurer *i*'s total degree in year *t*, and $Net_{i,t}$, defined as the first principal component of insurer *i*'s total degree centrality, eigenvalue centrality, betweenness centrality, and clustering coefficient in year *t*. $X_{i,t}$ is a vector of insurer *i*'s characteristics in year *t* to control for the heterogeneity among insurers. Our control variables *X* include the following variables.

Size: Size may play an important role in influencing an insurer's risk-taking behaviors and performance through its effect on investment opportunities, demand for reinsurance, and access to capital markets. Large insurers are usually more diversified by lines and geographical locations; they benefit from economies of scale in risk management and have greater ability to raise capital than small insurers. Previous studies have found firm size negatively affects the demand for reinsurance (Cole and McCullough 2006, Powell and Sommer 2007) and positively affects P/L insurers' performance (Cummins and Nini 2002). Size is measured as the natural logarithm of an insurer's total admitted assets.

Organizational form: There are two main types of insurers in the insurance industry – stock insurers, owned by stockholders, and mutual insurers, owned by policyholders. Generally speaking, stock firms have better access to the capital market and can raise capital more easily than mutual insurers. We therefore expect stock insurers to use less reinsurance. However, the effect of organizational form on insurers' losses and performance is ambiguous. For instance, Cummins et al. (1999) and Liebenberg and Sommer (2008) find that mutuals have higher costs than stocks because the former have more difficulties in controlling managerial perquisite consumption. By contrast, Greene and Segal (2004) find no significant difference in accounting profitability between mutual and stock life insurers. We use a dummy variable, *Dummy_stock,* which is equal to one if an insurer is a stock insurer and zero otherwise.

Group affiliation: Reinsurance transactions can occur among group affiliated insurers or between (re)insurers that are not part of the group. Previous studies consider group affiliated transactions as internal capital market activities that help affiliated insurers stabilize their performance and maintain a target capital structure (Powell and Sommer 2007, Fier et al. 2013). Park and Xie (2014) also find that group affiliated transactions account for a major portion of reinsurance market activities in terms of reinsurance premiums ceded. We therefore expect that group affiliated insurers use more reinsurance and obtain better loss experience and performance. We use a dummy variable, *Dummy-group*, to denote insurers that belong to an insurance group.

Leverage: Leverage can be an indicator of an insurer's insolvency risk which tends to affect returns and losses. A high debt ratio can worsen the underinvestment problem and increase bankruptcy costs. We expect leverage to be negatively associated with an insurer's reinsurance usage, loss experience, and performance. We define *Leverage* as the ratio of the total liabilities to total admitted assets.

Business concentration: In addition to using reinsurance, an insurer can diversify its underwriting risk across different lines of business or geographic regions. The predicted effect of business concentration on firm performance is undetermined. On the one hand, the pro-conglomeration arguments suggest that geographically diversified insurers face lower risk and can thus charge higher prices. On the other hand, pro-focus arguments suggest that geographically focused insurers can avoid monitoring costs associated with operations across different areas and gain efficiencies through market specialization (Cummins et al. 2010). The degree of an insurer's diversification is measured by the Herfindahl index by lines of business and by geographical areas based on net premium written.

Business mix: Business mix is the degree of concentration in an insurer's core business. Following Cummins et al. (2008) and Lin, Yu and Peterson (2014), we classify an insurer's lines of business in four categories: short-tail personal, long-tail personal, short-tail commercial and long-tail commercial. We use the percentage of net premiums written for each line to indicate an insurer's business mix. The variable defined as the short-tail personal line is omitted in the regression.

We list major dependent variables and independent variables, along with their definition in Table1.

5. Empirical Results

In this section, we present regression results of the two-way fixed effects model concerning the impact of an insurer's network position on its performance. Our original sample includes 23,367 firm-year observations. We remove observations with (1) missing values for the geographic Herfinahl index; (2) negative combined ratio or negative incurred loss; (3) missing values for RAROA and RAROE.[2] We then winsorize the main dependent variable, combined ratio, risk adjusted ROA and ROE at the 5 and 95 percentiles. Our final sample is an unbalanced panel with 17,723 firm-year observations, which account for 83% (86%) of the entire US P/L insurance market in terms of total assets in year 2000 (2011).

[2] We remove 2,631, 1,066, and 1,319 observations in step (1)-(3) respectively, resulting in 18,351 observations for the next step – outlier analysis.

The endogeneity of an insurer's reinsurance network position in the performance regression can raise serious concern in our empirical analysis. For instance, an insurer's performance could possibly affect its reinsurance strategy and hence its reinsurance network position. We adopt an instrumental variable regression approach to overcome potential endogeneity bias.

Table 2 reports the summary statistics for the dependent variables and independent variables. The mean value for the centrality measure, *Degree*, is 0.005 and that for *Net* is 0.0033. The mean values for our main dependent variables, *Combined Ratio*, *RAROA*, and *RAROE*, are 1.021, 2.090, and 1.871, respectively. On average, our sample insurers assume liability exceeding 57% of its total assets. Long-tail commercial lines account for 45.1% of total net premiums written, followed by long-tail personal lines (27.9%), short-tail commercial lines (15.4%), and short-tail personal lines (11.6%). 69.7% of our sample insurers are stock insurers and 67.2% are group affiliated insurers. Only 3% of firm-year observations are reinsurers according to the A.M Best reinsurer definition.

We first test Hypothesis 1 using the combined ratio as a measure of an insurer's underwriting experience. To overcome the potential endogeneity problem, we use two main instrumental variables: (1) an insurer's network position in the previous year; (2) the average network position of an insurer's neighbors (i.e. reinsurance counterparties) in the current year. The instrumental variables estimators are estimated through two-step generalized method moments.

We report the instrumental variable regression results in Table 3. We observe that the combined ratio is positively associated with the centrality measure (Degree or Net) but negatively related to its quadratic term, both statistically significant at the 1% level. That is, when an insurer becomes more connected with other (re)insurers in the reinsurance market, its loss experience deteriorates at first. We conjecture that this is because the search and monitoring costs outweigh the benefits of risk diversification below a certain threshold. However, when the insurer plays a more important role in the reinsurance network such that this threshold is passed, it can diversify the risk in a more efficient way and thus its loss experience starts to improve (the combined ratio decreases) with the centrality measure.

The regression results also show that size is negatively related to the combined ratio, suggesting that larger insurers may enjoy economies of scale in risk diversification which can lead to better underwriting performance. There is a statistically significant, positive relationship between an insurer's leverage and combined ratio. Intuitively, an insurer with a higher leverage faces with higher insolvency risk, which can drive up transaction costs of acquiring new businesses in the primary market and lead to an increase in the expense ratio; in the meanwhile, the insurer with higher insolvency risk may have to charge lower premiums in order to compete with other insurers in the market, resulting in an increase in its loss ratio. Moreover, stock insurers tend to have a better underwriting performance than mutual insurers, consistent with the fact that stock insurers have an easier access to the capital market which can lower their capital costs. We find that the business line Herfindahl index is positively related to an insurer' combined ratio, i.e., an insurer with highly concentrated business may incur high costs and suffer large losses. It is also interesting to note that the percentage of net premiums written in long-tail personal, short-tail commercial and long-tail commercial lines are all negatively related with the combined ratio, with the coefficients on short-tail and long-tail commercial lines significant at the 10% level. It can be explained by the high level of losses associated with short-tail personal lines (the omitted category) which contains homeowners insurance subject to catastrophe risk.

We also report the diagnosis for the instrumental variable regression results at the bottom of Table 3. The results for the endogeneity test suggest that our variable of interest, an insurer's reinsurance network position, is endogenous. The underidentification test results indicate that our selected instrument variables (i.e., an insurer's reinsurance network position in the previous year and the average neighbors' network position in the current years) are correlated with the endogenous variable (i.e., an insurer's network position in the current year). The results for weak identification tests suggest that we are able to reject the null hypothesis that the chosen instrumental variables are weak instruments. That is, our choice for the instruments is appropriate. Lastly, the results for Hansen's J test suggest that we are not able to reject the null hypothesis, i.e. the instruments satisfy the orthogonality conditions required for their employment.

We then test Hypothesis 2 by regressing an insurer's *RAROA* (*RAROE*) on the network centrality measure. The results are presented in Table 4. The linear models show a statistically significant, negative impact of an insurer's network position on its profitability. In the non-linear models, the coefficient on *Degree* or *Net* is negative and that on the squared term is positive, both statistically significant at the 1% level, indicating a U-shaped relationship between an insurer's profitability and its centrality in the reinsurance network. This result is also consistent with the inverse U-shaped curve of the insurer's combined ratio reported in Table 2. Among other explanatory variables, an insurer's size and leverage are statistically significant in the profitability regressions. That is, an insurer with a larger size and a lower leverage ratio tends to have a higher profitability. In addition, the coefficient on *Dummy_reinsurer* is significantly negative in both the *RAROA* and

RAROE regressions. This could possibly result from the fact that multiple catastrophic events occurred during the sample period which caused more volatile *ROA* (and *ROE*) for reinsurers and thus lower *RAROA* (and *RAROE*).

The diagnosis for the instrumental variable regression results are reported at the bottom of Table 4. Among eight model specifications, only one indicates an insurer's total degree centrality is endogenous while the other seven models suggest we can treat an insurer's network position as an exogenous variable. We therefore run the two-way fixed effect regressions on firm profitability without adding the instrumental variable. The regression results are largely the same.

We are composing the efficiency scores for each sample insurer and will conduct further analysis to test Hypothesis 3, i.e., the relationship between an insurer's reinsurance network position and its cost (revenue and profit) efficiency.

6. Conclusion

The importance of interconnectedness driven by reinsurance transactions among insurers cannot be overstated. While the economic implications of individual insurer's utilization of reinsurance to insurers' capital decision, risk-taking, and performance have been examined in prior literature, the relationship between an insurer's reinsurance market position as determined by the transactional relationship formed with other insurers and its performance has been left unexplored. This paper fills in the gap and investigate an insurer's network position and its performances using various measures.

Our results show that an insurer's reinsurance market position can affect its performance in a non-linear manner. In particular, we find that there is an inverse-U shaped (U shaped) relationship between an insurer's reinsurance network position and its loss experience (ROA and ROE) due to the tradeoff between the benefits and costs associated with its network position. These results are robust when we take into account the possible endogeneity problem that insurers position themselves in the reinsurance market under the performance pressure.

As with all research, some limitations exist. For instance, an important part of the reinsurance network is still missing due to the lack of the reinsurance transaction data among the non-state regulated insurers, which could further increase the complexity of the reinsurance network. For future research, this paper can be extended in several ways. For instance, what will be the determinants that will determine an insurer's reinsurance network position would be an interesting research topic. One can also examine how the transactional relationship in the reinsurance network affects a firm's key decisions, such as capital structure and mergers and acquisitions.

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Table 1: Definitions of variables

Variable	Measurement	Expected sign	
Dependent variables		Combined Ratio	RAROA/ RAROE
Combined Ratio	The sum of the loss ratio and the expense ratio, where the loss ratio is defined as the sum of loss incurred and loss adjustment expenses divided by net premium earned, and the expenses ratio is defined as expenses divided by net premium written.		
RAROA	Risk adjusted return on assets, defined as return on assets divided by the standard deviation of return on assets in previous 3 years, where return on assets is calculated as net income before dividends to policyholders and before federal and foreign income taxes divided by total admitted assets.		
RAROE	Risk adjusted return on equity, defined as return on equity divided by the standard deviation of return on equity in previous 3 years, where return on equity is calculated as net income before dividends to policyholders and before federal and foreign income taxes divided by total surplus.		
Efficiency	Cost, revenue, and profit efficiency obtained using data envelop analysis.		
Independent variables			
Degree	An insurer's total degree centrality in the reinsurance network	+/-	+/-
Degree2	The square term of Degree	+/-	+/-
Net	The first principal component of an insurer's reinsurance network position measured by degree centrality, eigenvalue centrality, betweenness centrality and clustering coefficient.	+/-	+/-
Net2	The square term of Net	+/-	+/-
Ln(asset)	The logarithm of total admitted assets	-	+
Leverage	The ratio of total liabilities to total admitted assets	-	+
HHI_geo	Herfindahl index of direct premium written across geographic areas	+/-	+/-
HHI_line_npw	Herfindahl index of net premium written across all business lines		
Percent_lp_npw	The percentage of net premium written in long-tail personal lines to total direct premium written	+/-	+/-
Percent_sc_npw	The percentage of net premium written in short-tail commercial lines to total direct premium written	+/-	+/-
Percent_lc_npw	The percentage of net premium written in long-tail commercial lines to total direct premium written	+/-	+/-
Dummy_Stock	1 for stock insurers, 0 otherwise	+/-	+/-
Dummy_Group	1 for group affiliated insurers, 0 otherwise	+	+
Dummy_Reinsurer	1 for an insurer satisfying the A.M. Best definition for professional reinsurer, 0 otherwise	+/-	+/-

Table 2: Summary Statistics

This table reports the summary statistics for the variables used in regression analysis. *Degree* is an insurer's normalized total degree; *Net* is the first principal component of degree centrality, eigenvalue centrality, betweenness centrality and clustering coefficient; *RAROA* is the ratio of return on total admitted assets divided by the standard deviation of return on total admitted assets in previous three years; RA*ROE* is the ratio of return on total surplus divided by the standard deviation of return on total surplus in previous three years; *Ln(asset)* defined as the natural logarithm of total admitted assets; *Leverage* is the total liabilities to total admitted assets; *Combined Ratio* is the sum of loss ratio and expense ratio; *HHI_geo* is the geographic Herfindahl index;*HHI_line_npw* is the business line Herfindahl index based on net premium written; *Percent_npw_lp*, *Percent_npw_sc*, *Percent_npw_lc*) is the percentage of net premium written in long-tail personal lines, short-tail commercial lines and long-tail commercial lines, respectively; *Dummy_stock* is equal to 1 if the firm is a stock insurer and 0 otherwise; *Dummy_group* is equal to 1 if the firm is affiliated with some insurance group and 0 otherwise; *Dummy_reinsurer* is equal to 1 if the insurer satisfies the A.M. Best definition of reinsurer and 0 otherwise.

Variable	**# of obs**	**Mean**	**Std Dev**	**p5**	**Median**	**p95**
Combined Ratio	17723	1.021	0.195	0.693	0.993	1.536
RAROA	17723	2.090	3.423	-1.539	1.344	8.353
RAROE	17723	1.871	2.973	-1.599	1.306	7.451
Degree	17723	0.005	0.012	0.000	0.002	0.020
Net	17723	0.033	1.481	-0.615	-0.421	1.904
Ln(asset)	17723	18.368	1.948	15.296	18.287	21.725
Leverage	17723	0.571	0.182	0.195	0.609	0.804
HHI_line_npw	17723	0.489	0.302	0.124	0.407	1.000
HHI_geo	17723	0.567	0.385	0.055	0.536	1.000
Percent_npw_lp	17723	0.279	0.302	0.000	0.169	0.802
Percent_npw_lc	17723	0.451	0.394	0.000	0.427	1.000
Percent_npw_sc	17723	0.154	0.266	0.000	0.042	1.000
Dummy_stock	17723	0.697	0.460	0.000	1.000	1.000
Dummy_group	17723	0.672	0.469	0.000	1.000	1.000
Dummy_reinsurer	17723	0.031	0.173	0.000	0.000	0.000

Table 3: Instrumental variable regression model on insurer's underwriting performance

This table reports the results for the instrumental variable regression model with year and firm fixed effect. The instrumental variables are (1) insurer's network position (degree or Net) in previous year; (2) average of an insurer's neighborhood network position (degree or Net) in current year. The main dependent variable is combined ratio. The clustered standard errors are reported in parenthesis. Statistical significance at 1%, 5%, and 10% level are denoted by ***, **, and * respectively.

VARIABLES	(1) Combined ratio	(2) Combined ratio	(3) Combined ratio	(4) Combined ratio
Degree	1.835***	6.225***		
	(0.646)	(1.339)		
Degree2		-36.11***		
		(9.495)		
Net			0.0196***	0.0540***
			(0.00561)	(0.0116)
Net2				-0.00267***
				(0.000645)
lnasset	-0.0567***	-0.0673***	-0.0667***	-0.0711***
	(0.0138)	(0.00704)	(0.00709)	(0.00725)
leverage	0.176***	0.187***	0.192***	0.192***
	(0.0345)	(0.0319)	(0.0319)	(0.0318)
percent_npw_lp	0.0815	0.0793*	0.0746	0.0754
	(0.0506)	(0.0475)	(0.0475)	(0.0472)
percent_npw_lc	-0.0240	-0.0297	-0.0328	-0.0336
	(0.0477)	(0.0442)	(0.0441)	(0.0439)
percent_npw_sc	0.0159	0.0138	0.00874	0.00972
	(0.0434)	(0.0486)	(0.0486)	(0.0482)
hhi_geo	-0.0673***	-0.0599***	-0.0640***	-0.0595***
	(0.0189)	(0.0222)	(0.0222)	(0.0224)
hhi_line_npw	0.0597*	0.0581**	0.0508*	0.0577**
	(0.0357)	(0.0280)	(0.0281)	(0.0281)
Dummy_stock	-0.0352**	-0.0399**	-0.0443**	-0.0433**
	(0.0170)	(0.0194)	(0.0193)	(0.0195)
Dummy_group	0.0549***	0.0480***	0.0507***	0.0484***
	(0.0145)	(0.0145)	(0.0145)	(0.0145)
Dummy_reinsurer	-0.00294	-0.00581	0.000337	-0.00219
	(0.0181)	(0.0225)	(0.0224)	(0.0224)
Underidentification test	5.614	253.209	45.326	186.775
(Kleibergen-Paap LM statistics)	(0.0604)	(0.0000)	(0.0000)	(0.0000)
Weak identification	191.993	347.142	121.723	199.647
(Kleibergen-Paap Wald F statistic)	(<0.1)	(<0.05)	(<0.1)	(<0.05)
Endogeneity test	2.808	14.064	11.404	15.412
	(0.0938)	(0.0009)	(0.0007)	(0.0005)
Hansen J test for overidentification	0.295	5.592	1.729	1.058
	(0.5868)	(0.0611)	(0.1885)	(0.5891)
Observations	17,723	17,723	17,723	17,723
R-squared	0.026	0.026	0.025	0.024
Number of insurers	2,202	2,202	2,202	2,202

Table 4: Instrumental variable regression model on insurer's overall financial performance

This table reports the results for the instrumental variable regression model with year and firm fixed effect. The instrumental variable is insurer's network position (degree or Net) in previous year. The main dependent variable is risk adjusted ROA and ROE. The clustered standard errors are reported in parenthesis. Statistical significance at 1%, 5%, and 10% level are denoted by ***, **, and * respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	RAROA	RAROA	RAROA	RAROA	RAROE	RAROE	RAROE	RAROE
Degree	-30.25***	-74.65***			-28.83***	-70.75***		
	(8.707)	(17.90)			(8.722)	(16.65)		
Degree2		384.2***				363.3***		
		(127.9)				(124.5)		
Net			-0.244**	-0.621***			-0.224**	-0.590***
			(0.102)	(0.167)			(0.102)	(0.158)
Net2				0.0292***				0.0285***
				(0.0113)				(0.0106)
lnasset	0.798***	0.828***	0.838***	0.887***	0.632***	0.660***	0.669***	0.716***
	(0.0819)	(0.0828)	(0.0840)	(0.0860)	(0.0748)	(0.0761)	(0.0773)	(0.0795)
leverage	-5.449***	-5.367***	-5.544***	-5.541***	-4.426***	-4.346***	-4.519***	-4.511***
	(0.334)	(0.333)	(0.333)	(0.333)	(0.304)	(0.304)	(0.304)	(0.305)
percent_npw_lp	-1.278*	-1.317*	-1.251*	-1.275*	-1.358**	-1.399**	-1.329**	-1.352**
	(0.709)	(0.709)	(0.711)	(0.715)	(0.649)	(0.650)	(0.651)	(0.655)
percent_npw_lc	0.230	0.237	0.249	0.250	0.225	0.234	0.241	0.241
	(0.621)	(0.623)	(0.623)	(0.629)	(0.559)	(0.562)	(0.560)	(0.566)
percent_npw_sc	-0.282	-0.276	-0.261	-0.281	-0.304	-0.304	-0.283	-0.302
	(0.627)	(0.629)	(0.629)	(0.635)	(0.567)	(0.571)	(0.569)	(0.575)
hhi_geo	1.050***	1.031***	1.081***	1.033***	0.976***	0.950***	1.009***	0.962***
	(0.285)	(0.285)	(0.285)	(0.286)	(0.261)	(0.261)	(0.261)	(0.262)
hhi_line_npw	0.106	0.0219	0.122	0.0387	0.0962	0.0143	0.116	0.0340
	(0.324)	(0.324)	(0.325)	(0.327)	(0.297)	(0.298)	(0.298)	(0.300)
Dummy_stock	0.255	0.229	0.280	0.270	0.240	0.213	0.264	0.254
	(0.312)	(0.313)	(0.314)	(0.317)	(0.262)	(0.262)	(0.263)	(0.266)
Dummy_group	-0.482***	-0.467**	-0.480***	-0.463**	-0.395**	-0.383**	-0.396**	-0.377**
	(0.183)	(0.183)	(0.183)	(0.183)	(0.154)	(0.154)	(0.155)	(0.154)
Dummy_reinsurer	-0.657***	-0.627***	-0.704***	-0.680***	-0.538**	-0.507**	-0.581**	-0.557**
	(0.241)	(0.242)	(0.243)	(0.243)	(0.235)	(0.236)	(0.237)	(0.237)
Underidentification test	22.947	253.209	45.326	186.775	22.947	253.209	45.326	186.775
(Kleibergen-Paap LM statistics)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Weak identification	403.684	347.142	121.723	199.647	403.684	347.142	121.723	199.647
(Kleibergen-Paap Wald F statistic)	(<0.1)	(<0.1)	(<0.1)	(<0.1)	(<0.1)	(<0.05)	(<0.1)	(<0.05)
Endogeneity test	1.436	3.455	1.225	4.321	2.636	6.035	0.595	4.761
	(0.2313)	(0.1777)	(0.2683)	(0.1153)	(0.1045)	(0.0489)	(0.4405)	(0.0925)
Hansen J test for overidentificantion	0.006	2.842	0.534	0.351	0.118	2.974	0.882	0.487
	(0.9403)	(0.2414)	(0.4648)	(0.8391)	(0.7310)	(0.2261)	(0.3477)	(0.7840)
Observations	17,723	17,723	17,723	17,723	17,723	17,723	17,723	17,723
R-squared	0.044	0.045	0.043	0.044	0.036	0.037	0.036	0.036
Number of insurers	2,202	2,202	2,202	2,202	2,202	2,202	2,202	2,202