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Interactions Between Risk-Taking, Capital, and Reinsurance for Property-Liability Insurance Firms

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Abstract:

Theory and empirical evidence suggest short-run interactions between capital and risk. This paper analyzes the effects of reinsurance, as a new endogenous decision variable, on this policy mix. We examine this issue using a system of simultaneous equations applied to the U.S. property-liability insurance industry. The results identify significant interactions between capital, risk and reinsurance. The relationship between risk and capital is positive, indicating the effectiveness of regulatory mechanisms. Reinsurance is negatively associated with capital, for which it appears to act as a substitute. These results are sensitive to the level of capital held in excess of the regulatory minimum requirements. Weakly capitalized firms adjust their reinsurance and risk levels more quickly and try to rebuild an appropriate capital buffer. Unlike other decision variables, the capital ratio converges toward a long-run target level.

Keywords: Risk-taking, Capital based Regulation, Insurance, Simultaneous Equations, Instrumental Variables.

JEL Classification: G22, G28, G32

1. Introduction

Insurance firms have always been subject to various constraints regarding risk-taking and capital holding. The introduction of risk-based capital (RBC) appears to have consolidated the interdependence between these two decision variables (Cheng and Weiss, 2012). Capital adjustments are generally made through the retention of benefits or issuance of new shares. Hoerger et al. (1990) and Garven et al. (2003) demonstrate that reinsurance directly affects such adjustments by reducing risk and acting as contingent capital. Wells et al. (1995) find that mutual insurers use reinsurance to reduce funding difficulties. The broad adoption of the ERM framework further strengthens the links between risk-taking, capital, and reinsurance (Nocco and Stulz, 1996). Similarly, recent regulatory changes are more amenable to defining capital requirements in terms of certain qualitative aspects of reinsurance (Holzmüller and Eling, 2008 and Scordis and Steinorth, 2012). Understanding the relationship between capital, risk, and reinsurance is of great relevance, particularly for regulators, who must craft prudential rules regulating insurers' conduct.¹ Shareholders are also concerned about the possible transmission of shocks to capital that can result from unanticipated losses or macroeconomic events. Negative shocks often entail forced liquidations of assets, which adversely affect firm value.

Among the interactive relationships between the three decision variables considered here, those between capital and risk are by far the most studied in the literature. Several hypotheses related to moral hazard, agency costs and regulatory pressures have been advanced to explain the interactions between these two variables. A first hypothesis, based on agency costs and buffer capital theory, predicts a positive relationship between capital and risk. An alternative hypothesis, based on information asymmetry regarding the activation of the guarantee fund in case of bankruptcy, predicts a negative relationship. The conflicting predictions of these hypotheses have led to active empirical research. Shrieves and Dahl (1992) and Jacques and Nigro (1997) were the first to examine this issue for U.S. banks. In a subsequent paper, Cummins and Sommer (1996) investigate the issue for non-life insurance firms, providing empirical support for a positive relationship between capital and risk. Baranoff and Sager (2002) empirically explore these interactions in the case of life insurance, finding a positive (negative) relationship between capital and asset (liability) risk. Recent studies, such as Shim (2010) and Cheng and Weiss (2012), also confirm a positive relationship between these variables.

Although this question has been extensively studied in the literature, few papers have explored the interaction of capital and risk with reinsurance to date. However, there are several reasons to believe that this risk transfer mechanism (reinsurance) is endogenously influenced by the choice of capital and risk levels, and vice versa. MacMinn (1987) and Plantin (2006), for instance, find that reinsurance is determined jointly with capital structure. Dionne and Triki (2004) note a strong positive relationship between leverage as a risk indicator and reinsurance demand. Shiu (2011) focuses on the endogenous nature of reinsurance and illustrates that it positively impacts leverage, and vice versa. All of these results support the hypothesis of interdependence between reinsurance, capital, and risk.

The aim of this paper is to analyze capitalization policy and its relationship to risk-taking and reinsurance. More specifically, we aim to determine the nature of short-run adjustments between these decision variables and whether they converge toward long-run targets. To this end, we use a simultaneous equation system, which considers the potential endogeneity of these variables. The contribution of this paper to the existing insurance literature is to examine the joint relationship between these three decision variables. Although such links are indirectly implied in the theoretical literature, to our knowledge, they have not been empirically examined. This study documents several new findings. We confirm the existence of simultaneous adjustment of the three decision variables. Under specific conditions, capital and reinsurance appear to be substitutable. Our main finding is that weakly capitalized insurers try to build an adequate capital buffer by increasing capital and reducing risk. In contrast, those with large capital buffers tend to increase both risk and reinsurance demand. We provide empirical evidence that the capital ratio converges slowly toward its long-run target level.

¹ The theoretical literature often provides conflicting answers to these questions (Scannella, 2012). Strict regulation may create distortions in the operations of solvent firms. In contrast, permissive regulations may lead to high-risk exposure, threatening the creditworthiness of insurers. This situation often implies a slowdown in innovation, inefficient investment strategies, or passive capital accumulation.

This paper is organized as follows. Section 2 sketches the theoretical underpinnings of the potential interactions between risk-taking, capitalization, and reinsurance and develops a set of hypotheses. Section 3 identifies and discusses the main determinants of each decision. Section 4 presents our econometric model specification and estimation techniques. Section 5 describes our sample and provides summary statistics. Section 6 analyzes our empirical results and provides some robustness checks. Section 7 provides some concluding remarks.

2. Theoretical background and research hypothesis

In this section, we briefly outline the theoretical literature that highlights the interactions between capital, reinsurance, and risk-taking and derive the hypotheses used in our empirical analysis.

2.1 Interactions between capital and risk

Interactions between capital and risk have been the focus of active research, particularly in the banking sector. The introduction of RBC appears to reinforce the interdependence between these two types of decisions (Cheng and Weiss, 2012). These two decisions are interconnected under the influence of several factors, such as agency costs, moral hazard, and regulatory pressure. Limited liability of shareholders may create a conflict of interest with policyholders through excessive risk-taking by the former (Jensen, 1986; Berger, 1995). Managers can also behave opportunistically, particularly in companies that focus on long tail lines of business and have an excess of cash (Cummins and Nini, 2002). The literature makes contradictory predictions regarding the nature of such interactions, and the hypotheses are largely not mutually exclusive. For example, agency costs may explain why some insurers respond to increases in capital by taking more risk and why others respond by doing the opposite.

A first hypothesis in the theoretical literature predicts a negative relationship between risk and capital, reflecting insurers' incentives to utilize the insurance company's guarantee fund in case of failure, given that insolvency costs will be borne by contributors. When participation in the fund is not correlated with actual risk, this opportunity can encourage insurers to increase risk and reduce capital, by analogy with banks' behavior (Horiuchi and Shimizu, 2001). However, the relevance of this hypothesis is tempered by the growing effectiveness of supervisory mechanisms and market discipline. In addition, the coverage of the guarantee fund is less complete than in the banking sector (Cheng and Weiss, 2012). Therefore, the incentive to take excessive risk, for non-life insurers, is restrained.

A second hypothesis suggests a positive relationship between these two variables. According to capital buffer theory, insurers hold more capital than is required as a guarantee against unanticipated extreme losses. Contrary to predictions based on moral hazard considerations, insurers focus more on their own target level of capital. The analysis of Jokipii and Milne (2011), informed by the notion of a capital buffer, distinguishes between long- and short-run relationships. The authors predict that capital regulation will have limited effects on the long-run choice of risk level, whereas the short-run relationship will depend on the level of capitalization, specifically the amount of capital held above the regulatory threshold. Insurers with acceptable levels of capital may not respond to the RBC requirement and may even increase their risk level. However, those with relatively low capital levels try to build a capital buffer by raising capital and/or reducing risk and respond strongly to regulatory pressure and market discipline. Fonseca and Gonzalez (2010) argue that market discipline can further affect the recapitalization decision. Thus, insurers exposed to strong market discipline are incentivized to adjust their capital more quickly. Therefore, our first main hypotheses are as follows:

H_{1A}: *The adjustments between capital and risk are positive.*

H_{1B}: *Weakly capitalized insurers adjust their capital and risk more rapidly than highly capitalized insurers.*

2.2 Interactions between capital and reinsurance

The analysis of the relationship between capital and reinsurance is poorly represented in the financial literature. Reinsurance is typically viewed as a substitute for capital (Armstrong and Dror, 2007). Stulz (1996) and Adiel (1996) demonstrate that reinsurance affects solvency and can function as off-balance sheet capital. In addition, reinsurance increases an insurer's surplus and strengthens its underwriting capacity (Graham and Rogers, 2002 Aunon-Nerin and Ehling, 2008, Zou and Adams, 2008, Bartram, Brown and Fehle, 2009). Transferring risk to a reinsurer relaxes capital restrictions for an insurer and allows the firm to expand its capacity to issue new policies. Thus, this risk transfer reduces the required capital on the insurer's

balance sheet by enabling it to use capital ‘rented’ from the reinsurer. Using traditional sources of capital, such as corporate debt, contingent capital, or new equity, in response to a shock is typically an expensive and delicate operation. Thus, insurers tend to anticipate this situation by using reinsurance. This source of capital allows the insurer to maintain an acceptable level of solvency and to create value for shareholders in two ways (Chen, Hamwi and Hudson, 2001 and Liebenberg, 2010; Shah and Hole, 2004). First, when the cost of reinsurance is less than the cost of the other sources of capital cited above, then reinsurance can function as a substitute for these other sources and increase returns to shareholders. Second, when the cost of reinsurance is less than the reduction in the opportunity cost of capital, reinsurance reduces expected returns and risk. If shareholders believe that the reduction in risk exceeds the reduction in expected return, the net effect is to increase the value of the company (Shah and Hole, 2004). Thus, the third hypothesis investigated in this research is as follows:

H₂: *The adjustments between capital and reinsurance are negative.*

2.3 Interactions between reinsurance and risk

One way to reduce the ultimate costs of claims is to use reinsurance. Most insurance companies use reinsurance to reduce volatility, insolvency, and/or specific risk and thus capital requirements. The effects of risk-taking on insurers’ demand for reinsurance can be analyzed from several perspectives. According to the bankruptcy-cost argument, highly leveraged insurers are more exposed than others to risk of insolvency. Thus, reinsurance protects these insurers against unexpected losses and reduces the risk of insolvency. In contrast, agency theory suggests a positive relationship between risk-taking and reinsurance. Policyholders and shareholders have divergent interests, a fact that fits with agency cost theory and the notion of information asymmetry. Excessive risk-taking limits the ability of insurers to retain projects with positive net present value. Reinsurance is a way of mitigating this problem by transferring part of the risk to reinsurers. Adams (1996) demonstrates that insurers tend to reinsure more as the level moves closer to solvency constraints to reduce the risk of extreme loss. In addition, reinsurance can play the same role as the guarantee fund and encourage insurers to take on more risk or reduce capital. Thus, we formulate the following hypothesis:

H₃: *Adjustments between risk and reinsurance are positive.*

2.4 Impact of transversal factors

Size

The neoclassical theory of the firm identifies several factors that may affect the main financial decisions of insurers. Within this context, size plays an important role in influencing the insurer’s risk appetite through its effect on investment opportunities, the firm’s demand for reinsurance, and the firm’s access to capital. Large firms are generally subject to low information asymmetry between managers and potential investors, which reduces the cost of capital (Smith, 1977). Moreover, they are likely to have a better qualitative and geographical allocation of risks and hold proportionally less capital than small firms. Due to economies of scale in risk management and the greater ability of large firms to raise capital in the short run, the capital requirements of large firms will be moderate, and their incentives to take risk will be strong (Titman and Wessels, 1988; Aggarwal and Jacques, 2001).

Numerous studies point out that firm size negatively affects the demand for reinsurance (Hoerger et al., 1990; Adams, 1996 and Powell and Sommer, 2007). In contrast, the external funding opportunities are likely to be less important for small firms (Adams, 1996), which use reinsurance for at least two main reasons. First, the direct costs of financial failure are not proportional to the size of a company (Warner, 1977). Second, raising capital in financial markets is an expensive undertaking. Cole and McCullough (2006) view size as an inverse measure of bankruptcy costs and find a negative relationship between this variable and the demand for reinsurance. Thus, large insurers will be less dependent on reinsurance for expansions of their underwriting capacity. We formulate the following hypothesis:

H₄: There is a negative (positive) relationship between size, reinsurance, and capital (risk taking).

Organizational form

There are two main forms of organization in the insurance industry: stock firms, which are owned by shareholders, and mutual firms, which are owned by policyholders. The managerial discretion hypothesis suggests that stock insurers tend to undertake relatively more complex and risky projects (Mayers and

Smith, 1990). However, shareholders have more control over managers in such firms than in other organization forms. The implications of pecking order theory will vary, depending on organizational form. Stock firms have greater access to the financial markets. Mutual firms are less dependent on external capital than stock insurers because of difficulties in raising capital. In addition, agency costs vary depending on a firm's organizational form. Conflicts between shareholder managers and shareholder policyholders may impact the choice of capital level. Harrington and Niehaus (2002) find that mutual insurers tend to hold more capital than stock insurers. Cummins et al. (2001) predict that managers of mutual firms are more risk averse because of the specific organization capital and other difficulties in diversifying their wealth. Thus, such firms are more likely to manage risk through reinsurance. Indeed, Cole and McCullough (2006) note that mutual firms, which have less access to capital markets in cases of catastrophic loss, use more reinsurance. Thus, we formulate the following hypothesis:

H₅: There is a negative (positive) relationship between stock firms and reinsurance or capital (risk-taking).

Group affiliation

An extensive literature has focused on capital transfer within financial groups (Stein, 1997; Campello, 2002). Affiliated insurers generally hold less capital, as they have access to internal resources provided by other affiliates. It is also easier for affiliated firms to obtain capital injections from parent firms when their capital levels become insufficient. Powell et al. (2008) provide evidence of these internal capital markets, whose effectiveness depends on the allocation of capital to the subsidiaries with the highest expected rates of return. Moreover, affiliated insurers have incentives to take more risk. Reinsurance demand depends on the characteristics of insurers. For affiliated insurers, this decision can be regarded as an internal capital market transaction (Mayers and Smith, 1990; Garven and Lamm-Tennant, 2003; Powell and Sommer, 2007). Reinsurance can transfer income within the group and reduce the overall tax burden. In addition, affiliated insurers have an advantage with respect to risk diversification within the group through intra-group reinsurance. Mayers and Smith (1989) and Cole and McCullough (2006) find some support for this hypothesis. According to these arguments, we state the following hypothesis:

H₆: *There is a negative relationship between group affiliation and both reinsurance and capital and a positive relationship between group affiliation and risk taking.*

3. Control variables

The empirical literature identifies several factors that may affect the endogenous variables. Here, we present the most important factors in the empirical model developed below.

3.1 Determinants of Capital

Performance

Firms with high profitability generally have sufficient internal funds that may be transformed into capital. According to pecking order theory, firms prefer internal to external financing (i.e., debt or new equity), perhaps due to the costs of issuing new equity or debt. Alternatively, in the presence of asymmetric information, the use of external funding may convey negative information to the market about the firm's value. If the behavior of insurers is consistent with pecking order theory, we expect profitability to positively affect capital levels. Following Titman and Wessels (1988) and Fama and French (2002), we use return on assets as an indicator of profitability.

Cost of capital

The cost of holding capital is an important determinant of capital levels (Estrella, 2004). Various costs, such as agency and information asymmetry costs, are related to the use of capital, and the level of capital is expected to be inversely related to such costs. The cost of holding capital is difficult to measure in practice. Similarly to (Ayuso et al., 2004 and Jokipii and Milne, 2008), we approximate this cost as the average of positive returns on equity (ROE) over the last five years.

Information asymmetry

Signal theory suggests that information asymmetry and the opacity of the insurance industry are important determinants of capital levels (Pottier and Sommer, 2006 and Morgan, 2002). Insurers with volatile incomes are likely to use retained earnings rather than external capital to address future losses or cope with shocks. Insurers can overcome information asymmetry by building a capital stock in periods of high profitability. We use the volatility of ROE as a measure of information asymmetry (Cummins and Nini, 2002 and Grubisic and Leadbetter, 2007).

Exposure to extreme risk

Exposure to extreme risks is also likely to influence the level of capital. Zanjani (2002) illustrates that companies that insure heavily against natural disasters have higher capital levels than those that are less exposed to such events. The level of exposure to extreme risk is measured in our model as a percentage of total premiums written in the earthquake line of business (Cummins and Song, 2008).

Liquidity risk

Insurers with a large share of liquid assets are more likely than others to face regulatory constraints. The low risk associated with these assets allows for easy adjustments to capital levels. Therefore, insurers with more liquid assets are expected to have less capital and take greater risk. De Ceuster (2003) finds that the major source of illiquidity is asset-liability mismatch, which may encourage insurance firms to hold more capital. In this study, liquidity risk is measured by the ratio of liabilities to liquid assets.

Cost inefficiency

Hughes and Moon (1995) emphasize the importance of analyzing the impact of inefficiency on capital, establishing a negative relationship between these two variables. For instance, Altunbas et al. (2007) note that the cost inefficiency of European banks is due to their high capital levels and moderate risk-taking. This factor is generally estimated using non-parametric methods. However, some studies argue that financial ratios are very simple estimates of cost inefficiency. For simplicity, this variable is measured in this study as the ratio of operating expenses to net income.

Deficit

Deficits reflect the need for external financing when internal cash flows are exhausted. This variable is used to test for the existence of a preference ordering among funding sources for insurers. According to pecking order theory, this factor, which is measured hereafter by the level of investment plus changes in working capital minus internal cash flow, has a positive impact on the level of capital (De Bie and De Haan, 2007).

Growth opportunities

Insurers with better growth opportunities are expected to hold more capital. The literature uses the book-to-market ratio or changes in R&D expenses to measure this variable.² However, due to a lack of data, we use an alternative measure, as in Carayannopoulos and Kelly (2005), namely, the past growth (over five years) in premiums.

3.2 Determinants of risk-taking

Existing theoretical and empirical work suggests that risk-taking will be affected by various factors, including the following.

Leverage

Empirical work in the insurance industry (e.g. Borde and al, 1994) confirms the relevance of firm's leverage and argues that risk-taking can be influenced by this factor, which tends to amplify returns and/or losses. A high debt ratio worsens the underinvestment problem, the risk of insolvency, and bankruptcy

² Hovakimian et al. (2001) and Fama and French (2002) use the market-to-book value ratio of assets as a proxy for a firm's growth opportunities (GROWTH). This proxy is defined as the ratio of the book value of total assets minus the book value of equity and debt plus the ratio of market value of equity and debt to the book value of total assets (Barclay and Smith, 1995; Rajan and Zingales, 1995).

costs. Thus, we expect a negative relationship between risk-taking and leverage. Therefore, we expect a negative relationship between risk taking and leverage. In the empirical model below, this variable is approximated by the ratio of liabilities to the surplus

Cost inefficiency

Cost inefficiency can also have an effect on risk-taking. For the banking sector, Berger and DeYoung (1997) and Williams (2004) introduce the “bad management” hypothesis and demonstrate that a decline in costs or revenue efficiency and income temporally precede increases in risk-taking. Thus, we expect a positive relationship between inefficiency and risk-taking.

Business mix

The Business mix is the degree of centering on the firm’s core business. Previous research has found that differences in risk across a firm’s various lines of business affect positively reinsurance levels. Thus, we expect a positive relationship between the degree of centering and risk-taking. This variable is approximated by the Herfindahl index of the four major branches of non-life insurance business, namely, short- and long-term personal insurance and short-term and long-term commercial insurance.

Geographic and line of business diversification

An insurer may reduce its overall risk by holding a portfolio whose components are not perfectly correlated across regions and/or activities. Empirical studies find that in the banking sector, diversification is associated with moderate risk-taking (Hughes, Lang and Mester, 1996 and Deng et al., 2007), a hypothesis based on the benefits of cost reduction and income synergy (Saunders and Cornett, 2007). Alternatively, diversification may be associated with higher risk-taking because of the agency problem and competition. The degree of diversification is measured by the Herfindahl index percentages of direct premiums written by line of business and geographical area.

3.3 Determinants of reinsurance

Researchers have documented that reinsurance can be affected by several firm-specific factors.

Performance

Adams et al. (2008) predict that the poorest-performing insurance companies tend to use more reinsurance than profitable companies, which have more resources to cope with financial risk and thus lower probabilities of bankruptcy. The performance is measured by the return on assets ratio.

Loss volatility

Reinsurance is generally used to stabilize underwriting profits. When the loss ratio has high volatility, the insurer has less certainty of future value losses and thus greater incentive to use reinsurance. According to Hoerger et al., (1990), an increased volatility of claims gives rise to increased reinsurance demand. This factor is approximated by the standard deviation of the loss ratio over the last three years.

Liquidity risk

Lee and Urrutia (1996) find that the liquidity ratio is an important indicator of solvability. An insurer with relatively liquid assets has more stable finances and is thus expected to use less reinsurance. Conversely, insurance companies with insufficient liquidity are likely to use more reinsurance (Plantin, 2006).

Reinsurance price

Cole and McCullough (2006) explore the impact of reinsurance prices on reinsurance demand, finding a negative correlation between the costs of the use of reinsurance and demand for this risk management tool. This price is approximated by the ratio of premiums ceded minus losses.

Inefficiency

The impact of inefficiency on reinsurance adjustment is similar to that of performance in the sense that less efficient insurers tend to use more reinsurance than other firms. The relationship between inefficiency and the level of reinsurance is expected to be negative.

Mayers and Smith (1990) examine the effects of the composition of a firm's portfolio of activities on the demand for reinsurance. They observe that an increased concentration of activities increases the volatility of cash flows and the risk of bankruptcy. Reinsurance could be a solution to the risk of insolvency arising from this source. Moreover, Shortridge et al. (2004) and Cole et al. (2006) demonstrate that this factor reflects the degree of centering on the core business. In contrast, the economic benefits of specialization can reduce the demand for reinsurance. We predict a negative relationship between the degree of specialization and the demand for reinsurance.

Line-of-Business and geographic concentration

A high concentration of premiums in certain lines of business exposes insurers to significant risk. However, high concentration may also reflect specialization and better risk pricing. Thus, the effect of concentration on the demand for reinsurance has not been clearly established. In contrast, geographical concentration reflects the degree of diversification of an insurer across states. Cole and McCullough (2006) find a negative relationship between geographic concentration and reinsurance and between lines-of-business concentration and reinsurance. Garven and Lamm-Tenant (2003) and Mayers and Smith (1990) also find a negative relationship using a different measure of diversification. These variables are measured by the Herfindahl index of the percentage of direct premiums written by lines of business and geographic area, respectively.

4. Methodology

4.1 Model

In this section, we investigate the short-run relationships between capital, reinsurance, and risk using simultaneous equations. Importantly, the observed variations of these variables are both discretionary and caused by factors exogenous to the insurer (Shrieves and Dahl, 1992; Jacques and Nigro 1997; Cummins and Sommer, 1996; Baranoff et al., 2007; Shim, 2010). To account for this behavior, we introduce lagged variables as partial adjustment components (*cf. appendix 1*). The model has the following specification:

$$\begin{aligned} \Delta Cap_{i,t} = & \lambda_0 - \varphi_{Cap} Cap_{i,t-1} + \lambda_1 \Delta Reins_{i,t} + \lambda_2 \Delta Risk_{i,t} + \lambda_3 Perf_{i,t} + \lambda_4 Cost_cap_{i,t} + \lambda_5 Catastrophe_{i,t} + \lambda_6 Assy_{i,t} \\ & + \lambda_7 Lqt_risk_{i,t} + \lambda_8 Cost_ineff_{i,t} + \lambda_9 Growth_{i,t} + \lambda_{10} Deficit_{i,t} + \lambda_{11} Org_{i,t} + \lambda_{12} Group_{i,t} + \lambda_{13} Size_{i,t} + Year_t + e_{i,t} \end{aligned} \quad (1)$$

$$\begin{aligned} \Delta Reins_{i,t} = & \beta_0 - \varphi_{Reins} Reins_{i,t-1} + \beta_1 \Delta Cap_{i,t} + \beta_2 \Delta Risk_{i,t} + \beta_3 Loss_vol_{i,t} + \beta_4 Perf_{i,t} + \beta_5 Lqt_risk_{i,t} + \beta_6 Reins_price_{i,t} \\ & + \beta_7 Mix_{i,t} + \beta_8 Hibl_{i,t} + \beta_9 Higeo_{i,t} + \beta_{10} Cost_ineff_{i,t} + \beta_{11} Org_{i,t} + \beta_{12} Group_{i,t} + \beta_{13} Size_{i,t} + year_t + u_{i,t} \end{aligned} \quad (2)$$

$$\begin{aligned} \Delta Risk_{i,t} = & \gamma_0 - \varphi_{Risk} Risk_{i,t-1} + \gamma_1 \Delta Reins_{i,t} + \gamma_2 \Delta Cap_{i,t} + \gamma_3 Lev_{i,t} + \gamma_4 Mix_{i,t} + \gamma_5 Hibl_{i,t} + \gamma_6 Higeo_{i,t} \\ & + \gamma_7 Cost_ineff_{i,t} + \gamma_8 Org_{i,t} + \gamma_9 Group_{i,t} + \gamma_{10} Size_{i,t} + year_t + v_{i,t} \end{aligned} \quad (3)$$

where $e_{i,t}$, $v_{i,t}$, and $u_{i,t}$ are error terms.

Cap , $Reins$, and $Risk$ denote the capital ratio, reinsurance ratio, and risk level, respectively. The definitions and descriptions of various control variables are reported in Table 1. Time effects are included in the model to consider systematic events and high losses associated with man-made and natural disasters.

4.2 Variables construction

Capital (Cap):

As most of the insurers in our sample are not listed, it is not possible to determine their market values. Similar to Aggarwal and Jacques (2001), Cummins and Sommer (1996), and Shim (2010), we proxy the capital ratio by the book value of the surplus divided by the total value of assets.

Reinsurance (Reins):

This variable is given, for each insurer, by the ratio of total reinsurance premiums ceded to total business premiums (Garven and Lamm-Tenant, 2003; Cole and McCullough, 2006; and Powell and Sommer, 2007).

Risk (Risk):

Based on portfolio theory, we measure total risk by the volatility of the asset-to-liability ratio. According to Cummins and Sommer (1996) and Shim (2010), an insurer's asset volatility can be expressed as follows:

$$\sigma = \sqrt{\sigma_A^2 + \sigma_L^2 - 2\sigma_{AL}} \quad (4)$$

where σ_A and σ_L are the volatilities of the insurer's assets and liabilities, respectively, and $\sigma_{A,L}$ is the covariance of the logarithms of the assets and liability values. Let us denote the proportion of assets of asset type (i) in the investment portfolio by x_i and the proportion of liabilities from business line (j) by y_j . The respective volatilities of the asset and liability portfolios and the covariance of the logarithms of the liability and asset returns are given as follows:

$$\sigma_A^2 = \sum_{i=1}^N \sum_{j=1}^N x_i x_j \rho_{A_i A_j} \sigma_{A_i} \sigma_{A_j} \quad (5)$$

$$\sigma_L^2 = \sum_{i=1}^M \sum_{j=1}^M y_i y_j \rho_{L_i L_j} \sigma_{L_i} \sigma_{L_j} \quad (6)$$

$$\sigma_{VL} = \sum_{i=1}^N \sum_{j=1}^M x_i y_j \rho_{A_i L_j} \sigma_{A_i} \sigma_{L_j} \quad (7)$$

σ_{A_i} and σ_{L_j} denote the volatilities of the log of asset type (i) and the log of liabilities in business line (j), respectively. The parameter $\rho_{A_i L_j}$ reflects the correlation between the log of the i^{th} asset and the log of the liabilities in the j^{th} business line, whereas N is the number of asset categories and M is the number of lines of business. To measure risk using this measure of volatility, one must first define different lines of activities and asset categories. Following Shim (2010), we aggregate each insurer's lines of business into 12 categories: homeowners/farm-owners, auto physical damage, auto liability, commercial multiple peril, special property, fidelity/surety, accident, health, and financial guaranty, medical malpractice, workers' compensation, other liability, special liability, and miscellaneous liability. The types of assets are classified into seven categories: stocks, government bonds, corporate bonds, real estate, mortgages, cash and other invested assets, and non-invested assets. A second risk measure used to assess the robustness of our results is the RBC ratio, introduced by the National Association of Insurance Commissioners (NAIC). This measure offers an alternative way of accounting for the risk of insurers (Chang and Weiss, 2012^b). More specifically, it reflects the minimal capital level required of insurers. All else equal, an insurer's capital requirement must be higher as more risk is taken on.

Table 1. Variable definition

Variable	Measure	Expected sign		
		ΔCap	$\Delta Reins$	$\Delta Risk$
Endogenous variables				
<i>Cap</i>	Ratio of surplus to total admitted assets	.	(+/-)	(+/-)
<i>Reins</i>	Ratio of reinsurance premiums ceded to direct business written plus reinsurance assumed	(-)	.	(+)
<i>Risk1</i>	Volatility of the asset to liability ratio	(+)	(+)	.
<i>Risk2</i>	Ratio of RBC to total admitted assets	(+)	(+)	.
Exogenous variables				
<i>Reg</i>	1 if firm's net premium to surplus ratio = or >300%, 0 otherwise	.	.	.
<i>Perf</i>	Return on assets ratio	(+)	(-)	.
<i>Cost_cap</i>	Average of positive ROE over the last five years	(-)	.	.

<i>Catastrophe</i>	Proportion of direct premiums written in earthquake line of business	(+)	.	.
<i>Roe_vol</i>	The standard deviation of the firm's ROE over the last five years	(+)	.	.
<i>Cost_ineff</i>	Ratio of total expenses to net earnings	(+)	(+)	(+)
<i>Reinsprice</i>	Ratio of reinsurance premiums minus ceded-reinsurance commission earned to claims recovered from reinsurers	.	(-)	.
<i>Mix</i>	Herfindahl index of short and long tails of personal and commercial lines	.	(-)	(+)
<i>Lqt_risk</i>	Ratio of liabilities to liquid assets	(+)	(+)	.
<i>Loss_vol</i>	Standard deviation of the loss ratio over the last three years	.	(+)	.
<i>Lev</i>	Ratio of direct business written to surplus			(-)
<i>Hibl</i>	Herfindahl index of direct premium written across all lines of business	.	(+)	(+/-)
<i>Higeo</i>	Herfindahl index of direct premium written across geographic areas	.	(+)	(+/-)
<i>Growth</i>	Percentage growth of written premiums	(+/-)	.	.
<i>Deficit</i>	Financial deficit ratio calculated as cash dividends plus investments plus change in working capital minus internal cash flow.	(+/-)	.	.
<i>Stock</i>	1 if the insurer is a stock firm, 0 if it is a mutual firm	(-)	.	.
<i>Group</i>	1 if the insurer is a member of a group in year t , 0 otherwise	(-)	.	.
<i>Size</i>	The logarithm of total admitted assets	(-)	.	.
<i>Year</i>	Annual temporal effect	.	.	.

This table describes the variables used in the empirical model.

4.1 Estimation methodology

In capturing interactions between capital, risk, and reinsurance, simultaneous equation models have shown better performance than estimating the equations individually, as the latter approach ignores the problem of endogeneity and may violate the condition of no correlation between exogenous variables and error terms (Baltagi, 2005). To address this problem in the relationship between the key variables and to avoid biased OLS estimates, we employed the three-stage least-squares (3SLS) technique (Shim, 2010; Rime, 2001; Jacques and Nigro, 1997 and Aggarwal and Jacques, 1998). We used instrumental variables, checking their validity using the Sargan Hansen test. In a first step, we estimate the model using the OLS and 3SLS methods, comparing the results using the Durbin-Wu Hausman test. As we find significant differences in the estimates, the endogeneity problem is confirmed. Regarding the choice of instruments, we use the risk and reinsurance variables (lagged two periods), the economic growth rate, and the ratio of unrealized gains (with no lag and lagged one period). All of the other predetermined variables are used as instruments in the structural estimation. Prior to estimation, we check whether the time series are stationary based on the Levin-Lin-Chu test.³

5. Data

5.1 Sample

The data used in this study are collected from the National Association of Insurance Commissioners (NAIC) annual statement database for U.S. property-liability insurers from 1999 to 2008. The sample is limited to solvent insurers reporting positive values of admitted assets, gross and net premiums written, equity capital, and ceded reinsurance premiums. We retain only active insurers with no regulatory actions in process. After applying these sample screens, our final sample consists of 11929 year-firm observations. It accounts for 81% (84%) of the entire U.S. property-liability market in terms of total assets in the year 1999

³ All models are estimated using the software package Stata 11.

(2008). We use an unbalanced data panel to allow for a comprehensive evaluation of the property-liability market. The sample includes firms that entered or left the market during the study period. In addition to the NAIC database, we also collected data from DataStream to estimate asset returns.⁴

5.2 *Descriptive statistics and correlation analysis*

Table 2 presents descriptive statistics of all variables used in this study. The mean and median of the capital ratio are approximately 38% and 42%, respectively. These statistics are (39%, 34%) and (0.026, 0.004), respectively, for the reinsurance ratio and risk level. As these values exceed those reported in Garven and Lamm-Tennant (2003), suggesting a significant increase in reinsurance demand over the last decade. The distributions of the two risk measures are positively skewed. With regard to the diversification profiles measured by the two Herfindahl indices (Higeo and Hibl), we note small variations across insurers. Approximately 73% of insurers are stock firms, and 70% are affiliated. Before conducting the regression analysis, we first considered the possibility of multi-collinearity among independent variables, which may lead to biased estimates. Table 3 reports the Pearson correlation between the variables included in the regression model. Table 3 indicates that the correlation between capital and risk is positive, confirming the hypothesis that insurers adjust their capital levels upward following increases in risk. The relation between risk and reinsurance is negative, which is in line with the view of reinsurance as a guarantee fund. Another interesting result reported in Table 3 is the low correlation between the two risk measures.⁵ The Spearman nonparametric correlation between these two risk measures (not reported here) is statistically significant at the 1% level and is equal to 0.1. Interestingly, cost inefficiency correlates significantly with all key variables. Consistent with standard econometric practice, for each equation, we assess the degree of multi-collinearity among the independent variables using the variance inflation factor (VIF). All VIF values reported in Table 4 range between 1.01 and 2.2. Thus, no multi-collinearity was observed among the independent variables.

⁴ We use the S&P 500 global index, Barclays capital, US 20 year Treasury bond, Dow Jones Corporate bond index, Merrill Lynch Mortgage, U.S. real estate & rental & leasing and the three-month U.S. treasury bill as proxies for asset returns.

⁵ Many criticisms have been addressed regarding RBC as an insolvency predictor (e.g., Cummins, Grace and Phillips, 1999; Cummins, Harrington and Klein, 1995). Cheng and Weiss (2012) find that the accuracy of the RBC ratio in predicting insolvencies is inconsistent over time.

Table 2. *Descriptive statistics*

	Mean	Median	Std dev.	Min	Max	5% quantile	95% quantile	No. of obs.
<i>Cap</i>	0.417	0.380	0.166	0.092	1.000	0.153	0.912	11929
<i>Reins</i>	0.389	0.340	0.277	0.000	2.679	0.000	0.948	11929
<i>Risk1</i>	0.026	0.004	0.181	0.000	2.839	0.000	0.346	11929
<i>Risk2</i>	0.139	0.099	0.356	0.001	8.817	0.006	0.790	11929
<i>Perf</i>	0.025	0.027	0.049	-0.603	0.667	-0.117	0.151	11929
<i>Loss_vol</i>	1.325	0.741	4.472	0.043	171.054	0.141	8.720	11929
<i>Asy</i>	0.077	0.048	0.100	0.000	2.034	0.004	0.450	11929
<i>Cost_cap</i>	0.058	0.062	0.108	-0.996	1.783	-0.308	0.316	11929
<i>Lqt_risk</i>	0.748	0.733	0.518	0.000	19.446	0.092	1.938	11929
<i>Growth</i>	0.124	0.050	0.633	-8.470	9.989	-0.857	2.653	9578
<i>Deficit</i>	0.059	0.058	0.153	-1.467	0.842	-0.413	0.502	11929
<i>Cost_ineff</i>	0.115	0.098	0.111	-0.908	6.110	0.000	0.447	11929
<i>Higeo</i>	0.388	0.376	0.095	0.250	0.773	0.260	0.500	11929
<i>Hibl</i>	0.368	0.351	0.067	0.272	0.753	0.281	0.500	11929
<i>Mix</i>	0.333	0.281	0.320	0.000	1.000	0.000	1.000	11929
<i>Reins_price</i>	0.527	8.775	3.103	7.091	4.817	4.296	5.595	11929
<i>Lev</i>	1.735	1.293	1.609	0.000	9.928	0.008	8.003	11929
<i>Size</i>	18.546	18.456	1.812	12.845	24.384	14.887	23.279	11929
<i>Stock</i>	0.735	1.000	0.442	0.000	1.000	0.000	1.000	11929
<i>Group</i>	0.692	1.000	0.462	0.000	1.000	0.000	1.000	11929
<i>Cycle</i>	0.017	0.019	0.021	-0.035	0.042	-0.035	0.042	11929
<i>Ucg</i>	-0.036	0.000	1.287	-99.872	8.104	-0.210	0.070	11929
<i>Dev_ni</i>	0.047	-0.111	0.893	-2.816	2.846	-2.189	2.737	9578

This table reports the mean, median, minimum, maximum, standard deviation, fifth percentile, and 95th percentile of all variables. The data are collected from the NAIC and Datastream databases covering U.S. property-liability insurance firms from 1999 to 2008.

Table 3. Correlation coefficient matrix

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)	
<i>Cap</i>	(a)	1																	
<i>Reins</i>	(b)	-0.007	1																
<i>Risk1</i>	(c)	0.041*	-0.043*	1															
<i>Risk2</i>	(d)	0.009	-0.007	0.009	1														
<i>Perf</i>	(e)	0.213*	-0.058*	0.014	-0.009	1													
<i>Loss_vol</i>	(f)	0.068*	0.076*	0.008	0.009	-0.068*	1												
<i>Asy</i>	(g)	-0.233*	0.025*	-0.027*	0.032*	-0.167*	0.102*	1											
<i>Cost_cap</i>	(h)	0.093*	-0.082*	0.021	-0.026*	0.640	-0.098*	-0.378*	1										
<i>Lqt_risk</i>	(i)	-0.492*	0.162*	-0.023	-0.007	-0.137*	-0.015	0.135*	-0.081*	1									
<i>Growth</i>	(j)	-0.025*	-0.047*	-0.006	0.003	-0.082	0.112*	-0.018	-0.032*	0.049*	1								
<i>Deficit</i>	(k)	-0.139*	-0.044*	0.020	0.003	0.018	0.011	-0.044*	0.041*	0.126*	0.388*	1							
<i>Cost_ineff</i>	(l)	-0.075*	0.116*	-0.030*	0.001	-0.163*	0.050*	0.123*	-0.175*	0.013	-0.133*	-0.250*	1						
<i>Higeo</i>	(m)	0.155*	-0.192*	-0.053*	0.029*	0.001	0.007	0.047*	-0.052	-0.071*	-0.007	0.011	0.049*	1					
<i>Hibl</i>	(n)	0.103*	-0.132*	0.088	0.014	0.040*	0.060*	0.045*	0.008*	-0.009	0.037*	0.048*	0.074*	0.204	1				
<i>Mix</i>	(o)	0.081*	0.040*	-0.066*	0.018	-0.032*	-0.007	-0.012	-0.056*	-0.098*	-0.004	-0.004	0.009	0.054*	-0.189*	1			
<i>Reins_price</i>	(p)	0.041*	-0.052*	0.013	-0.007	0.050	0.017	0.004	0.045*	-0.038*	0.033*	0.055*	-0.027*	0.037*	0.134*	-0.008	1		
<i>Lev</i>	(q)	-0.390*	0.470*	-0.047*	0.016	-0.113*	-0.022	0.187*	-0.116*	0.395*	0.061*	0.121*	-0.003	0.001	-0.116*	-0.106*	-0.057*	1	
<i>Size</i>	(r)	-0.368*	-0.037*	0.002	-0.070*	0.059	-0.035*	-0.036*	0.156*	0.153*	-0.025*	0.023	-0.032*	-0.478*	-0.221*	-0.076*	-0.030*	-0.115*	1

* represents statistical significance at 1% level.

Table 4. Variance inflation factors

	<i>Eq ΔCap</i>	<i>Eq ΔReins</i>	<i>Eq ΔRisk</i>
<i>ΔRisk</i>	1.02	1.02	1.11
<i>Cap(t-1)</i>	1.67	1.24	1.04
<i>ΔReins</i>	1.12	1.18	1.03
<i>Cost_cap</i>	2.2	1.1	1.1
<i>Perf</i>	1.97	1.03	1.06
<i>Asy</i>	1.26	1.03	1.18
<i>Deficit</i>	1.36	1.27	1.41
<i>Growth</i>	1.36	1.18	1.49
<i>Cost_ineff</i>	1.14	1.12	1.14
<i>Lqt_risk</i>	1.38	1.44	1.24
<i>Catastrophe</i>	1.01	1.51	1.18
<i>Size</i>	1.39	1.28	
<i>Stock</i>	1.09	1.21	
<i>Group</i>	1.22		
Mean VIF	1.37	1.2	1.18

For definitions of these variables, see Table 1.

6. Results

This section discusses the empirical results. The system of equations is estimated under two specifications, which alternatively exclude and include the regulatory pressure mechanisms. We estimate the model for the full sample and for various subgroups, reflecting the level of capital, size, and organizational form of firms. Finally, we perform several robustness tests.

6.1. Full sample

Equation of capital

The main hypothesis tested in this paper concerns the existence of interconnections between risk-taking, capital, and reinsurance. Table 5 reports the 3SLS⁶ estimation of the simultaneous equations using volatility as a risk measure. The Hansen and Sargan test shows the validity of the selected instrumental variables used in the first step of the estimation process. A closer look at the individual equations' coefficients indicates that most key variable estimations are in line with expectations.

The first column of Table 5 reports the results for the capital equation. Overall, the coefficients are significant, except for that on exposure to extreme risks. The risk variable is positive and statistically significant, a result that is consistent with the capital buffer hypothesis, suggesting that an increase in portfolio risk leads to positive adjustments of capital insurers as guaranty against unanticipated extreme losses (Jokipii and Milne, 2011).

Second, the negative sign of the *Reins* adjustment variable supports the original hypothesis regarding the substitutability between these two variables. This result is in line with Stulz (1996) and Armstrong and Dror (2006) who argue that reinsurance can be an off-balance sheet capital that reduces capital requirements and allows the insurer to expand its capacity to issue new policies.

Concerning main control variables, table shows that the partial adjustment factor, a measure of convergence toward the desired long-run capital ratio which is captured by the lagged endogenous variable, is low (0.0519). This result can be explained by the presence of various adjustment costs.⁷ The performance seems to have a significant and positive effect on capital, confirming the pecking order theory and suggesting that profitable firms prefer internal financing and rely heavily on retained earnings to raise capital due to the costs of external funds. The cost of capital variable is negative and significant which highlights the important costs related to the use of capital. Moreover, an increase in information asymmetry, measured by the volatility of ROE, drives insurers to hold more capital. This variable reflects the level of risk to some extent and thereby confirms the positive relationship between these two variables. Economic inefficiency is positively related to capital adjustment. The coefficient on this variable is significantly and negatively associated with liquidity. We also note the presence of significant temporal effects, which may be explained by the impact of various macroeconomic shocks or extreme losses of capital.

The introduction of regulatory pressure mechanisms in the second specification (First column of the right hand side part of the table) slightly alters the estimation results. For the most part, the coefficients of the new variables are statistically significant. The estimates of the capital equation provide support for the hypothesis that undercapitalized insurers bearing more risk seek to avoid regulatory intervention. Only the coefficient on $Reg_{t-1} \times Reins_{t-1}$ is positive and statistically significant. These results indicate that highly leveraged companies in the previous period tend to increase their levels of reinsurance to adjust their capital levels to avoid regulatory costs.

Equation of reinsurance

Table 2.5 also presents also the estimation results for the equation of the ratio of reinsurance. The chi-square statistic is significant at the 1% level, illustrating the validity of the estimation. Positive adjustments of risk-taking or capital generate an increase in the ratio of reinsurance. Unlike the inverse effect, we find

⁶ As a robustness check, we also perform the estimates using the GMM methodology, although the data are not presented here for the sake of brevity. There are no significant differences between the parameter estimates using these various techniques, indicating the robustness of our estimates.

⁷ We do not examine the possibility of asymmetric adjustment costs. It may be simpler to reduce capital by increasing dividends or buying back equity than by raising capital.

that capital is not a substitute for reinsurance. This result can be explained by the fact that the marginal cost of the reinsurance unit of risk is lower than the capital and explains the asymmetrical relationship. Another explanation may lie in the imperfect substitutability between the two mechanisms in the sense that reinsurance can play the same role as capital, whereas the reverse is not the case. For example, capital does not reduce the volatility of losses.

Moreover, results show that the partial adjustment factor is not significant and illustrates that the reinsurance policy does not converge toward a long-run target level. An increase in inefficiency positively affects the level of reinsurance. Consistent with the findings of Cole and McCullough (2006), diversified firms use less reinsurance. Moreover, stock firms appear to use less reinsurance than mutual firms. This result supports the idea that stock firms have easier access to external funding and are less risk averse than mutuals. The size variable, which can be associated with diversification, is significant and negative. Accordingly, large firms tend to have better risk allocation and use less reinsurance. The introduction of regulatory pressures does not change the pattern of results.

Equation of Risk

The last part of Table 2.5 presents the estimation results for the risk equation. The chi-square statistic is significant at the 0.001 level. A positive capital adjustment leads to lower risk. We also note the asymmetric nature of the relationship between capital adjustments and risk. One possible explanation for this result may be that the lagged effect of capital on risk counters the inverse relationship, with a positive adjustment of reinsurance increasing risk. This finding is consistent with the view of Shiu (2011) and Aunon-Nerin and Ehling (2008) that the heavy use of reinsurance leads to high risk-taking. The partial adjustment factor is not significant, indicating that risk-taking does not converge to a long-run target. The *Mix* and *Hibl* variables, which reflect the degree of concentration of the main underwriting branches and lines of business, are positive and significant. As the activities of the company become more concentrated, the company's risk-taking increases in the short term. Insurers with a low level of efficiency are more prone to high risk-taking than insurers with greater cost efficiency. As expected, size encourages risk-taking, which is more prevalent among stock firms than among mutual firms.

Table 5. Estimation results of the simultaneous equations using volatility as a risk measure

	<i>Spécification I</i>						<i>Spécification II</i>					
	ΔCap_t		$\Delta Reins_t$		$\Delta RiskI_t$		ΔCap_t		$\Delta Reins_t$		$\Delta RiskI_t$	
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
ΔCap_t			0.570 ***	3.82	-0.224 ***	-2.85			0.569 ***	3.75	-0.214 ***	-2.71
$\Delta Reins_t$	-0.155 ***	-4.72			0.456 ***	12.53	-0.149 ***	-4.44			0.442 ***	11.96
$\Delta RiskI_t$	0.216 **	2.36	2.133 ***	12.95			0.175 *	1.93	2.184 ***	12.8		
Cap_{t-1}	-0.0519 ***	-2.73					-0.038 **	-2				
$Reins_{t-1}$			-0.00997	-1.00					-0.0107	-1.04		
$RiskI_{t-1}$					0.0041	0.54					0.00379	0.47
$Reg_{t-1} * Cap_{t-1}$									-0.358 **	-2.37	0.197 ***	2.63
$Reg_{t-1} * Reins_{t-1}$							0.049 ***	3.34			-0.0192	-1.21
$Reg_{t-1} * RiskI_{t-1}$							0.16	0.67	0.027	0.07		
Perf	0.544 ***	5.84	-0.0569	-1.42			0.5325 ***	25.37	0.0369	0.23		
Cost_cap	-0.0535 ***	-5.42					-0.0487 ***	-4.87				
Catastrophe	-0.00403	-0.20					-0.00522	-0.25				
Assy	0.0455 ***	4.34					0.04567 ***	4.32				
Lqt_risk	-0.0165 ***	-5.42					-0.0151 ***	-4.88				
Cost_ineff	0.0717 ***	8.61	0.147 ***	2.93	-0.0738 ***	-2.81	0.0731 ***	9.03	0.20478 **	2.11	-0.075 ***	-2.87
Reinsprice			9.92E-08	0.03					-8.49E-06	-0.08		
Mix			-0.411 ***	-5.75	0.203 ***	5			0.034 ***	3.17	0.2142 ***	5.11
Loss_vol			0.000323	0.65					0.0034 **	2.1		
lev					0.000427	0.44					0.0004	0.52
Hibl			-0.530 ***	-5.13	0.254 ***	4.46			0.0299124	0.64	0.2673 ***	4.62
Higeo			-0.0377	-0.73	0.0184	0.73			-0.0149727	-0.57	0.014	0.54
Growth	-0.0309 ***	-12.56					-0.0313 ***	-12.85				
Deficit	-0.0933 ***	-13.35					-0.092 ***	-13.23				
Stock	0.000992	0.59	-0.0675 ***	-4.43	0.0337 ***	4.17	0.00114	0.71	-0.070 ***	-4.45	0.0346 ***	4.23
Group	0.00441 ***	2.66	-0.0131	-1.22	0.00653	1.19	0.00455 ***	2.84	-0.0150	-1.37	0.0074	1.34
Size	-0.000879	-1.35	-0.00839 **	-2.53	0.00412 **	2.32	-0.00055	-0.84	-0.008 ***	-2.61	0.0043 **	2.42
2001.year	-0.0142 ***	-2.76	-0.124 ***	-6.31	0.0592 ***	6.49	-0.012 **	-2.35	-0.128 ***	-6.38	0.0598 ***	6.56
2002.year	0.0133 **	2.57	0.0862 **	4.6	-0.040 ***	-4.60	0.01171 **	2.3	0.0884 ***	4.63	-0.040 ***	-4.61
2003.year	0.0251 ***	8.76	-0.0253	-1.52	0.0111	1.28	0.0258 ***	9.25	-0.0247	-1.46	0.01046	1.21
2004.year	0.0148 **	5.33	-0.0159	-0.97	0.00696	0.82	0.01576 ***	5.79	-0.0165	-0.99	0.00701	0.83
2005.year	0.0166 ***	5.46	-0.0106	-0.57	0.00459	0.48	0.0173 ***	5.88	-0.01047	-0.56	0.00436	0.46
2006.year	0.0216 ***	7.14	-0.0128	-0.69	0.00525	0.55	0.0222 ***	7.55	-0.01212	-0.64	0.00468	0.49
2007.year	0.0154 ***	5.3	-0.0036	-0.20	0.00135	0.14	0.0157 ***	5.61	-0.00372	-0.2	0.00133	0.14
Intercept	0.02	0.91	0.566 ***	4.88	-0.274 ***	-4.18	0.006464	0.29	0.602 ***	4.91	-0.286 ***	-4.3
Chi-2		2636.9		297.3		323.6		2857.00		281.48		361.17
P-value		0		0		0		0		0		0
Hansen-Sargan statistic				40.197						46.812		
P-value				0.3305						0.2131		

This table reports the results of the 3SLS estimation for the full sample, without (specification I) and with (specification II) interaction terms. *, **, *** represent statistical significance at 10%, 5% and 1% levels, respectively. The Hansen-Sargan test evaluates the validity of the instruments.

Table 6. Estimation results following the capital level

	Undercapitalized firms						Well-capitalized firms							
	ΔCap_t		$\Delta Reins_t$		$\Delta RiskI_t$		ΔCap_t		$\Delta Reins_t$		$\Delta RiskI_t$			
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat		
ΔCap_t														
$\Delta Reins_t$	-0.939***	-6.15	-0.907**	-2.19	0.137	1.93	-0.189***	-2.72	0.0678	0.48	0.287	1.63	0.288	1.35
$\Delta RiskI_t$	3.594***	4.5	6.590***	7.04	0.160***	11.23	0.168***	2.7	0.33	1.87				
Cap_{t-1}	-0.295***	-3.06					-0.408**	-2.38						
$Reins_{t-1}$			-0.0275	-0.80					-0.0951***	-3.97				
$RiskI_{t-1}$					0.0845	0.33					-0.242***	-2.89		
Perf	0.705***	4.72	0.0722	0.68			0.0758	1.14	-0.298**	-2.34				
Cost_cap	-0.148***	-3.91					0.0295	0.56						
Catastrophe	-0.0704	-0.56					-0.0638	-0.77						
Assy	-0.0466	-1.51					-0.0185	-0.46						
Lgt_risk	-0.0127***	-2.67					-0.398***	-6.75						
Cost_ineff	0.0993	1.15	0.21	0.84	-0.029	-0.69	-0.11	-0.93	-1.444***	-3.06	0.662	1.38		
Reinsprice			-0.000363	-0.61					-1.19 E-5	-0.61				
Mix			-0.0139	-0.56	0.0033	0.63			0.073**	2.45	-0.0309	-0.91		
Loss_vol			0.0029	0.91					0.004	1.84				
lev					1.67E-4	0.34					0.0133	1.16		
Hibl			-0.0447	-0.33	0.00211	0.07			-0.111	-1.03	0.17	1.28		
Higeo			0.021	0.26	-0.0016	-0.09			0.011	0.13	-0.0161	-0.15		
Growth	-0.0476***	-3.57					0.00005	0						
Deficit	-0.0282	-1.40					-0.0366	-0.48						
Stock	0.0153	0.72	0.0302	0.49	-0.0063	-0.58	0.0012	0.19	-0.0526**	-2.48	0.0076	0.31		
Group	0.0215	1.33	0.0134	0.29	-0.0017	-0.22	0.0026	0.5	0.039**	2.49	-0.0076	-0.37		
Size	-0.0027	-0.51	0.0101	0.7	-0.0017	-0.69	5.2 E-5	0.03	-0.0085	-1.62	0.0054	0.77		
2001.year	-0.113***	-3.53	-0.198**	-2.46	0.0298**	2.28	-0.031***	-3.24	-0.0557**	-2.09	0.0587	1.77		
2002.year	0.0558	1.88	0.125	1.66	-0.022	-1.50	-0.0176	-1.67	-0.0570**	-2.08	0.0695**	2.13		
2003.year	-0.002	-0.08	0.0073	0.11	-0.0013	-0.11	0.003	0.22	-0.0423	-1.47	0.0112	0.31		
2004.year	-0.0264	-1.03	-0.0246	-0.34	0.0035	0.29	-0.0102	-0.85	-0.0575	-1.93	0.0453	1.23		
2005.year	-0.0139	-0.50	-0.0177	-0.22	0.0025	0.19	0.007	0.6	0.0172	0.55	0.0329	0.83		
2006.year	-4.43 E-4	-0.02	0.0026	0.03	-7.17 E-4	-0.05	0.0075	0.6	-0.0371	-1.20	-0.0078	-0.20		
2007.year	0.00149	0.05	0.0101	0.12	-0.0017	-0.12	-0.0018	-0.16	-0.0417	-1.40	0.0178	0.46		
Intercept	0.143	1.22	-0.181	-0.66	0.0331	0.66	0.422**	2.45	0.370***	2.76	-0.226	-1.29		
Chi-2		97.77		61.63		199.1		706.7		43.79		27.8		
P-value		7.13E-12		4E-6		1.49E-32		5.18E-136		0.0016		0.0652		
Hansen-Sargan statistic				15.805						16.854				
P-value				0.9892						0.9514				

This table reports the results of the 3SLS estimation following the buffer level. *, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively. The Hansen-Sargan test evaluates the validity of the instruments.

6.2. Sub-sample estimation

To reduce the effect of sample heterogeneity and the aggregation bias that it implies, we divided the overall sample into several sub-samples. The first sub-sample is based on the level of capital held beyond the regulatory minimum. We first estimate a new regression using a sample of the bottom third of firms in terms of the ratio of capital to the regulatory minimum. The threshold obtained for the first sub-sample was 2.41. Thus, this sub-sample includes all insurers that have almost 2.5 times the minimum capital requirement. The estimation results, reported in Table 6, illustrate that the relationship between capital adjustment and risk remains positive. The coefficient is significant with a relatively high value, indicating a high sensitivity of the ratio of capital to risk. Adjustments to the level of reinsurance appear to have a greater impact on capital. Reinsurance is a perfect substitute for capital for these companies. The capital ratio is the only variable that converges to a long-term level, with the speed of adjustment in this sub-sample greater than that observed in the overall sample. The second part of the table shows the top third of most capitalized insurers, with a threshold of 5.65. We observe a positive fit in the relationship between capital and risk, although it is less than that observed for small-cap companies. Partial adjustment factors of the endogenous variables are all significant. These results can be explained by the fact that insurers have significant flexibility in their funding sources, which allows them to achieve their goals through different financial policies. The sample is divided into two sub-groups by the value of assets corresponding to the top and bottom thirds. The results presented in Table 7 generally confirm those obtained with the total sample, except for the relationship between capital and risk for major insurance companies, a relationship that is negative in both directions. A final estimation is performed by dividing the sample into mutual and stock companies. The results, presented in Table 8, confirm our hypotheses. The results for the other explanatory variables are also affected by the organizational form.

Table 7. Estimation results for stock and mutual firms

	Small firms						Large firms					
	ΔCap_t		$\Delta Reins_t$		$\Delta RiskI_t$		ΔCap_t		$\Delta Reins_t$		$\Delta RiskI_t$	
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
ΔCap_t												
$\Delta Reins_t$	-0.08*	-1.66	0.355**	2.45	-0.1100	-0.99	-0.191***	-3.06	1.249***	3.47	-0.314**	-2.42
$\Delta RiskI_t$	0.37356**	2.39	1.752***	13.31	0.514***	8.97	-0.269*	-1.88	2.905***	5.85	0.323***	7.79
Cap_{t-1}	-0.0424	-1.15					-0.01097	-0.39				
$Reins_{t-1}$			-0.039***	-2.82					-0.0040	-0.17		
$RiskI_{t-1}$					-0.0076	-0.49					-0.0125	-0.31
$Reg_{t-1} * Cap_{t-1}$			-0.1530	-1.01	0.1435	1.4			-0.3444	-1.15	0.1029	0.77
$Reg_{t-1} * Reins_{t-1}$	0.0512	1.59			-0.0484	-1.5	0.0175	0.77			-0.0084	-0.22
$Reg_{t-1} * RiskI_{t-1}$	0.3843	0.79	0.2146	0.34			2.930***	3.04	-0.3164	-0.12		
Perf	0.4685***	15.63	-0.0413	-1.2			0.4299***	12.08	-0.2390	-1.76		
Cost_cap	-0.025	-1.5					-0.0260*	-1.94				
Catastrophe	0.0461	0.36					0.0241	0.86				
Assy	0.0566***	2.7					0.0501***	3.47				
Lqt_risk	-0.0258***	-3.32					-0.009***	-3.2				
Cost_ineff	0.0697***	4.64	0.323***	5.09	-0.2***	-4.18	0.0904***	6.3	-0.0055	-0.06	-0.0099	-0.3
Reinsprice			0.00001*	1.65				0.0000	1.12			
Mix			-0.344***	-4.26	0.262***	3.68		-0.1718	-1.27		0.0388	0.78
Loss_vol			0.0008	0.9				-0.0006	-0.37			
lev			-0.264***	-2.79	0.0043	1.62		-0.447**	-1.98		0.0002	0.15
Htbl			0.0873	1.05	0.162***	2.37		-0.0184	-0.24		0.1281	1.48
Higeo					-0.089	-1.54					-0.0010	-0.03
Growth	-0.150***	-10.59					-0.042***	-7.46				
Deficit	0.00083	0.26					-0.012	-1.4				
Stock	0.0041	1.33	-0.112***	-4.13	0.084***	3.75	0.0008	0.33	0.0010	0.15	0.0015	0.22
Group	0.0024	0.89	-0.0144	-1.15	0.012	1.38	0.0039	1.33	-0.0050	-0.28	0.0053	0.64
Size	-0.0009	-0.18	0.014*	1.76	-0.011*	-1.92	-0.0010	-1.1	-0.0151	-0.73	-0.0005	-0.18
2001.year	0.0008	0.16	-0.039*	-1.82	0.026*	1.74	0.0234	1.5	-0.301***	-4.81	0.103***	8.89
2002.year	0.0285***	4.39	-0.0035	-0.16	0.0042	0.28	-0.027	-1.56	0.337***	5.29	-0.115***	-9.85
2003.year	0.0199***	3.35	0.0013	0.06	-0.002	-0.13	0.024***	5.49	-0.0157	-0.56	0.0021	0.19
2004.year	0.0201***	3.17	-0.0101	-0.46	0.0051	0.33	0.0124***	3.01	-0.0099	-0.38	0.0017	0.16
2005.year	0.0226***	3.5	0.0065	0.27	-0.0036	-0.21	0.0140***	3.04	-0.0052	-0.18	0.0004	0.03
2006.year	0.0159***	2.57	-0.0103	-0.42	0.0046	0.27	0.0244***	5.35	-0.0095	-0.31	0.0012	0.1
2007.year	-0.035	-0.53	-0.0006	-0.02	0.0005	0.03	0.0164***	3.82	-0.0043	-0.15	0.0001	0.01
Intercept	-0.1502***	-10.59	0.0193	0.13	0.0135	0.14	-0.00071	-0.03	0.2182	1.03	-0.0495	-0.58
Chi-2	1082.36		261.46		135		755.59		73.19		471.84	
P-value	0		0		0		0		0		0	
Hansen-Sargan statistic			37.646						47.07			
P-value			0.576						0.205			

This table reports the results of the 3SLS estimation for stock and mutual firms. *, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively. The Hansen-Sargan test evaluates the validity of the instruments.

Table 8. Estimation results for small and large firms

	Stock firms						Mutual firms					
	ΔCap_t		$\Delta Reins_t$		$\Delta RiskI_t$		ΔCap_t		$\Delta Reins_t$		$\Delta RiskI_t$	
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
ΔCap_t												
$\Delta Reins_t$	-0.063	-1.17	0.818***	2.61	-0.162*	-1.68	-0.1633***	-4.7	0.602**	3.92	-0.2282***	-2.4
$\Delta RiskI_t$	-0.388***	-2.68	3.32***	9.17	0.278***	8.27	0.2165**	2.31	1.928***	11.29	0.4809***	9.63
Cap_{t-1}	-0.069*	-1.8					-0.046*	-2.12				
$Reins_{t-1}$			-0.0189	-1.18					-0.0169	-1.43		
$RiskI_{t-1}$					0.0019	0.01					0.0042	0.35
$Reg_{t-1} * Cap_{t-1}$			-0.2337	-0.7	0.0508	0.42			-0.3032**	-2.13	0.1981**	2.33
$Reg_{t-1} * Reins_{t-1}$	0.166***	4.41			0.0126	0.26	0.0406**	2.39			-0.0294	-1.16
$Reg_{t-1} * RiskI_{t-1}$	-0.1860	-0.46	0.3689	0.31			0.1497	0.55	0.0945	0.18		
Perf	0.5652***	16.75	-0.1950	-1.43			0.5086***	19.19	-0.0963*	-1.79		
Cost_cap	0.0117	0.81					-0.0524***	-4.31				
Catastrophe	-0.0011	-0.01					-0.0012	-0.05				
Assy	0.0312**	2.22					0.045***	3.67				
Lqt_risk	-0.0481**	-2.18					-0.0153***	-4.95				
Cost_ineff	0.0267**	2.21	0.283***	2.62	-0.097***	-2.69	0.0763***	7.7	0.0894*	1.73	-0.0547*	-1.78
Reinsprice			0.00006	0.1	0.07**	2.24		0.00003	0.61	0.2068***	4.54	
Mix			-0.179*	-1.9	0.0013	1.03		-0.3820***	-5.29	0.0009	0.77	
Loss_vol			0.0029	0.77				0.0007	0.87			
lev			-0.321**	-2.22				-0.4644***	-4.65		0.2395***	3.94
Htbl			-0.0817	-0.88	0.115**	2.27		0.0035	0.07		-0.0053	-0.18
Higeo					0.0261	0.8						
Growth	-0.0687***	-6.52					-0.030***	-11.37				
Deficit	-0.0866***	-7.56					-0.0942***	-12.13				
Group	0.0053**	2.38	-0.015*	-1.78	0.0023	0.36	0.0050**	2.45	0.0004	0.11	0.0058	0.86
Size	-0.00055	-0.79	-0.0064	-0.34	0.006**	2.07	-0.0007	-0.96	-0.0102	-0.89	-0.0003	-0.16
2001.year	0.0255***	3.51	-0.144***	-4.18	0.044***	4.55	-0.0169**	-2.92	-0.1145***	-5.49	0.0605***	5.41
2002.year	-0.00774	-0.97	0.1704***	4.91	-0.049***	-3.95	0.01317**	2.35	0.0753***	3.83	-0.0399***	-3.73
2003.year	0.0342***	8.48	-0.0102	-0.33	0.0020	0.19	0.0236***	6.74	-0.0269	-1.54	0.0118	1.11
2004.year	0.0278***	7.26	-0.0239	-0.78	0.0063	0.62	0.01228***	3.58	-0.0136	-0.79	0.0057	0.54
2005.year	0.02313***	5.36	-0.0131	-0.36	0.0036	0.3	0.01447***	3.94	-0.0077	-0.41	0.0028	0.25
2006.year	0.02761***	6.25	-0.0298	-0.8	0.0078	0.64	0.01965***	5.36	-0.0090	-0.47	0.0029	0.25
2007.year	0.0170***	4.19	-0.0136	-0.37	0.0039	0.33	0.0142***	4.05	-0.0029	-0.15	0.0006	0.05
Intercept	0.0404	0.95	0.5135***	2.07	-0.1928**	-2.29	0.0171	0.66	0.2960***	3.21	-0.1480***	-2.62
Chi-2	1606.36		113.35		208.2		1830.34		187.3		237.37	
P-value	5.77E-203		3.03E-39		5.83E-19		3.24E-19		5.35E-13		3.91E-28	
Hansen-Sargan statistic			24.97						43.380			
P-value			0.9697						0.3293			

This table reports the results of the 3SLS estimation for small and large firms. *, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively. The Hansen-Sargan test evaluates the validity of the instruments.

Table 8. Estimation results of the simultaneous equations using the RBC ratio as a risk measure

	Specification I						Specification II					
	ΔCap_t		$\Delta Reins_t$		$\Delta Risk2_t$		ΔCap_t		$\Delta Reins_t$		$\Delta Risk2_t$	
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
ΔCap_t												
$\Delta Reins_t$	0.628***	6.53	1.41***	5.85	0.736***	4.72	0.369***	4.93	1.6466***	6.16	0.6786***	4.48
$\Delta Risk2_t$	1.344***	6.2	-1.662***	-7.71	-0.549***	-6.88	1.037***	6.15	-1.7099***	-6.14	-0.4099***	-4.33
Cap_{t-1}	0.0095	0.15					-0.012	-0.22				
$Reins_{t-1}$			-0.0124	-1.14					-0.0164	-1.29		
$Risk2_{t-1}$					0.0130	0.14					-0.1061	-0.81
$Reg_{t-1} * Cap_{t-1}$							-0.024	-0.68	-0.0797	-0.44	-0.1499	-1.08
$Reg_{t-1} * Reins_{t-1}$							0.324**	2.05			0.0290	0.39
$Reg_{t-1} * Risk2_{t-1}$							0.209***	3	-0.3911	-1.18	-0.0223	-0.42
$Perf$	0.0671	0.7	-0.1799*	-1.65			-0.001	-0.08	-0.2948**	-2		
$Cost_cap$	0.0005	0.03					-0.014	-0.41				
$Catastrophe$	-0.0099	-0.24					0.0152	0.57				
$Assy$	0.008	0.24					-0.005	-0.63				
Lqt_risk	0.0002	0.03					0.0538	1.22				
$Cost_ineff$	0.0301	0.44	-0.0172	-0.2	-0.0062	-0.11	-0.024	-0.68	-0.0525	-0.63	-0.0223	-0.42
$Reinsprice$			0.00003	0.63					0.00005	0.54		
Mix			-0.0798	-1.44	-0.0031	-0.08			-0.0404	-0.62	0.0581	1.01
$Loss_vol$			0.0009	0.66					0.0014	0.83		
lev					-0.0002	-0.17			-0.0532	-0.69	-0.0002	-0.09
$Htbl$			-0.0944	-1.4	-0.0038	-0.08			-0.0165	-0.6	0.0465	0.68
$Higeo$			-0.0128	-0.52	0.00051	0.03					-0.0082	-0.31
$Growth$	-0.0085	-0.93					-0.016	-2.23				
$Deficit$	0.0159	0.56					0.005	0.23				
$Stock$	-0.008	-0.54	-0.0001	-0.02	0.0067	0.46	-0.005	-0.5	0.0005	0.11	-0.0038	-0.26
$Group$	0.0045	0.32	0.0222	1.06	-0.0026	-0.2	0.0063	0.69	0.0136	0.64	-0.0044	-0.38
$Size$	-0.0013	-0.34	-0.0063	-0.35	0.0012	0.32	-0.002	-0.59	-0.0080	-0.45	0.0000	0
2001_year	-0.013	-0.58	0.0132	0.46	0.0099	0.49	-0.012	-0.82	0.0198	0.7	0.0140	0.76
2002_year	-0.0152	-0.67	0.0148	0.52	0.0114	0.58	-0.013	-0.89	0.0199	0.71	0.0154	0.86
2003_year	0.0217	0.96	-0.0340	-1.19	-0.0172	-0.86	0.0194	1.35	-0.0354	-1.26	-0.0119	-0.65
2004_year	0.0230	1.02	-0.0349	-1.24	-0.0193	-0.97	0.0181	1.27	-0.0365	-1.32	-0.0141	-0.78
2005_year	-0.488***	-5.69	0.60***	6.94	0.361***	16.38	-0.376***	-5.75	0.6168***	5.69	0.3653***	18.27
2006_year	0.585***	6.33	-0.728***	-7.63	-0.442***	-9.69	0.453***	6.34	-0.7519***	-6.23	-0.3903***	-6.66
2007_year	0.0171	0.69	-0.0241	-0.77	-0.0143	-0.65	0.0147	0.94	-0.0268	-0.87	-0.0129	-0.65
$Intercept$	0.0031	0.03	0.0968	0.87	-0.0108	-0.12	0.0144	0.19	0.0705	0.61	-0.0092	-0.09
χ^2	230.66		110.65		1150.2		204.8		102.4		1390.48	
P -value	0		0		0		0		0		0	
Hansen-Sargan statistic			28.039						43.487			
P -value			0.8556						0.3252			

This table reports the results of the 3SLS estimation following the buffer level. *, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively. The Hansen-Sargan test evaluates the validity of the instruments.

6.3. Robustness checks

In this section, we conduct additional robustness tests, covering additional aspects of the empirical study, such as risk measurement, the sample structure, and the choice of instrumental variables. Unlike capital and reinsurance measures, which have straightforward definitions, risk assessment remains an open issue. Several measures have been proposed in the literature, for example, the standard deviation of the loss ratio (De Hass et al. 2010, Meyers 1989; Guo and Winter, 1997) and an insurer's exposure to external factors as captured by market betas (Eling and Schuhmacher, 2007). Equity volatility reflects both external and firm-specific factors (systematic and unsystematic risk). In contrast, Myers and Read (2001) propose the default ratio. An alternative measure is the ratio of regulatory capital RBC. Similar to Chen et al. (2012^a), we provide new estimates of the model presented above using this alternative risk measure. The results, although not reported here, confirm those initially obtained. The relationships remain significant in all cases, although in some cases, the signs differ from cases where risk is measured by volatility. The results can be explained in terms of the various criticisms of the RBC system.

The second robustness test is related to the sample structure. Indeed, we use an unbalanced panel so that the final sample contains missing values that may affect the quality of the results. This consideration is especially important when there are several consecutive values missing in the sample. To resolve this issue, we introduce a data screen requiring that an insurer appears in the sample for at least k consecutive periods. This condition was not applied in the original sample. For example, for k up to six, all interactions remain significant. Similarly, with k greater than six, some of the adjustment relationships become insignificant. A third robustness test concerns the choice of instruments, an important step in the estimation process. There are a number of instruments for which the results are stable. For example, the deviation of earnings over the medium term, the size of the business over the last five years and the average loss, as proposed by Shim (2010), are valid instruments.

Conclusion

This paper analyzes the short-run interactions between capital, reinsurance, and risk-taking for property-liability insurance firms. We develop a system of simultaneous equations to identify the potential links between these variables while controlling for endogeneity. The main objective of this paper is to determine how changes in capital levels impact the other decision variables, reinsurance, and risk-taking, and vice versa. A second objective of this research is to analyze the long-run trajectories of these policies. Such issues are of particular importance for regulators interested in how insurers will respond to given prudential rules. The sample size was sufficient to conduct an effective empirical analysis. The results are consistent with our theoretical hypotheses overall, highlighting the existence of significant relationships between the key variables and supporting the view that they are jointly determined. In their efforts to maximize firm value, insurers simultaneously adjust the various decision variables to mitigate the agency problem. The short-run adjustments between risk and capital are positive, providing interesting insights into the effects of regulation on insurer behavior. In contrast, reinsurance is negatively associated with capital, for which it acts as a substitute. The capital ratio slowly converges to a long-run target and can thus be viewed as a leading decision variable, reflecting insurers' priorities.

Regulatory pressures play an active role in moderating risk-taking and capital toward acceptable levels. Short-run adjustments depend on the level of capital held in excess of the minimum requirement. Weakly capitalized insurers reconstruct a buffer level of capital by raising capital and reducing risk. In contrast, adequately capitalized insurers maintain their capital reserves and increase both their risk and reinsurance levels. For these firms, higher capital ratios may prevent moral hazard and mitigate informational frictions between policyholders and shareholders. However, these results cannot tell us whether insurers operate efficiently.

Appendix 1

The observed changes in the insurer's capital, reinsurance, and risk levels are the sum of two components, a discretionary adjustment and a change caused by factors exogenous to the insurer. Formally, the equations are as follows:

$$\Delta Cap_{i,t} = \varphi_{Buf} \Delta Cap_{i,t-1}^d + v_{i,t} \quad (A.1)$$

$$\Delta Reins_{i,t} = \varphi_{Reins} \Delta Reins_{i,t-1}^d + u_{i,t} \quad (A.2)$$

$$\Delta Risk_{i,t} = \varphi_{Risk} \Delta Risk_{i,t-1}^d + e_{i,t} \quad (A.3)$$

where $\Delta Cap_{i,t}$, $\Delta Reins_{i,t}$, and $\Delta Risk_{i,t}$ are the observed changes in capital, reinsurance, and risk levels, respectively, for insurer i in period t . The variables $\Delta Cap_{i,t-1}^d$, $\Delta Reins_{i,t-1}^d$, and $\Delta Risk_{i,t-1}^d$ represent discretionary adjustments in capital and risk, whereas $v_{i,t}$, $u_{i,t}$, and $e_{i,t}$ are exogenous adjustments to capital, reinsurance, and risk, respectively. The partial adjustment model supposes that insurers may not be able to adjust their desired capital, risk, and reinsurance levels instantaneously. Thus, discretionary changes are proportional to the differences between target levels and the levels existing in period $t-1$:

$$\Delta Cap_{i,t}^d = \varphi_{Cap} (Cap_{i,t}^* - Cap_{i,t-1}) \quad (A.4)$$

$$\Delta Reins_{i,t}^d = \varphi_{Reins} (Reins_{i,t}^* - Reins_{i,t-1}) \quad (A.5)$$

$$\Delta Risk_{i,t}^d = \varphi_{Risk} (Risk_{i,t}^* - Risk_{i,t-1}) \quad (A.6)$$

The coefficients φ_{Cap} , φ_{Reins} , and φ_{Risk} measure speeds of adjustments. $Cap_{i,t}^*$, $Reins_{i,t}^*$, and $Risk_{i,t}^*$ are target capital, risk, and reinsurance levels, respectively. Substituting equations (A.4), (A.5), and (A.6) into (A.1), (A.2), and (A.3) yields the following:

$$\Delta Cap_{i,t} = \varphi_{Cap} (Cap_{i,t}^* - Cap_{i,t-1}) + v_{i,t} \quad (A.7)$$

$$\Delta Reins_{i,t} = \varphi_{Reins} (Reins_{i,t}^* - Reins_{i,t-1}) + u_{i,t} \quad (A.8)$$

$$\Delta Risk_{i,t} = \varphi_{Risk} (Risk_{i,t}^* - Risk_{i,t-1}) + e_{i,t} \quad (A.9)$$

The target levels of capital, risk, and reinsurance for an insurer are not observable. As in Flannery and Rangan (2006), Rime (2001), and Shim (2010), these target levels may differ across insurers or over time and

depend on the insurer's specific characteristics (Shim, 2010). Thus, the target levels of capital, risk, and reinsurance for an insurer can be written as follows:

$$Cap_{i,t}^* = \rho \cdot X_{i,t} \quad (A.10)$$

$$Reins_{i,t}^* = \omega Y_{i,t} \quad (A.11)$$

$$Risk_{i,t}^* = \theta \cdot Z_{i,t} \quad (A.12)$$

Substituting equations (A.13), (A.14), and (A.15) into (A.10), (A.11), and (A.12), we obtain this final form of the model:

$$\Delta Cap_{i,t} = -\varphi_{Cap} Cap_{i,t-1} + \varphi_{Cap} \rho \cdot X_{i,t} + v_{i,t} \quad (A.13)$$

$$\Delta Reins_{i,t} = -\varphi_{Reins} Reins_{i,t-1} + \varphi_{Reins} \omega \cdot Y_{i,t} + u_{i,t} \quad (A.14)$$

$$\Delta Risk_{i,t} = -\varphi_{Risk} Risk_{i,t-1} + \varphi_{Risk} \theta \cdot Z_{i,t} + e_{i,t} \quad (A.15)$$

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