Product Market Competition and Corporate Demand for Insurance[1]

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Abstract

This article shows through a simple model that there is a monotonic relation between the competitiveness of the product market and firms' demand for insurance. The more competitive the product market is, the more likely firms competing in the market will acquire insurance or purchase full coverage. This holds true no matter whether firms exhibit risk aversion or not in their preferences. Investment in risk management prior to competition is used as a strategic commitment device in the product market competition. Firms optimize their risk management investment by balancing the strategic commitment benefit and the cost of insurance. Therefore, the "outside the box factors" such as the industry characteristics, the market environment and the competitive pressure are important ones shaping firms' risk management strategies. This provides clear empirical implications for corporate investment in risk management and its relation to the product market environment.By focusing on primary insurers' reinsurance purchases, we provide strong empirical support forthe theoretical predictions.

Key Words*Corporate Demand for Insurance, Risk Management, Product Market Competition, Strategic Commitment*

JEL*G22 L13L22*

[1]Email: John.Liu@indstate.edu; hennyjung@gmail.com. We are grateful for the helpful comments from Marty Grace, Bob Hoyt, Ping Lin, Rich Phillips, Chengzhong Qin, Harris Schlesinger, and participants to the 2011 Annual Meeting of the American Risk and Insurance Association, 2011 Annual Meeting of the Southern Risk and Insurance Association, 2011 Annual Meeting of the Asian Law and Economics Association, and the Sixth Conference on Industrial Economics and Economic Theory at Shandong University.HyeonSeong Yun provided excellent research assistance. The usual disclaimer applies.

1. Introduction

Every year corporations spend billions of dollars in insurance premiums to obtain property and casualty coverage. According to Davidson, Cross and Thornton (1992, p.61), "in 1989, businesses paid property and casualty premiums of $112 billion, compared to dividend payments of approximately $85 billion." Also, according to Mayers and Smith (1982, p.281), "business insurance accounted for approximately 54.2 percent of the $79,032,923,000 in direct property and liability insurance premiums written in the United States in 1978."[2]Why do corporations purchase a significant amount of insurance?Researchers have argued that firms purchase insurance to reduce tax liability (Main, 1983), to avoid or reduce the cost of financial distress (MacMinn, 1987; Mayers and Smith, 1982), to mitigate agency conflicts (MacMinn and Han, 1990; Mayers and Smith, 1987), to signal private information (Grace and Rebello, 1993; Thakor, 1982), or to fulfill creditors' requirements (Cheyne and Nini, 2010). Recently, Seog (2006) provides an interesting analysis of firms' insurance demand out of strategic motives in competitive environments. He shows that corporate insurance leads to more aggressive competition in the product market, while the optimal insurance coverage is determined by a tradeoff between the strategic effect of insurance and the cost of insurance.

An unanswered question following this line of explanation for corporate insurance demand is how the degree of product market rivalry affects firms' insurance demand. Seog (2006) analyzes firms' strategic demand for insurance in a *given* competitive environment. In this article, we willshow using a simple conjectural variations model how a*change in the competitive market environment* influences firms' strategic demand for insurance. The main result is that a more competitive product market environment induces firms to purchase insurance in order to reduce their risk exposures, and furthermore, induces them to fully insure their losses given that they do purchase insurance. Importantly, we show that the monotonic relation between the competitiveness of the product market and firms' risk management investment holds true no matter whether firms exhibit risk aversion or not in their preferences. These results provide a clear empirical prediction for firms' investment in risk management and its connection to their product market environment.

Studying corporate insurance demand in a strategic product market competition framework provides an interesting path to analyze corporate risk management strategies. The recent wave of financial crisis and collapses of some famous institutions such as Lehman Brothers stimulate strong incentives for corporations to emphasize risk management along a broad range of their business activities. However, what most companies do in risk management is to determine optimal financial hedging portfolios, largely ignoring the effects of risk management activities on product market competition through their rivals' strategic feedback. This paper demonstrates that those "outside the box factors" such as the industry characteristics, the market environment and the competitive pressure are important ones shaping firms' risk management strategies. Investment in risk management prior to competition is used as a strategic commitment device in the product market competition. Firms optimize their risk management investment by balancing the strategic commitment benefit and the cost of insurance, and it turns out that this tradeoff exhibits monotonic characteristics.

To empirically test the predictions of the model, we use the data from the property-liability insurance industry. We mainlyinvestigate the relation between reinsurance purchases by primary insurers and the competitiveness of insurance markets in which the primary insurersdo business. We compute firm-specific measures of market competitiveness (via firm-specific weighted averages of concentration ratios and Herfindahl-Herschman indexes across insurance markets segmented by lines of businessand states in which insurers operate), and associate these measures with reinsurance purchases by the insurers. The regression results provide strong support for the

[2]A survey by Tillinghast-Towers Perrin and Risk and Insurance Management Society (1995) finds that direct property-casualty insurance costs for most North American business organizations typically average around 0.4% of revenues. See footnote 1 of MacMinn and Garven (2000).

theoretical prediction that corporate demand for insurance is monotonically increasing with the competitiveness of the product market in which firms do business.

In the next section weoutline the setup. In Section 3 we study the equilibrium when firms have risk averse preferences. Then we investigate the case of no risk aversion in Section 4. In Section 5 we test the empirical predictions of the model using the data from the insurance industry. Finally weconclude in Section 6.

2. The Model

There are n firms competing in the product market, indexed by $i = 1, 2, \ldots, n$. The insurance market is competitive and characterized by free entry and zero equilibrium profit. The premium could be actuarially unfair with a premium loading factor, $\lambda \geq 0$.

There are two periods in the model. Firms choose insurance coverage in the first period before they determine the output levels in the second period.Payoffs are not discounted.Firms purchase insurance coverage in the first period to reduce their second-period risk exposures in the competitive market. Here the firms' strategic insurance purchase before production can be interpreted as risk management strategies in a more general sense. The essential feature is that firms invest in risk management before the market competition. For instance, before launching a new product, firms in the final round may commit resources in pre-market research to evaluate more thoroughly the risk of the productand consequentially may invest in further product improvement if from the research they found it to be necessary. All these are for the purpose of reducing the potential post-sale operational risk. The question is how much resources they should commit to such research. There is a tradeoff between the cost of research and the expected benefit of research in reducing the risk exposure in the competitive market. Therefore our paper may also shed some light on how the competitiveness of the expected market environment in which firms compete affects these tradeoffs in more generalized settings.

Firm i's output level is q_i, and for simplicity the marginal cost of production is normalized to zero. The (inverse) market demand is $P = a - bQ = a - b\sum_{i=1}^{n} q_i$, where $a, b \in \mathbb{R}_{++}$ are constant, and Q is the aggregate output.Each firm faces a potential loss that is random and depending on its output level. For example, we can think of the loss as one caused by product problems that would potentially trigger a recall, whose costs would be proportional to sales; or we can think of the loss as operational risks such as environmental harms caused by production and the consequential litigation risks, costs of which would be related to the production levels. Denote firm i's random loss by $L(q_i) \equiv kq_i\theta$,where $k > 0$ is a constant representing the sensitivity of the risk to the production scale, and θ is normally distributed: $\theta \sim N(\mu, \sigma^2)$, $\mu \in \mathbb{R}_+, \sigma \in \mathbb{R}_{++}$.The risk exposure in our model best mimics the risks of commercial liability, product liability, professional liability, and business disruption insurance, etc. Firm i chooses an insurance coverage, $\alpha_i \in [0,1]$,of its potential lossbefore its production decision.Before studying the case of no risk aversion in the next section, we assume in this section that firms(more precisely, firms' agents or decision-makers who decide output choices and risk management strategies) have CARA utility functions[3] with risk aversion parameter $\gamma \geq 0$. Then given the insurance coverage, α_i, chosen at period 1, we can write firm i's expected payoff in the second period as

$$U_i(q_i, q_j) \equiv \mathbb{E}_\theta \left[-exp \left\{ -\gamma \left[\begin{matrix} \left(a - b\sum_{i=1}^{2} q_i\right) q_i \\ -(1-\alpha_i) k q_i \theta \end{matrix} \right] \right\} \right]. (1)$$

Inside the square brackets of the exponential function, the first item is the gross profit, and the second item is the uncovered loss.

The firm's ex ante expected payoff net of the insurance premium in the first period is

[3] The sources of firms' risk aversion could be the convexity of taxes, costs of bankruptcy or financial distress, or risk aversion of shareholders or managers (in this sense we are using a reduced-form model here in which the compensation of the firms' agents or decision makers is positively correlated with firms' net income), etc.

$$w_i(\alpha_i,\alpha_j) \equiv \mathbb{E}_\theta\left[-exp\left\{-\gamma\begin{bmatrix}(a-b\sum_{i=1}^{2}q_i^*)q_i^*\\ -(1-\alpha_i)kq_i^*\theta\\ -(1+\lambda)\alpha_i kq_i^*\mu\end{bmatrix}\right\}\right],(2)$$

where q_i^* is firm i's optimal output choice in the second period given its first period selection of insurance coverage. The last term inside the square brackets of the exponential function above is the (actuarially unfair) insurance premium payment.

3. Competitiveness of the Product Market and Corporate Demand for Insurance: The Case of Risk Averse Firms

The Equilibrium

We work backwards to solve for the equilibrium. In the second period, given the insurance coverage, α_i, chosen at period 1, firm i chooses its output level to maximize its expected payoff

$$Max_{q_i}U_i(q_i,q_j) = \mathbb{E}_\theta\left[-exp\left\{-\gamma\begin{bmatrix}\left(a-b\sum_{i=1}^{2}q_i\right)q_i\\ -(1-\alpha_i)kq_i\theta\end{bmatrix}\right\}\right]$$

$$= -exp\left\{-\gamma\begin{bmatrix}\left(a-b\sum_{i=1}^{2}q_i\right)q_i-(1-\alpha_i)kq_i\mu\\ -\frac{1}{2}\gamma(1-\alpha_i)^2k^2{q_i}^2\sigma^2\end{bmatrix}\right\}.$$

For ease of notations, we denote

$$\varphi_i(q_i,q_j,\alpha_i) \equiv \begin{bmatrix}(a-b\sum_{i=1}^{2}q_i)q_i-(1-\alpha_i)kq_i\mu\\ -\frac{1}{2}\gamma(1-\alpha_i)^2k^2{q_i}^2\sigma^2\end{bmatrix}. (3)$$

Therefore,

$$U_i(q_i,q_j) = -exp\{-\gamma\varphi_i(q_i,q_j,\alpha_i)\}.$$

The first-order condition (FOC) entails:

$$\partial\varphi_i/\partial q_i = \begin{bmatrix}a-(1-\alpha_i)k\mu\\ -[2b+\gamma k^2\sigma^2(1-\alpha_i)^2]q_i\\ -bq_j-bvq_i\end{bmatrix} = 0,(4)$$

wherewe denote by $v \equiv dq_j/dq_i$ the *conjectural variations* parameter, which indicates firm i's conjecture of firm j's response to a unit changein its own output level. The conjectural variations (CV) model captures a broad range of market environments.Therefore, it is typically used to study the impact of market competitiveness (see Bresnahan, 1981; Perry, 1982; Kamien and Schwartz, 1983). For example, in our current model if for the moment abstracting from the random loss part, the first-order condition becomes $a-2bq_i-bq_j-bq_iv=0$. When $v=0$, CV model characterizesthe Cournot model as a special case.When v approaches -1, each firm expects its output expansion is almost exactly absorbed by a corresponding output reduction by the other firm. This implies that each firm is a price-taker, and the market isperfectly competitive with price equal to the marginal cost. When v approaches 1, the market is collusive in that firms behave so as to maximize their joint profits. Therefore, we let $v\in(-1,1)$represent the competitiveness of the market, and investigate in this paper how the degree of market competitiveness affects firms' strategic demand for insurance. Seog (2006) shows that corporate insurance coveragemakes firms more aggressive in the product market competition. Wewill study, in a reverse path, how different degrees of rivalry in the market environment influence corporate insurance demand.

We make the following assumptions:

A1 $v\in(-1,1)$.

A2 $a>k\mu$.

As we see from the discussion above, the support of v from assumption A1 covers all competitive market environments thatwe observe in real life and are interested to study. Assumption A2 is made to ensure that the market size (a as a proxy) is not too small to cover the expected lossrelated to one unit of output. Otherwise, there would be no entry into this market.

A similar first-order condition for firm j's output choice in the second period entails

$$\partial\varphi_j/\partial q_j = \begin{bmatrix}a-(1-\alpha_j)k\mu\\ -\left[2b+\gamma k^2\sigma^2(1-\alpha_j)^2\right]q_j\\ -bq_i-bvq_j\end{bmatrix} = 0,(5)$$

wherewe implicitly assume that firms hold symmetric conjectural variations (which is typical in CV models and is reasonable since firms are ex ante identical): $dq_j/dq_i = dq_i/dq_j = v$.

For ease of notations, we denote

$$A \equiv a - (1-\alpha_i)k\mu;$$

$$B \equiv (2+v)b + \gamma(1-\alpha_i)^2 k^2\sigma^2;$$

$$C \equiv (2+v)b + \gamma\left(1-\alpha_j\right)^2 k^2\sigma^2;$$

and $$D \equiv a - \left(1-\alpha_j\right)k\mu. \quad (6)$$

The equilibrium output levels as the solution to the equations (4) and (5) are given by

$$q_i^*\left(\alpha_i, \alpha_j, v\right) = \max\left(\frac{AC - bD}{BC - b^2}, 0\right);$$

$$q_j^*\left(\alpha_i, \alpha_j, v\right) = \max\left(\frac{BD - bA}{BC - b^2}, 0\right). (7)$$

Lemma 1*Given the insurance coverage firms purchased in the first period,*

(a)$\partial q_i^*/\partial \alpha_i \geq 0; \partial q_i^*/\partial \alpha_j \leq 0$.

(b) $\partial q_i^*/\partial \gamma < 0$*if and only if*$C(1-\alpha_i)^2 q_i^* > b\left(1-\alpha_j\right)^2 q_j^*$;

(c) $\partial q_i^*/\partial v < 0$*if and only if*$C q_i^* > b q_j^*$;

(d) *For the symmetric case where* $\alpha_i = \alpha_j = \alpha, \partial Q^*/\partial \alpha > 0, \partial Q^*/\partial \gamma \leq 0, \partial Q^*/\partial k \leq 0$, *and* $\partial Q^*/\partial v < 0$. *Moreover,* $\partial Q^*/\partial \alpha$ *is strictly decreasing in* v.

Proof: See Appendix A.□

From Lemma 1 we observe that, as found in Seog (2006), insurance coverage or more generally pre-competition risk management leads to more aggressive competition in the product market.[4]Also, Lemma 1 states that a higher degree of risk aversion, a higher sensitivity of risk exposures to the production scale, or a less competitive market environment leads to reduced output levels in the symmetric equilibrium. Moreover, the strategic effect of insurance under the symmetric equilibrium is strictly increasing in the competitiveness of the product market. For given asymmetric insurance coverage selections, the effect of risk aversion and/or the competitiveness of the market environment on the output choices depends on firms' relative market shares, insurance coverage selections, risk exposures and the competitive pressure.

In the followings, when appropriate, we may drop the arguments of the optimal output functions, and simply write as q_i^* and q_j^*.In the first period, firm i selects insurance coverage α_i to maximize its expected payoff

$$Max_{\alpha_i} w_i\left(\alpha_i, \alpha_j\right) = \mathbb{E}_\theta\left[-exp\left\{-\gamma\left[\left(a - b\sum_{i=1}^{2} q_i^*\right)q_i^* - (1-\alpha_i)kq_i^*\theta - (1+\lambda)\alpha_i k q_i^*\mu\right]\right\}\right]$$

$$= -exp\left\{-\gamma\left[\varphi_i\left(q_i^*, q_j^*, \alpha_i\right) - (1+\lambda)\alpha_i k q_i^*\mu\right]\right\}.$$

The first-order condition[5]entails

$$\frac{\partial\varphi_i}{\partial q_j}\frac{\partial q_j^*}{\partial\alpha_i} + \frac{\partial\varphi_i}{\partial\alpha_i} - (1+\lambda)k\mu q_i^* - (1+\lambda)\alpha_i k\mu\frac{\partial q_i^*}{\partial\alpha_i} = 0, (8)$$

where we omit a term $\frac{\partial\varphi_i}{\partial q_i}\frac{\partial q_i^*}{\partial\alpha_i}$ since $\frac{\partial\varphi_i(q_i^*,q_j^*)}{\partial q_i} = 0$ by equation (4).

From the definition of $\varphi_i\left(q_i, q_j, \alpha_i\right)$ given in equation (3), the definitions of A, B, C and D given in equations (6), and the definitions ofq_i^* and q_j^* given in equations (7), we have

$$\frac{\partial\varphi_i}{\partial q_j}\frac{\partial q_j^*}{\partial\alpha_i} = -bq_i^*\frac{-(BC-b^2)[2\gamma k^2\sigma^2(1-\alpha_i)D + bk\mu] + 2(BD-bA)\gamma k}{(BC-b^2)^2}$$

[4]Also, this is, in spirit, related to Brander and Lewis (1986) which shows that higher financial leverage can be used by firms as a commitment device to compete aggressively in the product market.

[5]We omitted a similar first-order condition for firm j's optimal insurance selection.

$$= \frac{bq_i^*}{(BC-b^2)^2}[bk\mu(BC-b^2) + 2b\gamma k^2\sigma^2(1-\alpha_i)(AC - bD)]$$

$$= \frac{b^2 q_i^*}{BC-b^2}[k\mu + 2\gamma k^2\sigma^2(1-\alpha_i)q_i^*].$$

$$\frac{\partial\varphi_i}{\partial\alpha_i} = k\mu q_i^* + \gamma k^2\sigma^2(1-\alpha_i){q_i^*}^2.$$

$$\partial q_i^*/\partial\alpha_i = \frac{(BC-b^2)k\mu C + 2(AC-bD)\gamma k^2\sigma^2(1-\alpha_i)C}{(BC-b^2)^2} = \frac{C}{BC-b^2}[k\mu + 2\gamma k^2\sigma^2(1-\alpha_i)q_i^*].$$

Therefore, from equation (8) we have:

$$\left[\frac{b^2 q_i^*}{BC-b^2}[k\mu + 2\gamma k^2\sigma^2(1-\alpha_i)q_i^*] + k\mu q_i^* + \gamma k^2\sigma^2(1-\alpha_i){q_i^*}^2\right] - (1+\lambda)\left[k q_i^*\mu + \frac{\alpha_i k\mu C}{BC-b^2}[k\mu + 2\gamma k^2\sigma^2(1-\alpha_i)q_i^*]\right] = 0,$$

which is simplified to

$$k\mu\left[(1+\lambda)\begin{bmatrix} b^2 q_i^* - \alpha_i k\mu C \\ -2\gamma k^2\sigma^2\alpha_i(1-\alpha_i)q_i^* C\end{bmatrix} - \lambda BC q_i^*\right] + \gamma k^2\sigma^2(1-\alpha_i){q_i^*}^2(BC+b^2) = 0.(9)$$

Since firms are ex ante identical, we will focus on symmetric equilibrium, where

$\alpha_i = \alpha_j = \alpha; A = D = a-(1-\alpha)k\mu \equiv \tilde{A}; B = C = (2+v)b + \gamma(1-\alpha)^2k^2\sigma^2 \equiv \tilde{B}.$ (10)

We have $q_i^* = q_j^* = q^*(\alpha, v) = \frac{\tilde{A}}{\tilde{B}+b}$.

Applying symmetry, from equation (9) the first-order condition becomes:

$$k\mu\left[(1+\lambda)\begin{bmatrix} b^2\frac{\tilde{A}}{\tilde{B}+b} - \alpha k\mu\tilde{B} \\ -2\gamma k^2\sigma^2\alpha(1-\alpha)\frac{\tilde{A}\tilde{B}}{\tilde{B}+b}\end{bmatrix} - \lambda\frac{\tilde{A}\tilde{B}^2}{\tilde{B}+b}\right] + \gamma k^2\sigma^2(1-\alpha)\left(\frac{\tilde{A}}{\tilde{B}+b}\right)^2(\tilde{B}^2+b^2) = 0.$$
(11)

Equation (11) can be rewritten as

$$k\mu(\tilde{B}+b)\left[(1+\lambda)\begin{bmatrix} b^2\tilde{A} - \alpha k\mu\tilde{B}(\tilde{B}+b) \\ -2\gamma k^2\sigma^2\alpha(1-\alpha)\tilde{A}\tilde{B}\end{bmatrix} - \lambda\tilde{A}\tilde{B}^2\right] + \gamma k^2\sigma^2(1-\alpha)\tilde{A}^2(\tilde{B}^2+b^2) = 0.(11')$$

In order to analyze whether firms will purchase insurance, we would like to investigate the behavior of FOC (11') at $\alpha = 0$. With respect to equations (10), we denote

$$\tilde{A}_0 \equiv \tilde{A}\big|_{\alpha=0} = a - k\mu,$$

and $\tilde{B}_0 \equiv \tilde{B}\big|_{\alpha=0} = (2+v)b + \gamma k^2\sigma^2.$ (12)

From the FOC(11') we have

$$FOC|_{\alpha=0} = \left[\frac{\partial\varphi_i}{\partial q_j}\frac{\partial q_j^*}{\partial\alpha_i} + \frac{\partial\varphi_i}{\partial\alpha_i} - kq_i^*\mu - \alpha_i k\mu\frac{\partial q_i^*}{\partial\alpha_i}\right]\Bigg|_{\alpha_i=\alpha_j=\alpha=0}$$

$$= \left[k\mu\tilde{A}(\tilde{B}+b)[(1+\lambda)b^2 - \lambda\tilde{B}^2] + \gamma k^2\sigma^2\tilde{A}^2(\tilde{B}^2+b^2)\right]\Big|_{\alpha=0}$$

$$= k\mu\tilde{A}_0(\tilde{B}_0+b)\left[(1+\lambda)b^2 - \lambda{\tilde{B}_0}^2\right] + \gamma k^2\sigma^2{\tilde{A}_0}^2({\tilde{B}_0}^2+b^2)$$

$$= k\mu\tilde{A}_0(\tilde{B}_0+b)\left[\frac{\gamma k^2\sigma^2\tilde{A}_0({\tilde{B}_0}^2+b^2)}{k\mu(\tilde{B}_0+b)} + b^2 - \lambda({\tilde{B}_0}^2 - b^2)\right]$$

$$= k\mu(a-k\mu)[(3+v)b+\gamma k^2\sigma^2]\{[(2+v)b+\gamma k^2\sigma^2]^2 - b^2\}[\bar{\lambda}(v) - \lambda],(13)$$

where

$$\bar{\lambda}(v) \equiv \frac{\gamma k\sigma^2(a-k\mu)[(2+v)b+\gamma k^2\sigma^2]^2 + b^2[(3+v)b\mu + a\gamma k\sigma^2]}{\mu[(3+v)b+\gamma k^2\sigma^2]\{[(2+v)b+\gamma k^2\sigma^2]^2 - b^2\}}.$$
(14)

Obviously, $\bar{\lambda}(v) > 0$.Fromequations (13) and (14), we know that if $\lambda > \bar{\lambda}(v), FOC|_{\alpha=0} < 0$,which implies that firms will not purchase insurance at all. When $\lambda \le \bar{\lambda}(v)$, firms will purchase insurance.Therefore, $\bar{\lambda}(v)$ is the cutoff level of insurance costs that determines whether firms will choose to invest in risk management prior to product market competition. This cutoff level of insurance costs is a function of the degree of the competitiveness of the product market environment.

Now assuming that $\lambda \leq \bar{\lambda}(v)$, therefore firms will choose to insure their potential losses, we would like to analyze whether firms will select full coverage in the risk management phase. This requires us to investigate the behavior of FOC (11') at $\alpha = 1$. Fromequations(10) we know

$$\tilde{A}\big|_{\alpha=1} = a, \text{and} \tilde{B}\big|_{\alpha=1} = (2+v)b.$$

Hence, from FOC (11') we have

$$FOC|_{\alpha=1} = [\frac{\partial \varphi_i}{\partial q_j}\frac{\partial q_j^*}{\partial \alpha_i} + \frac{\partial \varphi_i}{\partial \alpha_i} - kq_i^*\mu - \alpha_i k\mu \frac{\partial q_i^*}{\partial \alpha_i}]\Big|_{\alpha_i=\alpha_j=\alpha=1}$$

$$= k\mu(\tilde{B}+b)\left[(1+\lambda)[b^2\tilde{A} - k\mu\tilde{B}(\tilde{B}+b)] - \lambda\tilde{A}\tilde{B}^2\right]\Big|_{\alpha=1}$$

$$= b^3 k\mu(3+v)[(1+\lambda)[a - k\mu(2+v)(3+v)] - \lambda a(2+v)^2]$$

$$= b^3 k\mu(3+v)^2[a(1+v) + k\mu(2+v)][\underline{\lambda}(v) - \lambda], \qquad (15)$$

where

$$\underline{\lambda}(v) \equiv \frac{a - k\mu(2+v)(3+v)}{(3+v)[a(1+v)+k\mu(2+v)]}. \qquad (16)$$

From equation (15) we know that the sign of $FOC|_{\alpha=1}$ is the same as the sign of $\underline{\lambda}(v) - \lambda$. If $\underline{\lambda}(v) - \lambda < 0$, we have $FOC|_{\alpha=1} < 0$, which implies that firms will choose less-than-full coverage. If $\underline{\lambda}(v) - \lambda \geq 0$, we have $FOC|_{\alpha=1} \geq 0$, which implies that firms will choose to fully insure their potential losses.

Denote $f(v) \equiv (3+v)(2+v)$.Solving for v^* such that $f(v^*) = a/k\mu$,we have

$$v^* = \frac{\sqrt{1+4(a/k\mu)}-5}{2}. \qquad (17)$$

You can see an illustration of $f(v)$ and v^* in Figure 1. If $v > v^*$, from equation (16) we have $\underline{\lambda}(v) < 0$, which implies that $FOC|_{\alpha=1} < 0$, so firms will only select partial, if not none, insurance coverage of their potential losses. If $v \leq v^*$,from equation (16) we have $\underline{\lambda}(v) \geq 0$. In this case the equilibrium insurance coverage firms purchase depends on the competitiveness of the product market and the cost of insurance. Given $v \leq v^*$, when $\lambda > \underline{\lambda}(v)$, firms select partial insurancesince $FOC|_{\alpha=1} < 0$; when $\lambda \leq \underline{\lambda}(v)$, we have $FOC|_{\alpha=1} \geq 0$, which implies that firms will select full insurance. We summarize the results discussed above in Proposition 1.

Proposition 1 (a) *If $\lambda > \bar{\lambda}(v)$,firms do not purchase insurance at all.Only when $\lambda \leq \bar{\lambda}(v)$, do firms purchase insurance;*

(b) *Given $\lambda \leq \bar{\lambda}(v)$, when $v > v^*$, firms choose to only partially insure their potential losses. If $v \leq v^*$, then the equilibrium insurance coverage that firms purchase depends on the competitiveness of the product market and the cost of insurance: when $\lambda > \underline{\lambda}(v)$,firms select partial insurance; when $\lambda \leq \underline{\lambda}(v)$,firms select full insurance.*

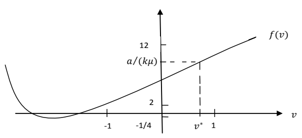

Figure 1 Critical Value v^* for Insurance Coverage Choice

Proposition 1 states that the cost of insurance and the competitiveness of the product market environment jointly shape firms' insurance decisions. Obviously, the higher the insurance costs, the less insurance firms purchase. When the insurance is too costly, firms choose not to insure at all. When insurance is not too costly, there exists a critical value of the competitiveness of the product market, which determines whether firms choose to acquire full or partial insurance.When the product market where firms compete is not so competitive[6] ($v > v^*$),even if the cost of insurance is below the insurance purchase threshold ($\bar{\lambda}(v)$), the firms will only select partial coverage. When the product market is quite competitive ($v \le v^*$), firms may still choose to partially insure if the cost of insurance is not low ($\lambda > \underline{\lambda}(v)$); only whenthe product market is competitive and the cost of insurance is low, do firms choose full insurance for the potential losses.

As you can see from Figure 1, $f(v)$ is strictly increasing for any $v \in (-1,1)$,the interval of possible conjectural variations we assumed that covers all market environments which we are interested to study. From equations (16) and (17), we can see how changes in a affect the threshold levels ----v^* and$\underline{\lambda}(v)$.When$a \in [2k\mu, 12k\mu]$, v^* falls within $(-1,1)$. If $a < 2k\mu$, we have $v^* < -1$; and $\underline{\lambda}(v) < 0, \forall v \in (-1,1)$. In this case Proposition 1 implies that firms never purchase full insurance. If $a > 12k\mu$,we have $v^* > 1$; and $\underline{\lambda}(v) > 0, \forall v \in (-1,1)$. In this case, according to Proposition 1, firms may purchase full coverage when insurance costs fall below $\underline{\lambda}(v)$. We summarize this in the following corollary:

Corollary 1*If* $a < 2k\mu$*, firms never acquire full insurance. If* $a > 12k\mu$*, firms may purchase full coveragewhenthe insurance costs are low---* $\lambda \le \underline{\lambda}(v)$*. If*$a \in [2k\mu, 12k\mu]$*, firms' insurance decisions are described by Proposition 1, depending on* v *and* λ*.*

When the market size is small, the equilibrium production scale accordingly will not be large. This implies that the risk exposure in the product competition is limited since the risk exposure is proportional to the production scale. Therefore, it never pays off for firms to fully insure in a small market. By the same token, in a large market, when facing high competitive pressure and a not-so-expensive insurance supply, firms may purchase full coverage since firms will produce large scale output in a large market, subjecting themselves to a high degree of risk exposure.

We would like to further investigate the impact of the competitiveness of the product market on the cutoff levels characterizing firms' risk management strategies. From equation (14), we have:

[6]Remember that a lower v represents a more competitive market environment.

$\bar{\lambda}'(v)$

$$= \frac{\mu(\tilde{B}_0 + b)(\tilde{B}_0^{\ 2} - b^2)\left(2\gamma k\sigma^2\tilde{A}_0\tilde{B}_0 b + b^3\mu\right) - \begin{bmatrix} \gamma k\sigma^2\tilde{A}_0\tilde{B}_0^{\ 2} \\ +(3+v)b^3\mu + ab^2\gamma k\sigma^2 \end{bmatrix} \begin{bmatrix} b\mu\left(\tilde{B}_0^{\ 2} - b^2\right) \\ +2\mu(\tilde{B}_0 + b)\tilde{B}_0 b \end{bmatrix}}{\left[\mu(\tilde{B}_0 + b)(\tilde{B}_0^{\ 2} - b^2)\right]^2}$$

$$= \frac{b\mu(\tilde{B}_0 + b)\left\{(\tilde{B}_0^{\ 2} - b^2)\left(2\gamma k\sigma^2\tilde{A}_0\tilde{B}_0 + b^2\mu\right) - \begin{bmatrix} \gamma k\sigma^2\tilde{A}_0\tilde{B}_0^{\ 2} \\ +(3+v)b^3\mu + ab^2\gamma k\sigma^2 \end{bmatrix} \begin{bmatrix} (\tilde{B}_0 - b) \\ +2\tilde{B}_0 \end{bmatrix}\right\}}{\left[\mu(\tilde{B}_0 + b)(\tilde{B}_0^{\ 2} - b^2)\right]^2}$$

$$= \frac{b\begin{Bmatrix} (\tilde{B}_0 - b)\left[2\gamma k\sigma^2\tilde{A}_0\tilde{B}_0^{\ 2} + b^2\mu\tilde{B}_0 + 2\gamma k\sigma^2\tilde{A}_0\tilde{B}_0 b + b^3\mu - \gamma k\sigma^2\tilde{A}_0\tilde{B}_0^{\ 2} - (3+v)b^3\mu - ab^2\gamma k\sigma^2\right] \\ -2\tilde{B}_0\left[\gamma k\sigma^2\tilde{A}_0\tilde{B}_0^{\ 2} + (3+v)b^3\mu + ab^2\gamma k\sigma^2\right] \end{Bmatrix}}{\mu(\tilde{B}_0 + b)(\tilde{B}_0^{\ 2} - b^2)^2}$$

$$= \frac{b\left\{(\tilde{B}_0 - b)\begin{bmatrix} \gamma k\sigma^2\tilde{A}_0\tilde{B}_0^{\ 2} + 2\gamma k\sigma^2\tilde{A}_0\tilde{B}_0 b \\ -ab^2\gamma k\sigma^2 + b^2\mu(\tilde{B}_0 - (2+v)b) \end{bmatrix} - 2\tilde{B}_0\begin{bmatrix} \gamma k\sigma^2\tilde{A}_0\tilde{B}_0^{\ 2} \\ +(3+v)b^3\mu + ab^2\gamma k\sigma^2 \end{bmatrix}\right\}}{\mu(\tilde{B}_0 + b)(\tilde{B}_0^{\ 2} - b^2)^2}$$

$$= \frac{b\left\{(\tilde{B}_0 - b)\gamma k\sigma^2\left(\tilde{A}_0\tilde{B}_0^{\ 2} + 2\tilde{A}_0\tilde{B}_0 b - ab^2 + b^2\mu k\right) - 2\tilde{B}_0\left[\gamma k\sigma^2\tilde{A}_0\tilde{B}_0^{\ 2} + (3+v)b^3\mu + ab^2\gamma k\sigma^2\right]\right\}}{\mu(\tilde{B}_0 + b)(\tilde{B}_0^{\ 2} - b^2)^2}$$

$$= \frac{b\left\{\gamma k\sigma^2(\tilde{B}_0 - b)\left(\tilde{A}_0\tilde{B}_0^{\ 2} + 2\tilde{A}_0\tilde{B}_0 b - b^2\tilde{A}_0\right) - 2\tilde{B}_0\left[\gamma k\sigma^2\tilde{A}_0\tilde{B}_0^{\ 2} + (3+v)b^3\mu + ab^2\gamma k\sigma^2\right]\right\}}{\mu(\tilde{B}_0 + b)(\tilde{B}_0^{\ 2} - b^2)^2}$$

$$= \frac{b\left\{\gamma k\sigma^2\left[(\tilde{B}_0 - b)\tilde{A}_0\left(\tilde{B}_0^{\ 2} + 2\tilde{B}_0 b - b^2\right) - 2\tilde{A}_0\tilde{B}_0^{\ 3} - 2ab^2\tilde{B}_0\right] - 2\tilde{B}_0(3+v)b^3\mu\right\}}{\mu(\tilde{B}_0 + b)(\tilde{B}_0^{\ 2} - b^2)^2}$$

$$= \frac{b\left\{\gamma k\sigma^2\left[-(\tilde{B}_0 - b)\tilde{A}_0(\tilde{B}_0^{\ 2} + b^2) - 2b^2\tilde{B}_0(\tilde{A}_0 + a)\right] - 2\tilde{B}_0(3+v)b^3\mu\right\}}{\mu(\tilde{B}_0 + b)(\tilde{B}_0^{\ 2} - b^2)^2} < 0. \qquad (18)$$

We obtain the inequality by the assumptions A1 and A2,and the fact that $\tilde{A}_0, \tilde{B}_0, \tilde{B}_0 - b, \tilde{B}_0 + b$,and $3 + v$are all positive.

Similarly, from equation (16), we have

$\underline{\lambda}'(v)$

$$= \frac{-(3+v)[a(1+v) + k\mu(2+v)]k\mu(5+2v) - [a - k\mu(2+v)(3+v)]\begin{bmatrix} a(1+v) + k\mu(2+v) \\ +(3+v)(a+k\mu) \end{bmatrix}}{\{(3+v)[a(1+v) + k\mu(2+v)]\}^2}$$

$$= \frac{-(3+v)[a(1+v) + k\mu(2+v)]k\mu(5+2v) - [a - k\mu(2+v)(3+v)][2a(2+v) + k\mu(5+2v)]}{\{(3+v)[a(1+v) + k\mu(2+v)]\}^2}$$

$$= \frac{-k\mu(5+2v)[a(1+v)(3+v) + k\mu(2+v)(3+v) + a - k\mu(2+v)(3+v)] - 2a(2+v)[a - k\mu(2+v)(3+v)]}{\{(3+v)[a(1+v) + k\mu(2+v)]\}^2}$$

$$= \frac{-ak\mu(5+2v)(2+v)^2 - 2a(2+v)[a - k\mu(2+v)(3+v)]}{\{(3+v)[a(1+v) + k\mu(2+v)]\}^2}$$

$< 0$when$v < v^*$. (19)

We obtain the inequality because, first, the

denominator is positive;and second, in the numerator, the first term is negative, and the second term is also negativewhen $v < v^*$.

Since $\bar{\lambda}(v)$ is the cost-of-insurance threshold characterizing firms' decision whether to acquire insurance, and $\underline{\lambda}(v)$ is the cost-of-insurance threshold characterizing firms' decision whether to select full coverage, we have the following proposition from inequalities (18) and (19):

Proposition 2*The more competitive the product market is, the more likely firms choose to insure their potential losses.Furthermore, when $v < v^*$, the morecompetitive the product market is, the more likely firms select full coverage.*

Proof of Proposition 2 follows from the inequalities (18) and (19), and Proposition 1. By inequality (18), a lower v, which represents a more competitive product market environment, leads to a higher $\bar{\lambda}$, thus a higher likelihood of satisfying $\lambda < \bar{\lambda}$, which triggers insurance purchase according to Proposition 1. Similarly, by inequality (19), given $v < v^*$,a lower v leads to a higher $\underline{\lambda}$, thus a higher likelihood of satisfying $\lambda < \underline{\lambda}$, which triggers full coverage selection according to Proposition 1.Proposition 2 illustrates that higher competitive pressure drives more strategic demand for insurance.

Discussion: The Case of$\gamma \to 0$

It would be interesting to examine how firms' insurance decisions are influenced by purely strategic factors characterized in the product market competition, absent any risk version considerations. Here I first discuss the case of the risk aversion parameter γ approaching zero.

In the three critical values characterizing firms' optimal insurance decisions, both v^* and $\underline{\lambda}(v)$ are independent of γ.According to Proposition 1, this implies that given firms will acquire insurance, whether they will select partial or full coverage does not depend on risk version at all, but only depends on the insurance costs and the competitiveness of the product market ---- a pretty counter-intuitive result implied from our analysis.

From equation (14), we know that $lim_{\gamma\to 0}\,\bar{\lambda}(v) = \frac{1}{(1+v)(3+v)} > \frac{1}{8}, \forall v \in (-1,1)$. This implies that firms will always purchase insurance if $\lambda \le 1/8$, according to Proposition 1. Moreover, $lim_{\gamma\to 0}\,\bar{\lambda}(v)$ is decreasing in v, which implies that the more competitive the product market is, the more likely firms will acquire insurance, by Proposition 1. We summarize the results in the following corollary.

Corollary 2 (a) *Given that firms will acquire insurance, whether they will select partial or full coverage does not depend on the risk aversion parameter, but only on the cost of insurance and the competitiveness of the product market;*
(b) *When $\gamma \to 0$, firms' likelihood of purchasing insurance is increasing in the competitiveness of the product market environment, and they will always purchase insurance if $\lambda \le 1/8$.*

4. The Case of No Risk Aversion

In this section, in order to focus on the pure strategic effect of corporate insurance on the product market competition, filtering any risk version considerations, we study the case of no risk aversion in a simplified version of the model where the risk (σ) itself does not affect firms' insurance selection per se.

The framework is basically the same as before, except that given the insurance coverage, α_i, chosen at period 1, firm i's expected payoff in the second period is

$V_i(q_i, q_j, \alpha_i) \equiv \left(a - b\sum_{i=1}^{2} q_i\right)q_i - (1 - \alpha_i)kq_i\mu$.(20)

Accordingly, the firm's expected payoff net of the insurance premium in the first period is

$\pi_i(\alpha_i, \alpha_j) \equiv \left(a - b\sum_{i=1}^{2} q_i^*\right)q_i^* - (1 - \alpha_i)kq_i^*\mu - (1 + \lambda)\alpha_i kq_i^*\mu$.(21)

In the second period, firm i chooses its output level to maximize its expected payoff

$$Max_{q_i} V_i(q_i, q_j, \alpha_i).$$

The first-order condition (FOC) entails:

$\partial V_i/\partial q_i = a - (1 - \alpha_i)k\mu - (2 + v)bq_i - bq_j = 0,$ (22)

where, again, v is the conjectural variationsparameter.

A similar first-order condition for firm j's output choice in the second period entails

$\partial V_i/\partial q_j = a - (1-\alpha_j)k\mu - (2+v)bq_j - bq_i = 0.$ (23)

The equilibrium output levels as the solution to the equations (22) and (23) are given by

$$q_i^*(\alpha_i, \alpha_j, v) = \max\left(\frac{(2+v)[a-(1-\alpha_i)k\mu] - [a-(1-\alpha_j)k\mu]}{b(3+v)(1+v)}, 0\right) = \max\left(\frac{(2+v)A - D}{b(3+v)(1+v)}, 0\right);$$

$$q_j^*(\alpha_i, \alpha_j, v) = \max\left(\frac{(2+v)[a-(1-\alpha_j)k\mu] - [a-(1-\alpha_i)k\mu]}{b(3+v)(1+v)}, 0\right) = \max\left(\frac{(2+v)D - A}{b(3+v)(1+v)}, 0\right). \quad (24)$$

For the symmetric case where $\alpha_i = \alpha_j = \alpha$, we have

$q^*(\alpha, v) = \frac{a-(1-\alpha)k\mu}{b(3+v)}$; and $Q^* = \frac{2[a-(1-\alpha)k\mu]}{b(3+v)}$. (25)

We have the following lemma:

Lemma 2*In the case of no risk aversion, given the insurance coverage firms purchased in the first period,*

(a) $\partial q_i^*/\partial \alpha_i \geq 0; \partial q_i^*/\partial \alpha_j \leq 0$. *In particular, if* $\alpha_i > (2+v)\alpha_j + (1+v)\frac{a-k\mu}{k\mu}, q_j^* = 0$, *and* $q_i^* = \frac{(2+v)A-D}{b(3+v)(1+v)} > 0$. *In other words, a firm with an insurance coverage sufficiently higher than the one selected by its rival may effectively drive out the rival and achieve monopoly;*

(b) $\partial q_i^*/\partial \alpha_i$ *is decreasing in* v; $\partial q_i^*/\partial \alpha_j$ *is increasing in* v;

(c) $\partial q_i^*/\partial v < 0$ *if and only if* $\frac{a-(1-\alpha_i)k\mu}{a-(1-\alpha_j)k\mu} > \frac{2(2+v)}{(2+v)^2+1}$; *i.e., if and only if the relative insurance commitment effect is greater than the competitive pressure effect. In particular,* $\partial q_i^*/\partial v < 0$ *when* $\alpha_i > \alpha_j$;

(d) *For the symmetric case where* $\alpha_i = \alpha_j = \alpha, \partial Q^*/\partial \alpha > 0, \partial Q^*/\partial k \leq 0$, *and* $\partial Q^*/\partial v < 0$.

Proof: See Appendix B.□

Lemma 2(a) confirms the strategic effect of corporate insurance in the product market competition in the case of no risk aversion. Especially, when the asymmetric commitment advantage through insurance is sufficiently great, a firm may successfully drive out its rival and attain monopoly. This implies that investment in risk management may be used as an exclusionary deviceby incumbent firms to prevent entry or induce exit of rivals if firms in the market are subject to differential liquidity constraints such as that supposed in the "long-purse" (or "deep-pockets") theory in industrial organization (see, for example, Tirole (1988), Benoit (1986), and Telser (1966)). Lemma 2(b) tells us that the strategic commitment effect of insurance is monotonically increasing in the competitiveness of the product market environment. A fiercer product market competition makes the strategic commitment effect of corporate insurance more salient. Lemma 2(d) states that a higher sensitivity of risk exposures to the production scale, or a less competitive market environment leads to reduced output levels in the symmetric equilibrium. According to Lemma 2(c), for given asymmetric insurance coverage selections, the effect of competitiveness of the product market environment on the output choices depends on firms' relative insurance coverage selections, and the competitiveness of the product market. In particular, a firm with relatively higher insurance coverage will be more aggressive as the product market environment becomes more competitive.

In the first period, firm i selects insurance coverage α_i to maximize its expected payoff

$$Max_{\alpha_i} \pi_i(\alpha_i, \alpha_j) = V_i(q_i^*, q_j^*, \alpha_i) - (1+\lambda)\alpha_i k q_i^* \mu.$$

The first-order condition entails

$$\frac{\partial V_i}{\partial q_j}\frac{\partial q_j^*}{\partial \alpha_i} + \frac{\partial V_i}{\partial \alpha_i} - (1+\lambda)k\mu q_i^* - (1+\lambda)\alpha_i k\mu\frac{\partial q_i^*}{\partial \alpha_i} = 0, \quad (26)$$

where we omitted a term $\frac{\partial V_i}{\partial q_i}\frac{\partial q_i^*}{\partial \alpha_i}$ since $\frac{\partial V_i(q_i^*,q_j^*,\alpha_i)}{\partial q_i} = 0$ by equation (22).

Using the definition of $V_i(q_i, q_j, \alpha_i)$ given in equation (20), and the definitions of q_i^* and q_j^* given in equations (24), we can simplify equation (26) as

$$bq_i^* - b\lambda(3+v)(1+v)q_i^* - (1+\lambda)(2+v)k\mu\alpha_i = 0. \quad (27)$$

Again, we will focus on symmetric equilibrium. Therefore, $\alpha_i = \alpha_j = \alpha$, and $q_i^* = q_j^* = q^*(\alpha, v) = \frac{a-(1-\alpha)k\mu}{b(3+v)}$. Substituting these into equation (27), we have

$$\alpha^* = \min\left(\max\left(\frac{1-\lambda(3+v)(1+v)}{v^2+5v+5+\lambda(3+v)(3+2v)}\frac{a-k\mu}{k\mu}, 0\right), 1\right). \quad (28)$$

Denote

$$g(v) \equiv \frac{1}{(3+v)(1+v)}; \quad (29)$$

and

$$\overline{v}(\lambda) \equiv \sqrt{1+\frac{1}{\lambda}} - 2, \text{when } \lambda > 0. \quad (30)$$

Then we have the following proposition:

Proposition 3 *In the case of no risk aversion,*

(a) *given the competitiveness of the product market as represented by v, firms will acquire insurance when $\lambda < g(v)$, i.e., when the cost of insurance is low compared to its strategic commitment effect; given the cost of insurance as represented by $\lambda > 0$, firms will acquire insurance when $v < \overline{v}(\lambda)$, i.e., when the product market is more competitive than represented by $\overline{v}(\lambda)$.*
(b) *The more competitive the product market is, the more likely firms will purchase insurance. Furthermore, the insurance coverage firms select is increasing in the competitiveness of the product market.*
(c) *Given firms will purchase insurance, the coverage they select is increasing in the market size, and is decreasing in the sensitiveness of risk to the production scale.*
Proof: See Appendix C.□

Proposition 3 states that even when there is no risk aversion in the utility function, firms may still acquire insurance, for the strategic effect in the product market. Similarly, the cost of insurance and the competitiveness of the product market environment jointly shape firms' insurance decisions. When the cost of insurance is less than the strategic benefit of insurance, or when the product market is quite competitive, firms will purchase coverage for their risk exposures. Both the likelihood and the coverage selected are monotonically increasing in the competitiveness of the product market. Moreover, the equilibrium insurance coverage is increasing in the market size, but decreasing in the sensitiveness of risk to the production scale. The latter is because the equilibrium production level is decreasing in the risk sensitiveness.

5. Empirical Test

From the theoretical results, we have and will test the following hypotheses:

Hypothesis 1: Given the cost of insurance, more intense product market competition faced by firms induces them to purchase a higher level of insurance coverage.

Hypothesis 2: Given the cost of insurance, firms will choose a higher level of insurance coverage as the size of product market in which they operate increases.

Hypothesis 3: Provided that product market characteristics remain unchanged, as the cost of insurance increases, the amount of insurance demanded by firms will decrease.

5.1. Data and Empirical Methodology

In order to test the implications of our theoretical model empirically, we examine the demand for reinsurance by U.S. primary insurers. Although it would provide a more general test on corporate demand for insurance to utilize data on insurance purchases by general firms as in recent studies such as Zou, Adams, and Buckle (2003,using Chinese data), Regan and Hur (2007, using Korean data), and Michel-kerjan, Raschky, and Kunreuther (2009, using U.S. catastrophe insurance data), we will focus on the property-liability insurance industry due to data limitations, as in most empirical studies on this subject

(Mayers and Smith, 1990; Garven and Lamm-Tennant, 2003; Cole and McCullough, 2006; Powell and Sommer, 2007). However, it should be emphasized that, to our knowledge, our empirical analysis is the first study that incorporates product market environment factors - the competitiveness and size of the market in which firms operate - and the costs of reinsurance that are defined as firm-specific based on detailed information about reinsurance transactions of primary insurers and their affiliated groups if they belong to any.

As in previous studies that utilize the insurance industry to test corporate demand for insurance, our dependent variable, *REINS*, measures how much portion of the total premiums of an insurer, which is the sum of its direct premiums written and reinsurance assumed, is ceded either to affiliates or to external companies. We also estimate the same equation with the ratio of reinsurance premiums ceded only to external companies, *EXT_REINS,* because insurers might have different incentives to purchase external reinsurance from those to transfer premiums to affiliates as concretely examined in Powell and Sommer (2007).

In our study, independent variables of main interest are product market related variables. Given that there are significant differences between different lines of business and states, we define a product market in which primary insurers operate as a market segmented by lines of business and states and compute its market size and concentration measures, such as the Herfindahl-Hirschman index (HHI), the four-firm and ten-firm concentration ratios (CR_4 and CR_{10}). More specifically, market size that represents the density of consumers in a market is measured by taking the sum of direct premiums written for firms operating in a given market. Market concentration measures enumerated above have been widely used to measureproduct market competitivenessin many studies. The underlying idea behind these measures is that lower concentration reflects a higher degree of market competition among firms in the market. After obtaining market size and concentration variables for each market, we construct firm-specific market related variables by computing the weighted averages of these variables over all the markets in which an insurer is doing business. Here, the weight for each market is the portion of direct premiums written in that particular market for the insurer. We thus obtain firm-specific market size and concentration ratios and label them as *MKTSIZE, CONC_HHI, CONC_CR4, CONC_CR10*, respectively, where *MKTSIZE* is log transformed because of itsskewness to the right. Given that most primary insurers tend to diversify their business for the purpose of risk pooling,[7] the firm-specific variables above are expected to capture the overall level of market demand size and market competitiveness for each insurer. Based on the results of our theoretical model, we expect a positive relation between *MKTSIZE* and reinsurance demand and a negative relation between either of market concentration variables and reinsurance demand.

We now describe how to measure reinsurance supply side variables that captures the cost of reinsurance and the financial status of reinsurers in our analysis. Cole and McCullough (2006) show the importance of incorporating reinsurance industry factors in the equation for reinsurance demand by primary insurers. However, in contrast with their study utilizing reinsurance industry average factors that are identically applied to all primary insurers, we consider differences across firms in terms of the source of reinsurance supply. Each firm may cede its premiums either to its affiliates or to U.S. or non-U.S. unaffiliated insurers. If the financial status of its affiliates or its reinsurance partners outside of its group changes, the insurer will take into account that situation when it decide the amount of reinsurance ceded. Since the status of affiliates or that of reinsurance partners varies across insurers, we can capture firm-specific reinsurance supply-side changes that may affect their demand for reinsurance. To do so, we use the combined ratio and the development of loss reserves as in Cole and McCullough (2006). The combined ratio of a firm, which includes both underwriting expenses and loss ratios, is negatively associated with the price of insurance provided by the firm (Cole and McCullough, 2006).[8] Thus, we expect to

[7]In our sample, the average number of lines of business for which a primary insurer is operating is 6 and that of states is 14.

[8] A more standard measure would be the economic premium ratio that is often used in the literature (e.g., Winter, 1994; Cummins and Danzon, 1997; Cole and McCullough, 2006) because it reflects the present value of expected loss cash flows whose patterns vary with lines of business. However, our regression results show

capture the cost of reinsurance by measuring the overall levels of combined ratios of affiliates and those of unaffiliated reinsurance partners. The loss development (the 2-year loss development in our analysis) shows whether or not the firm successfully anticipates and prepares for claim payments. Note that a positive (negative) value indicates that the firm has been under-reserving (over-reserving). As in Cole and McCullough (2006), this loss development variable is used not only as a firm-specific control variable influencing the demand for reinsurance by primary insurers, but also as anindication of a reinsurer's financial status. The former is because insurers under-reserving are expected to demand more reinsurance to complement reserving errors, whereas the latter is suggested by prior studies (e.g., Petroni, 1992) that show that financially troubled insurers are more likely to understate loss reserves.

To obtain the group level variables, we identify which firms engage in reinsurance transactions within the group more heavily using the variable of reinsurance assumed from affiliates and then compute the weighted averages of combined ratio and loss reserve developmentso as to reflect the status of those firms assuming more reinsurance from affiliates with higher weights. These group status variables are denoted by*GROUP_COMB* and *GROUP_LOSS_DEV* and included in the regression after being multiplied by group dummy variable, *G_DUMMY*, which is one only if the firm belongs to a group and zero otherwise.

In addition to reinsurance pooling and transactions with affiliates, many of reinsurance transactions of primary insurers occur with U.S. unaffiliated insurers, which are a professional reinsurer or another primary insurer.[9] Based on the data on reinsurance transactions in Schedule F (Part 3) of the NAIC database, we identify to whom and how much a primary insurer transfers its premiums among U.S. unaffiliated insurers. We then compute the weighted averages of combined ratios and loss development of those unaffiliated reinsurance partners with which the primary insurer transacts by placing a higher weight on a firm assuming more reinsurance. The first variable, *US_UNAFF_COMB,* is used to capture the firm-specific cost of reinsurance that the primary insurer faces for ceding its premiums to those U.S. unaffiliated insurers, whereas the second variable, *US_UNAFF_LOSS_DEV,* may reflect the financial quality of its reinsurance partners. The last source of reinsurance supply to be considered in our analysis is non-U.S. reinsurers. Due to data limitations, we are only able to measure the average combined ratios of non-U.S. reinsurers among the top 100-150 reinsurers around the world, *NONUS_COMB,* and include this variable multiplied by *NONUS_DUMMY*in the regression that is one only if the primary insurer purchases reinsurance from a non-U.S. reinsurer and zero otherwise.

Our empirical approach to examine the demand for reinsurance by primary insurers is presented by the following equations that are estimated by ordinary least squares (OLS) regression with standard errors that are robust to clustering at the firm level. The dependent variable, $REINS_{it}$, represents the overall reinsurance ratio for insurer *i* in year *t*. As mentioned earlier, we also test the demand for external reinsurance, EXT_REINS_{it} , with the same set of independent variables.

$$REINS_{it} = \beta_0 + \beta_1 CONC_{it} + \beta_2 MKTSIZE_{it} + \beta_3 G\_DUMMY_{it} * GROUP\_COMB_{jt} + \beta_4 G\_DUMMY_{it} * GROUP\_LOSS\_DEV_{jt} + \beta_5 US\_UNAFF\_DUMMY_{it} * US\_UNAFF\_COMB_{it} + \beta_6 US\_UNAFF\_DUMMY_{it} * US\_UNAFF\_LOSS\_DEV_{it} + \beta_7 NONUS\_DUMMY_{it} * NONUS\_COMB_{t} + \gamma' X_{it} + \delta_t + \varepsilon_{it} \quad (31)$$

Based on the discussion above, our main independent variables are explicitly specified in the equation. Note that the variables of market concentration and size are firm-specific and that we expect to see a negative impact of the former and a positive impact of the latter on reinsurance demand. The next five variables attempt to capture the cost of reinsurance offered by reinsurance partners, proxiedby the negative of the combined ratio, and their financial status, measured by theloss development, especially

that the measures based on the combined ratio are enough to show the implications of the cost of reinsurance.

[9] Of reinsurance transactions with U.S. unaffiliated insurers, 30-40 percent occur among primary insurers based on the NAIC or A.M. Best definition of professional reinsurers.

by distinguishing three channels of reinsurance supply. Both our model and prior studies predict a negative impact of reinsurance cost variable, that is, positive signs of β_3, β_5, and β_7. If ceding companies care about the financial soundness of affiliates and unaffiliated reinsurance partners and the loss development is negatively associated with a firm's financial quality, the demand for reinsurance through that channel will decrease, thereby negative signs of β_4 and β_6.

X_{it} is a vector of other firm-specific factors that are known to affect reinsurance activity from prior studies, such as a firm'ssize, ROA, leverage, tax-exempt investment, loss development, catastrophe exposure, line of business and geographic Herfindahl indexes, group affiliation, organizational form, and line of business controls. Finally, δ_t represents year fixed effects, and ε_{it} is a random error term.[10]

Our sample used in the empirical analysis is obtained from the National Association of Insurance Commissioners (NAIC) database for the years 1995 through 2008. The data on the combined ratios of non-U.S. reinsurers that are the top 100-150 reinsurers around the world are obtained from Standard and Poor's *Global Reinsurance Highlights* (1998-2009 editions). We remove consolidated financial data for insurance groups and observations with non-positive assets, surplus, and premiums earned. Since our analysis intends to look at reinsurance decisions by primary insurers, professional reinsurers, which are identified by the NAIC definition or the A.M. Best definition,[11] are excluded from the sample. To avoid the effects of extraordinary operating behaviors, we also exclude insurers with non-positive direct premiums written, those whose status is identified as inactive, and those with reinsurance ratios that are not between zero and one. We then winsorize several firm-specific variables to remove the potential effects of outliers, including assets, premiums earned, surplus, ROA, 2-year loss development, leverage, combined ratio, at the 2 percent and 98 percent levels for each year. The final sample consists of 2,996 U.S. primary insurers and 26,668 firm-year observations from 1995 to 2008.

5.2. Empirical Results

Table 2 provides the summary statistics for the variables used in the regression analysis. First, our dependent variables are shown in the top of the table. The average ratio of reinsurance ceded either to affiliates or to external insurers is 0.3796, whereas that of reinsurance ceded only to external insurers is 0.1715. Independent variables are classified into three categories – insurance market related variables, reinsurance supply side variables, and other firm-specific controls. The first four variables alternatively measure the weighted average of market concentration where the weights are the proportions of direct premiums written in specific markets for each firm. Accordingly, these variables are expected to capture the overall level of market competition that an insurer operating in different states for several lines of business faces. Given that a HHI index below 0.15 or a four-firm concentration ratio below 0.5 largely indicates low market concentration, primary insurers, on average, confront intense market competition. Of the entire observations, 63 percent are those of affiliated firms that engage in internal reinsurance activity, 72 percent cede premiums to U.S. unaffiliated insurers, and 51 percent transactwith a non U.S. reinsurer. The weighted average group combined ratio is 1.06, whereas that of U.S. unaffiliated reinsurance partners is 1.18 and the average combined ratio of non-U.S. reinsurers is 1.02. Contrary to Cole and McCullough (2006), the difference in the average combined ratio between non-U.S. reinsurers and U.S. unaffiliated insurers assuming reinsurance is negative. The reason might be different sample periods or that the latter combined ratio is not simply an average of all the U.S. reinsurers, but the weighted average combined ratio of firm-specific reinsurance partners. Using the 2-year loss development variable, we can say that

[10]To control for potential endogeneity, we use lagged independent variables as suggested by prior studies (e.g., Cole and McCullough, 2006). However, our main results still hold with non-lagged independent variables.

[11]Cole and McCullough (2008) summarize and compare different definitions of professional reinsurers from prior studies, including the NAIC definition – any firm in which reinsurance assumed from non-affiliates is more than 75 percent of reinsurance assumed from non-affiliates plus direct business written – and the A.M. Best definition – any firm in which reinsurance assumed from non-affiliates is more than 75 percent of reinsurance assumed from affiliates plus direct business written.

affiliated groups and U.S. unaffiliated reinsurance partners, on average, over reserved during the sample period, which implies the overall sound financial performance of the reinsurance supply-side even though there might be some fluctuation over time. The statistics for other firm-specific controls are similar to those in other studies (Cole and McCullough, 2006; Powell and Sommer, 2007).

Results for the regression equation (31) in which the dependent variable is the total reinsurance ratio, *REINS*, are shown in Table 3. Note that the three regressions are distinguished by the alternative market concentration variables and that the results are very similar in these specifications. To begin with, we find that firm-specific control variables, which are included based on prior studies, show fairly consistent results. The significant coefficients on size and leverage are consistent with those of prior studies that test the hypothesis that insurers with higher default risk tend to purchase more reinsurance. Consistent with the results of prior studies, insurers with higher catastrophe exposures and lower concentration in terms of business mix, geographically less concentrated insurers, those under-reserving more, stock insurers, and those affiliated demand more reinsurance. Only the effects of return on assets and tax-exempt investments are different from those found in the literature.[12]

As noted earlier, ourmaininterest concerns insurance market related variables that are defined as firm-specific. The results provide strong support for our predictions from the model regarding the intensity of market competition and market size. As predicted by our theory, the coefficient of the firm-specific level of market concentration is significantly negativeat the 10% level, whereas the coefficient of market size variable is positive and significantat the 10% level. Thus, these estimates suggest that greater market competition and greater market size lead to greater reinsurance demand. In addition, it should be emphasized that reinsurance supply side variables are largely found to significantly affect reinsurance demand by primary insurers. First, the coefficients of *GROUP_COMB* and *US_UNAFF_COMB* are significantly positive at the 5% and 1% level, respectively, thereby implying that regardless of whether affiliates or U.S. unaffiliated insurers provide reinsurance, the demand for reinsurance decreases as the cost of reinsurance increases. However, the price of a reinsurance contractoffered by non-U.S. reinsurers does not significantly affect the overall demand for reinsurance.

The variables capturing the financial status of reinsurance partners, *GROUP_LOSS_DEV* and *US_UNAFF_LOSS_DEV,* are found to be significantly positive and negative (at the 10% and 5% level, respectively). As discussed earlier, higher loss development implies poor financial status of reinsurance partners, which may, in turn, decrease the demand for reinsurance. However, there might be a substitution effect between reinsurance transactions through affiliates and those with U.S. unaffiliated insurers because our dependent variable combines both internal and external reinsurance in the regressions in Table 3. That is, for example, if affiliates undergo financial difficulties, insurers may not only reduce internal reinsurance, but also increase external reinsurance at the same time. The combined effect for transactions within the group turns out to be positive, that is, the substitution effect is dominant, whereas the combined effect for reinsurance purchases through U.S. unaffiliated insurers appears to

[12]The return on assets, which is included based on the underinvestment hypothesis that reinsurance is used to reduce the likelihood of rejecting positive net present value projects (Cole and McCullough, 2006), is significantly positive in contrast with the prediction. As Cole and McCullough (2006) point out, it could be because of the inclusion of both return on assets and leverage. Dropping *ROA* does not change the results except for the effect of tax-exempt investment. In our results, tax effect turns out to be significantly negative. The theory of Garven and Lamm-Tennant (2003) predicts higher demand for reinsurance by insurers with greater tax favored assets, thereby a positive association between reinsurance demand and tax favored assets. However,they and Cole and McCullough (2006) do not find evidence to support the hypothesis. Powell and Sommer (2007) find a significantly positive tax effect only for internal reinsurance. Our negative effect might be the interaction between *ROA* and tax-exempt investments, as the significance of tax-exempt investments disappears in the regression that drops *ROA*.

be negative, that is, the increase in the demand for internal reinsurance does not dominate the reduction in the demand for external reinsurance when U.S. unaffiliated reinsurance partners have some financial difficulties.

Furthermore, the estimated effects of these main variables are also economically significant. [13] From the coefficients in specification (1), a one standard deviation increase in the index of market competition faced by a primary insurer, captured by the negative of *CONC_HHI*, is associated with a 2.3% of one standard deviation increase in reinsurance demand. A one standard deviation increase in market size (log-transformed), *MKTSIZE*, increases the reinsurance ratio by 6.8%. The coefficients on *GROUP_COMB* and *US_UNAFF_COMB* can be interpreted as an 8.8% and 7.8% reduction in reinsurance demand when the cost of reinsurance offered by affiliates and U.S. unaffiliated insurers, respectively, increases by one standard deviation. A one standard deviation deterioration in the overall financial status of affiliates, measured by *GROUP_LOSS_DEV,* increase the reinsurance ratio by 2.3%, whereas that of U.S. unaffiliated reinsurance partners, captured by *US_UNAFF_LOSS_DEV,* lowers it by 3.7%. Given that the economic effects of the loss-developmentand catastrophe exposure are 4.9% and 3.7%, it can be argued that the firm-specific market related variables and reinsurance supply side variables also have considerable explanatory power even compared to other control variables suggested by prior studies.

The next set of regressions in Table 4 analyzes the demand for external reinsurance for the purpose of comparison. First, market competition shows both significantly and economically greater impact on external reinsurance than it does on total reinsurance including both external and internal reinsurance, whereas the significance and the size of economic effect of market size is reduced compared to the results in Table 3. Second, comparing the coefficients of reinsurance cost variables in Table 3 and Table 4, one can see the opposite sign of the coefficient on *GROUP_COMB*. If reinsurance can be obtained through affiliates at a cheaper price, that is, higher *GROUP_COMB*, the demand for external reinsurance is found to decrease. The cost of reinsurance provided by U.S. unaffiliated insurers have greater economic effect (17.7%), which is grater than the economic effect of size, -13.5% (the largest effect among other firm-specific controls). Moreover, the cost of reinsurancethat is incurred in the contract with non-U.S. reinsurers, *NONUS_COMB,* shows significant (at the 1% level) and economic impact of 2.9% on external reinsurance. The financial status of affiliates loses explanatory power for external reinsurance, but the sign change of the coefficients in specification (2) and (3) in Table 3 and 4 may imply that insurers alternatively use external reinsurance when their affiliates have financial difficulties. Changes in the estimates of other firm-specific controls are consistent with the results of Powell and Sommer (2007) that estimate external reinsurance demand separately. Taken together, the empirical results provide strong evidence for the predictions of our theory regarding the effects of market competition and market size as well as those of reinsurance cost. Furthermore, we complement prior empirical studies that examine reinsurance demand by taking into account the variables related to primary insurance markets (product markets) and reinsurance supply side variables that reflect differences across firms.

6. Conclusion

We show in this article through a simple conjectural variations model that the external product market environment plays an important role in firms' insurance decisions. Interestingly, there exists a monotonic relation between firms' insurance coverage selections and the competitiveness of the product market environment where firms compete. A more competitive product market induces firms to transfer more of their risk exposures to the insurance companies. The interaction of the strategic effect of insurance, the cost of insurance and the competitiveness of the product market leads to this clear prediction of the influence of the product market environment on firms' risk management strategies. The monotonic relation holds true no matter whether firms exhibit risk aversion or not in their preferences. This empirical prediction would be convenient for analyzing corporate risk management in a broader framework that is not restricted to financial hedging as considered in most of the literature. Our empirical tests using the data from the

[13] The economic effect of an independent variable is measured as the estimated coefficient multiplied by the ratio of the standard deviation of the independent variable to the standard deviation of the dependent variable.

insurance industry provide strong support of the theoretical predictions.

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Appendix

Table 1 Variable Definitions

Variables
(Dependent Variables) ***REINS***: Premiums ceded/(direct premiums written and reinsurance assumed) ***EXT_REINS***: Premiums ceded to affiliates/(direct premiums written and reinsurance assumed)
(Insurance Market Related Variables) ***CONC_HHI***: $\sum_i w_i HHI_{i,}$ where $i$represents each specific market segmented by states and lines of business, $w_i$is the portion of direct premiums written of the insurer in the specific market, and $HHI_{i,}$ is the Herfindahl index of the specific market ***CONC_CR4***: $\sum_i w_i CR4_{i,}$where $CR4_i$ is the four-firm concentration ratio of market *i*. ***CONC_CR10***: $\sum_i w_i CR10_{i,}$ where $CR10_i$ is the ten-firm concentration ratio of each market *i*. ***MKTSIZE***: $\sum_i w_i MKTSIZE_{i,}$ where $MKTSIZE_i$ is the sum of direct premiums written of all insurers operating in market *i*.
(Reinsurance Supply Side Variables) ***GROUP_COMB***: $\sum_j w_j COMB_{j,}$ where *j* represents each firm assuming premiums of other affiliates within the group in which the insurer belongs to, w_j is the ratio of firm *j*'s assumed premiums from affiliates to the sum of premiums from affiliates for all the firms within the group, and $COMB_j$ is the combined ratio of firm *j* **GROUP_LOSS_DEV**: $\sum_j w_j LOSS\_DEV_{j,}$ where $LOSS\_DEV_j$ is the 2-year loss development of firm *j* belonging to the same group as the insurer ***US_UNAFF_COMB***: $\sum_k w_k COMB_{k,}$ where *k* represents each U.S. unaffiliated firm to which the insurer cedes its premiums, w_k is the ratio of the insurer's premiums ceded to firm *k* to the insurer's total premiums ceded to U.S. unaffiliated firms, and $COMB_k$ is the combined ratio of firm *k* ***US_UNAFF_LOSS_DEV***: $\sum_k w_k LOSS\_DEV_{k,}$ where $LOSS\_DEV_k$ is the 2-year loss development of firm *k*, whichis the insurer's reinsurance partner that is not affiliated to the same group as the insurer ***NONUS_COMB***: Average combined ratio of non-U.S. reinsurers that are the top 100-150 reinsurers around the world ***US_UNAFF_DUMMY***: Dummy variable equals to one if the insurer is contracting with any U.S. unaffiliated insurers ***NONUS_DUMMY***: Dummy variable equals to one if the insurer is contracting with any non-U.S. reinsurers
(Other Firm-specific Controls) ***SIZE***: Natural logarithm of admitted assets ***ROA***: Net income/admitted assets ***LEV***: Direct business written/surplus ***TAX-EXEMPT***: Tax-exempt investment income (= bond interest exempt from federal taxes plus 70% of dividends received for common and preferred stock)/total investment income ***LOSS_DEV***: The development in estimated losses and loss expense incurred 2 years before the current year and prior year scaled by surplus ***CAT_EXPOSURE***: The percentage of direct premiums written by the insurer in Gulf Coast and Atlantic Coast states (TX, LA, MS, AL, FL, GA, SC, NC, and VA) in several related property lines (fire, multiple peril crop, farmowners, homeowners, and commercial multiple peril, ocean marine, and auto physical damage) plus the percentage of premiums in earthquake insurance ***LB_HERF***: Line-of-business Herfindahl index ***G_HERF***: Geographic Herfindahl index ***G_DUMMY***: Dummy variable equal to one if the insurer is affiliated to a group ***STOCK_DUMMY***: Dummy variable equal to one if the insurer is a stock company ***LINE1-LINE26***: Fire, Allied lines, Farmowners, Homeowners, Commercial, Mortgage guaranty, Ocean marine, Inland marine, Financial guaranty, Medical malpractice, Earthquake, Group A&H, Credit A&H, Other A&H, Workers' compensation, Other liability, Products liability, Auto liability, Auto physical damage, Aircraft, Fidelity, Surety, Glass, Burglary and theft, Boiler and machinery, Credit

Table 2 Summary Statistics(Sample period: 1995-2008)

Table 2 provides summary statistics of the main variables used in the regressions. The definitions of the variables are in Table 1.

Variables	N	Mean	Std. Dev.	Minimum	Maximum
(Dependent Variables)					
REINS	26,668	0.3796	0.3000	0	1
EXT_REINS	26,668	0.1715	0.2190	0	1
(Insurance Market Related Variables)					
CONC_HHI	26,668	0.0354	0.0563	0.0004	0.9840
CONC_CR4	26,668	0.1866	0.1911	0.0034	1
CONC_CR10	26,668	0.2689	0.2576	0.0065	1
MKTSIZE	26,668	19.3093	1.8376	12.5641	23.3325
(Reinsurance Supply-Side Variables)					
GROUP_COMB	14,297	1.0577	0.7470	-50.2053	19.7756
GROUP_LOSS_DEV	14,291	-0.0029	0.1626	-0.7544	4.7025
US_UNAFF_COMB	19,121	1.1773	1.2607	-0.3181	25.6847
US_UNAFF_LOSS_DEV	18,668	-0.0264	0.1851	-0.7544	0.8356
NONUS_COMB	26,668	1.0227	0.0964	0.8902	1.2204
US_UNAFF_DUMMY	26,668	0.7170	0.4505	0	1
NONUS_DUMMY	26,668	0.5107	0.4999	0	1
(Other Firm-specific Controls)					
SIZE	26,668	17.8323	1.9522	13.6165	22.4525
ROA	26,668	0.0231	0.0536	-0.1886	0.2014
LEV	26,668	1.8186	1.9606	0	10.2238
TAX-EXEMPT	26,496	0.2457	0.2620	0	0.9971
LOSS_DEV	25,651	-0.0234	0.1843	-0.7544	0.8356
CAT_EXPOSURE	26,668	0.0996	0.2244	0	1
LB_HERF	26,668	0.5774	0.2981	0.0964	1
G_HERF	26,668	0.6066	0.3848	0.0304	1
G_DUMMY	26,668	0.6336	0.4818	0	1
STOCK_DUMMY	26,668	0.6557	0.4751	0	1

Table 3 Regression Results (Dependent variable: total reinsurance ratio)

	REINS (1)		REINS (2)		REINS (3)	
Variables	**Coeff.**	**Std. Err.**	**Coeff.**	**Std. Err.**	**Coeff.**	**Std. Err.**
(Insurance Market Related Variables)						
CONC_HHI	-0.125*	0.072				
CONC_CR4			-0.058*	0.031		
CONC_CR10					-0.047*	0.025
MKTSIZE	0.011**	0.005	0.011**	0.005	0.012**	0.005
(Reinsurance Supply-Side Variables)						
GROUP_COMB	0.035**	0.016	0.035**	0.016	0.035**	0.016
GROUP_LOSS_DEV	0.042*	0.024	0.043*	0.024	0.042*	0.024
US_UNAFF_COMB	0.019***	0.003	0.019***	0.003	0.019***	0.003
US_UNAFF_LOSS_DEV	-0.060**	0.026	-0.060**	0.026	-0.059**	0.026
NONUS_COMB	-0.006	0.007	-0.006	0.007	-0.006	0.007
(Other Firm-specific Controls)						
SIZE	-0.036***	0.003	-0.036***	0.003	-0.036***	0.003
ROA	0.145***	0.050	0.145***	0.050	0.146***	0.050
LEV	0.057***	0.002	0.057***	0.002	0.057***	0.002
TAX-EXEMPT	-0.024*	0.014	-0.024*	0.014	-0.024*	0.014
LOSS_DEV	0.079***	0.025	0.079***	0.025	0.079***	0.025
CAT_EXPOSURE	0.049**	0.021	0.050**	0.021	0.049**	0.021
LB_HERF	-0.112***	0.017	-0.113***	0.017	-0.113***	0.017
G_HERF	-0.144***	0.020	-0.133***	0.021	-0.131***	0.021
G_DUMMY	0.118***	0.015	0.118***	0.015	0.118***	0.015
STOCK_DUMMY	0.028***	0.010	0.028***	0.010	0.028***	0.010
YEAR DUMMIES	YES		YES		YES	
LINE 1-LINE 26	YES		YES		YES	
CONSTANT	0.758***	0.178	0.760***	0.179	0.761***	0.180
NUM of OBS.	25,519		25,519		25,519	
R^2	0.2951		0.2952		0.2952	

note: ***p<0.01, **p<0.05, *p<0.1

Table 4 Regression Results (Dependent Variable: external reinsurance ratio)

Variables	EXT_REINS (1) Coeff.	Std. Err.	EXT_REINS (2) Coeff.	Std. Err.	EXT_REINS (3) Coeff.	Std. Err.
(Insurance Market Related Variables)						
CONC_HHI	-0.206***	0.055				
CONC_CR4			-0.053**	0.024		
CONC_CR10					-0.046**	0.019
MKTSIZE	0.006*	0.003	0.007*	0.004	0.007*	0.004
(Reinsurance Supply-Side Variables)						
GROUP_COMB	-0.014**	0.006	-0.014**	0.006	-0.014**	0.006
GROUP_LOSS_DEV	-0.00003	0.016	0.00014	0.016	0.00014	0.016
US_UNAFF_COMB	0.031***	0.003	0.031***	0.003	0.031***	0.003
US_UNAFF_LOSS_DEV	-0.036**	0.018	-0.036**	0.018	-0.036*	0.018
NONUS_COMB	0.067***	0.005	0.067***	0.005	0.067***	0.005
(Other Firm-specific Controls)						
SIZE	-0.015***	0.002	-0.016***	0.002	-0.016***	0.002
ROA	-0.007	0.044	-0.007	0.045	-0.006	0.044
LEV	0.015***	0.002	0.015***	0.002	0.015***	0.002
TAX-EXEMPT	-0.017*	0.010	-0.017*	0.010	-0.016*	0.010
LOSS_DEV	0.058***	0.016	0.058***	0.016	0.058***	0.016
CAT_EXPOSURE	0.114***	0.018	0.113***	0.018	0.113***	0.018
LB_HERF	0.004	0.014	0.003	0.014	0.003	0.014
G_HERF	-0.013	0.015	-0.010	0.016	-0.006	0.016
G_DUMMY	-0.084***	0.009	-0.084***	0.009	-0.084***	0.009
STOCK_DUMMY	-0.009	0.008	-0.008	0.008	-0.008	0.008
YEAR DUMMIES	YES		YES		YES	
LINE 1-LINE 26	YES		YES		YES	
CONSTANT	0.328*	0.170	0.329*	0.171	0.331*	0.172
NUM of OBS.	25,519		25,519		25,519	
R^2	0.2193		0.2185		0.2186	

note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Proof of Lemma 1

Proof: Given the assumptions and the support of parameter values, it is straightforward to verify that A, B, C and D are all positive. Also it is straightforward to verify that

$$BC - b^2 = [(2+v)^2 - 1]b^2 + \gamma k^2\sigma^2 \begin{bmatrix} (2+v)b\left[(1-\alpha_i)^2 + (1-\alpha_j)^2\right] \\ +\gamma k^2\sigma^2(1-\alpha_i)^2(1-\alpha_j)^2 \end{bmatrix} > 0.$$

$$AC - bD = \gamma k^2\sigma^2(1-\alpha_j)^2[a-(1-\alpha_i)k\mu] + b\begin{bmatrix}(1+v)[a-(1-\alpha_i)k\mu] \\ +(\alpha_i - \alpha_j)k\mu\end{bmatrix};$$

$$BD - bA = \gamma k^2\sigma^2(1-\alpha_i)^2[a-(1-\alpha_j)k\mu] + b\begin{bmatrix}(1+v)[a-(1-\alpha_j)k\mu] \\ +(\alpha_j - \alpha_i)k\mu\end{bmatrix};$$

$$\partial q_i^*/\partial\alpha_i = \begin{cases} \frac{(BC-b^2)k\mu C + 2(AC-bD)\gamma k^2\sigma^2(1-\alpha_i)C}{(BC-b^2)^2} > 0 \text{ when } AC - bD > 0 \\ 0 \text{ when } AC - bD \leq 0 \end{cases}$$

When $AC - bD \leq 0, \partial q_i^*/\partial\alpha_j = 0$; otherwise

$$\partial q_i^*/\partial\alpha_j = \frac{-(BC-b^2)[2\gamma k^2\sigma^2(1-\alpha_j)A + bk\mu] + 2(AC-bD)\gamma k^2\sigma^2(1-\alpha_j)B}{(BC-b^2)^2}$$

$$= -\frac{2b\gamma k^2\sigma^2(1-\alpha_j)(BD-bA) + bk\mu(BC-b^2)}{(BC-b^2)^2}$$

$$= -\frac{1}{(BC-b^2)}[2b\gamma k^2\sigma^2(1-\alpha_j)q_j^* + bk\mu] < 0.$$

$$\partial q_i^*/\partial\gamma = \frac{k^2\sigma^2}{(BC-b^2)^2}\begin{Bmatrix} (BC-b^2)A(1-\alpha_j)^2 \\ -(AC-bD)\begin{bmatrix} B(1-\alpha_j)^2 \\ +C(1-\alpha_i)^2 \end{bmatrix} \end{Bmatrix}$$

$$= \frac{k^2\sigma^2}{BC-b^2}\left\{b(1-\alpha_j)^2 q_j^* - C(1-\alpha_i)^2 q_i^*\right\}.$$

$$\partial q_i^*/\partial v = \frac{b}{BC-b^2}[A - (B+C)q_i^*] = \frac{b}{BC-b^2}(bq_j^* - Cq_i^*).$$

In the symmetric case, $\alpha_i = \alpha_j = \alpha$; $A = D = a - (1-\alpha)k\mu \equiv \tilde{A}$; and $B = C = (2+v)b + \gamma(1-\alpha)^2k^2\sigma^2 \equiv \tilde{B}$.We have $q_i^* = q_j^* = q^* = \frac{\tilde{A}}{\tilde{B}+b}$; $Q^* = 2q^*$; $\partial Q^*/\partial\alpha = \frac{2k\mu(\tilde{B}+b)+4\gamma k^2\sigma^2(1-\alpha)\tilde{A}}{(\tilde{B}+b)^2} > 0$; $\partial Q^*/\partial\gamma = \frac{-2k^2\sigma^2(1-\alpha)^2\tilde{A}}{(\tilde{B}+b)^2} \leq 0$; $\partial Q^*/\partial k = -\frac{2(1-\alpha)(\tilde{B}+b)\mu + 4\gamma(1-\alpha)^2k\sigma^2\tilde{A}}{(\tilde{B}+b)^2} \leq 0$; and $\partial Q^*/\partial v = -\frac{2b\tilde{A}}{(\tilde{B}+b)^2} < 0$.

Moreover, $\frac{\partial(\partial Q^*/\partial\alpha)}{\partial v} = \frac{2bk\mu(\tilde{B}+b)^2 - 2b(\tilde{B}+b)[2k\mu(\tilde{B}+b)+4\gamma k^2\sigma^2(1-\alpha)\tilde{A}]}{(\tilde{B}+b)^4} < 0$.□

Proof of Lemma 2

Proof: (a) Using equations (24), it is straightforward to verify that $\partial q_i^*/\partial\alpha_i \geq 0$; and $\partial q_i^*/\partial\alpha_j \leq 0$. In particular, $\alpha_i > (2+v)\alpha_j + (1+v)\frac{a-k\mu}{k\mu} \Rightarrow (2+v)[a - (1-\alpha_j)k\mu] < a - (1-\alpha_i)k\mu \Rightarrow q_j^* = 0$ by the equations (24). Moreover, since $v \in (-1,1)$, considering assumption A1, we have $a - (1-\alpha_j)k\mu < (2+v)[a - (1-\alpha_j)k\mu]$, and $a - (1-\alpha_i)k\mu < (2+v)[a-(1-\alpha_i)k\mu]$. Therefore, $\alpha_i > (2+v)\alpha_j + (1+v)\frac{a-k\mu}{k\mu} \Rightarrow a - (1-\alpha_j)k\mu < (2+v)[a - (1-\alpha_j)k\mu] < a - (1-\alpha_i)k\mu < (2+v)[a-(1-\alpha_i)k\mu] \Rightarrow q_i^* > 0$ by the equations (24).

(b) By equations (24), $\partial q_i^*/\partial\alpha_i = \frac{(2+v)k\mu}{b(3+v)(1+v)}$; $\partial q_i^*/\partial\alpha_j = -\frac{k\mu}{b(3+v)(1+v)}$. Therefore, $\frac{\partial(\partial q_i^*/\partial\alpha_i)}{\partial v} = \frac{(3+v)(1+v)-2(2+v)^2}{b(3+v)^2(1+v)^2}k\mu < 0$; and $\frac{\partial(\partial q_i^*/\partial\alpha_j)}{\partial v} = \frac{2(2+v)}{b(3+v)^2(1+v)^2}k\mu > 0$.

(c) By equation (24), $\partial q_i^*/\partial v = \frac{2(2+v)[a-(1-\alpha_j)k\mu]-[(2+v)^2+1][a-(1-\alpha_i)k\mu]}{b(3+v)^2(1+v)^2}$. Therefore, $\partial q_i^*/\partial v < 0 \Leftrightarrow$

$\frac{a-(1-\alpha_i)k\mu}{a-(1-\alpha_j)k\mu} > \frac{2(2+v)}{(2+v)^2+1}$.In particular, denote $h(v) \equiv \frac{2(2+v)}{(2+v)^2+1}$.It is straightforward to check that $h'(v) < 0, \forall v \in (-1,1)$. Therefore, $h(v) < h(-1) = 1, \forall v \in (-1,1)$. When $\alpha_i > \alpha_j$, we have $\frac{a-(1-\alpha_i)k\mu}{a-(1-\alpha_j)k\mu} > 1 > h(v), \forall v \in (-1,1)$.

(d)Under the symmetric equilibrium characterized by equations (25), we have $\partial Q/\partial \alpha = \frac{2k\mu}{b(3+v)} > 0; \partial Q/\partial k = -\frac{2(1-\alpha)\mu}{b(3+v)} \leq 0$; and $\partial Q/\partial v = -\frac{2[a-(1-\alpha)k\mu]}{b(3+v)^2} < 0$.□

Proof of Proposition 3

Proof: (a) When $\lambda < g(v)$ for a given v, or equivalently, when $v < \overline{v}(\lambda)$ given $\lambda > 0$, we have $\frac{1-\lambda(3+v)(1+v)}{v^2+5v+5+\lambda(3+v)(3+2v)} \frac{a-k\mu}{k\mu} > 0$, which implies that $\alpha^* > 0$ by equation (28).

(b) By equation (29), $g'(v) < 0$. This implies that a lower v (a more competitive product market) leads to a higher $g(v)$. Thus, more likely that $\lambda < g(v)$ will be satisfied, which implies that more likely firms will purchase insurance, according to Proposition 3(a). Moreover, $\alpha^{*\prime}(v) < 0$, by equation (28).

(c)Given $\alpha^* > 0$, we have $\alpha^{*\prime}(a) > 0$, and $\alpha^{*\prime}(k) < 0$, by equation (28). □