Product market competition and corporate demand for insurance[*]

Hae Won (Henny) Jung[†]
University of Melbourne
Zhiyong (John) Liu[‡]
Indiana State University
Nan Zhu[§]
Penn State University

Abstract

We analyze the corporate demand for insurance under duopoly by allowing for different degrees of product market competition. The more competitive a product market, the more likely that firms operating in the market will acquire insurance and the higher the insurance coverage that firms will choose. This holds true regardless of whether firms are risk neutral or risk averse. Firms covered by insurance commit themselves to taking a more aggressive output stance against their competitors. The strategic gain from insurance coverage is stronger when firms perceive less sensitive price movement in response to their output increase (i.e. a more competitive product market), thereby leading to a positive relation between insurance usage and the intensity of product market competition. We provide robust support for the model in an empirical analysis of reinsurance purchases by United States property and liability primary insurers.

Keywords: corporate demand for insurance; risk management; product market competition; strategic commitment; reinsurance demand
JEL classification: G22, L13, L22

---

[*]We thank Neal Galpin, Marty Grace, Bob Hoyt, Wei Huang, Dalida Kadyrzhanova, Gene Lai, Steve Lamb, Ping Lin, Xinli Liu, Lyndon Moore, Rich Phillips, Chengzhong Qin, Harris Schlesinger, Ajay Subramanian, John Tatom, Terrie Troxel, Jennifer Wang, Bill Warfel, Yi Yao, Wei Zheng, and participants at a workshop at Peking University, the Annual Meetings of the American Risk and Insurance Association, Southern Risk and Insurance Association, Asian Law and Economics Association, the Sixth Annual Conference on Industrial Economics and Economic Theory at Shandong University, and China International Conference on Insurance and Risk Management. The usual disclaimer applies.
[†]Department of Finance, University of Melbourne, Melbourne, VIC 3010, Australia.
Email: hae.jung@unimelb.edu.au
[‡]Scott College of Business & Networks Financial Institute, Indiana State University, Terre Haute, IN 47809, USA. Email: John.Liu@indstate.edu
[§]Risk Management Department, Smeal College of Business, Penn State University, University Park, PA 16802, USA. Email: nanzhu@psu.edu

1. Introduction

Business insurance accounted for approximately 48 percent of $520 billion in net property and casualty insurance premiums written in the United States (US) in 2015.[1] Another survey conducted for the same year shows that large US businesses, on average, paid $10.55 per $1,000 of revenue (around one percent) to cover the total costs of insurable risk (including insurance premiums, the costs of retained losses, and overall risk management administrative costs).[2] A significant portion of the expenditure was attributed to property, liability, and workers' compensation insurance premiums. Insurance related spending is comparable to the mean (median) dividend payment of large US companies, which is around five (two) percent of revenues.[3]

Why do firms purchase insurance? There are a variety of potentially insurable risks such as product liability suits, toxic torts, and physical damage to corporate assets for industrial corporations (Doherty and Smith, 1993). While the primary motive for individuals' insurance purchases is risk aversion, this might not be the main reason for the demand for insurance by publicly held corporations, as their owners can eliminate idiosyncratic losses through holding well-diversified portfolios (MacMinn and Garven, 2000). Theoretical studies find alternate explanations for corporate insurance demand which are interpreted as ex-ante costs that companies must bear because of their risk exposures. These explanations include tax advantage (Smith and Stulz, 1985), a reduction in financial distress or underinvestment costs (Mayers and Smith, 1990), managerial risk aversion (Tufano, 1996), real service provision by insurance companies (Mayers and Smith, 1982), and mandatory requirements by creditors (Cheyne and Nini, 2010).

To a lesser extent, the literature has also explored the strategic demand for insurance, that is, firms might purchase insurance contracts to take a more aggressive output stance against their competitors (Ashby and Diacon, 1998; Seog, 2006). Intuition suggests that such strategic motives should vary with their business environment. For example, let us consider workers'

[1] This proportion of business (rather than individual) insurance comes from *The Insurance Facts: 2016 Property/Casualty Fact Book*, Insurance Information Institute.
[2] This statistic comes from the 2016 *Risk & Insurance Management Society (RIMS) Benchmark Survey* based on the responses from more than 1,500 United States (US) corporations, including more than half of the Fortune 500 companies.
[3] We obtain the mean and median dividend payments relative to corporate revenues from Fortune 500 firms available in the Compustat database.

compensation insurance. Inasmuch as a company is responsible for potential employee injuries, the firm can implicitly reduce the expected marginal cost of labor by purchasing insurance, thereby expanding its ability to compete more aggressively in the product market. Taking a more aggressive output strategy with insurance contracts, however, would not be that profitable if the firm anticipates a greater downward movement in the market price with its output increase based on the underlying competitive structure of the product market environment.

We develop a simple model that builds on this intuition to explore how firms' insurance purchases, or more broadly, risk management decisions, vary with the intensity of product market competition faced by those firms. In a two-stage duopoly game, two firms first simultaneously determine their insurance coverage and then simultaneously determine their product market strategy, conditional on their first-stage insurance choices. To accommodate a wide range of market structures from perfect competition to complete collusion, we incorporate into this two-stage game a conjectural variations framework, a useful tool employed in the industrial organization literature (see Tirole, 1988; Cabral, 1995). To derive the Nash equilibrium of the *simultaneous move* output game in a duopoly market, we need to consider a firm's best response to the other firm's possibly off-equilibrium actions. The conjectural variations framework parsimoniously captures varying degrees of product market competition via a parameter that indicates a firm's conjecture of the other firm's output response to a one-unit change in its own output level. A lower conjectural variation thus implies that a smaller change in the market price is expected by the firm when it changes its output level, thereby indicating lower market power as perceived by the firm and thus a more competitive product market environment.

Consider the insurance purchase decision of a firm. For a given *anticipated* level of insurance coverage by the rival firm, the optimal insurance demand (or best response) of the firm is determined by the trade-off between the strategic effect of insurance and the cost of insurance. The strategic effect reflects the firm's operating benefits from the strategic commitment aspect of insurance choice in relation to output markets. By increasing its insurance purchase, the firm can implicitly decrease its expected marginal cost of production because a higher portion of potential insurable losses is transferred to the insurance company. The decline in the expected marginal cost enables the firm to be more aggressive in its quantity strategy for any given output level chosen by its rival. Because, in a simultaneous quantity competition setting, firms' output choices are strategic substitutes, this implies a lowered output level of the rival firm in equilibrium.[4] The decrease in the rival firm's output level, benefiting the firm, represents the strategic effect of insurance choice.

The magnitude of this strategic effect depends on the extent to which the firm will be aggressive in its output market strategy with a unit increase in its insurance coverage. The increase in the firm's output increases the total output in the market, thereby leading to a decline in the market price depending on the degree of product market competition. In a more competitive product market, an increase in the firm's output level would be expected to have a smaller negative effect on the product price. Consequently, the strategic effect of insurance should be larger in a more competitive product market environment when the firm can increase its output level without much negative effect on the market price. The above arguments imply that, in a more competitive product market, a firm's strategic demand for insurance is higher. Incorporating the firm's risk aversion (or costs of risk) reinforces the prediction as it strengthens the association between the size of insurable loss (i.e. production scale) and the demand for insurance. By focusing on primary insurers' reinsurance purchases, we provide empirical evidence for the positive relation between the intensity of product market competition and corporate demand for insurance.

Our study is closely related to those of Ashby and Diacon (1998) and Seog (2006). These two studies suggest that firms may have strategic reasons for insurance purchases as these decisions can influence strategic interactions with other firms in the same product market. The first study insightfully sketches the basic intuition of strategic motives using a two-by-two non-cooperative risk strategy game. The second formalizes the idea with a two-stage duopoly game of insurance and output market strategies, but only focuses on a specific form of product market structure: Cournot competition. We complement these studies by showing that firms' strategic demand for insurance can be stronger when they face more intense product market competition and providing empirical support for the implications of the model. In the spirit of Mayers and Smith (1990), we empirically test the model's implications by analyzing reinsurance purchases by US property and liability primary insurers.[5] Along with results consistent with the empirical

[4]As defined in Bulow, Geanakoplos, and Klemperer (1985), a firm's decisions are strategic substitutes when its marginal profits are decreasing in the rival's actions.
[5]Because of the difficulty of obtaining data on insurance purchases by non-financial firms, Mayers and Smith (1990) also use this empirical strategy when they test theories of corporate demand for insurance empirically. The authors

literature on reinsurance demand, we find robust evidence that a primary insurer's reinsurance purchase is positively associated with the intensity of market competition in primary insurance markets, supporting the main prediction of our model. Importantly, the positive coefficient estimates for the proxies of market competition are also economically meaningful: a one standard deviation increase in the degree of competition, on average, corresponds to an approximate two percent increase in reinsurance usage.

The seminal work of Brander and Lewis (1986), upon which our study builds, suggests strategic effects of leverage as a potential channel through which firms' financial and output decisions interact with each other. A firm's choice of higher debt prior to engaging in market competition serves to commit the firm to undertake a more aggressive product market strategy. The key insight for this strategic advantage of debt is the limited liability of debt financing that results in an asymmetric payoff structure to shareholders between solvent and bankrupt states. As shareholders can ignore potential losses in bankruptcy states, it is optimal for leveraged firms to pursue a more aggressive product market strategy that is likely to result in higher (lower) payoffs in good (bad) states.

In our model, a firm faces a potential insurable loss that is proportional to the production scale (e.g. risks of employee injury, product liability, or business interruption). Taking a more aggressive output market strategy can increase the firm's operating profit but also leads to greater risk exposure. By purchasing insurance, however, the firm can transfer potential insurable losses onto the insurer, thus enhancing its ability to compete more aggressively in the product market. In other words, the limited liability effect leads to more aggressive behavior of leveraged firms by shifting negative outcomes onto the shoulders of creditors, whereas insurance contracts enable the insured firms to compete more aggressively by shifting potential adverse outcomes to insurers.

In a broad sense, insurance is a corporate risk management strategy.[6] Our perspective on the strategic dimensions involved in insurance purchases is thus in line with studies that explore

---

argue that reinsurance purchases are like traditional insurance purchases by industrial corporations. Further, the US property and liability insurance industry provides a reasonable laboratory to test how firms' insurance demand varies with the operating characteristics of their business as this industry is distinguished by different lines of businesses and geographic areas (states), which differ in terms of the degree of market competition, market size, and underwriting risk (Cummins and Weiss, 1992; Suponcic and Tennyson, 1998; Choi and Weiss, 2005).

[6]According to a global survey of over 300 chief financial officers (CFOs) of non-financial companies by Servaes, Tamayo, and Tufano (2009), most companies use insurance policies (83 percent), derivatives such as foreign

the interaction between firms' risk management strategies and their product market decisions in an industry equilibrium framework. For example, Mello and Ruckes (2006) and Adam, Dasgupta, and Titman (2007) examine firms' hedging decisions. In contrast to insurance eliminating only adverse outcomes, hedging cash flows (even at fair terms) has the disadvantage that it may lead to the loss of upside cash flow outcomes. The authors address that, in such upside outcomes, firms can gain a strategic edge over their rivals in product market competition by achieving cost advantage with higher cash flows. By considering the potential strategic gain followed by the decision not to hedge, these studies suggest the possibility that firms may refrain from hedging when faced with more intense competition. In contrast, by focusing on the strategic gain from insurance decisions, we predict higher insurance usage in a more competitive product market environment.

Léautier and Rochet (2014) emphasize firms' use of hedging as a strategic commitment device when hedging takes place before firms decide their product market strategies. The authors show that hedging toughens (softens) quantity (price) competition. In contrast with their study, which focuses on two modes of competition (quantity and price competition), we consider a wide range of competition intensity and generate the empirically testable prediction that there is a positive relation between the use of insurance policies and the degree of product market competition.

Finally, we analyze and discuss several extensions of our main model. First, in reality, firms have some discretion in the disclosure of risk management activities and may not be able to credibly communicate such activities to competing firms. We thus develop a signaling framework in which insurance contracts are publicly unobservable but firms can signal their insurance choices by incurring some signaling costs. We show that, under reasonable conditions, firms choose to purchase insurance and signal their insurance choice to achieve strategic gain from lowering the rival firm's output level in the output market equilibrium, and, importantly, that firms will choose higher insurance coverage when they operate in a more competitive product market environment. Second, we examine the robustness of the prediction drawn from the static game in our main model by analyzing an infinitely repeated game that allows for a collusive equilibrium in which firms coordinate with no insurance purchase to soften their

exchange (FX) rate derivatives (82 percent) and interest rate derivatives (79 percent), FX denominated debt (45 percent), and operating alternatives (44 percent) to manage their risk exposures.

competition in the product market. We show that firms' incentives to unilaterally deviate from the collusive scheme and purchase insurance are positively associated with the competition intensity in the product market, which reinforces the conclusion drawn from the main model. Third, we discuss how the equilibrium results differ when the insurance premium loading factor charged by insurers also depends on the nature of the product market environment in which the insured firms will operate.

The rest of the paper is organized as follows. In Section 2, we describe the setup of our model. In Section 3, we characterize the equilibrium of the model when firms are risk neutral. We repeat the analysis by assuming that firms are risk averse in Section 4. We discuss several extensions of our main model in Section 5. Section 6 provides supporting empirical evidence for the main prediction of our model, and finally, Section 7 concludes the paper.

2. The model

There are two (ex-ante) identical firms competing in the product market, indexed by i or $j = 1, 2$. Each firm faces a random loss because of business risk, which is insurable and will be realized after its product market decision. The insurance market is assumed to be perfectly competitive, i.e., insurance companies make zero economic profits. The insurance premium charged by insurers (the costs of insurance contracts) may exceed the expected loss coverage by a premium loading factor, $\lambda \geq 0$, which covers the administrative costs of insurers and compensates them for taking over risk. In our main model, we assume that the loading factor is constant and independent of the level of the expected loss or the insurance coverage chosen by firms. In Section 5, we discuss the possibility that the premium loading factor may depend on the nature of the product market environment in which firms operate. This could be, for example, because insurance companies are likely to price insurance contracts by anticipating firms' product market behavior after being insured.

We consider a two-stage game. Firms first simultaneously choose insurance coverage and then simultaneously determine output levels, conditional on their first-stage insurance choices. Firms may choose to purchase insurance to reduce their risk exposure in the output market, which, in a general sense, can be interpreted as a risk management strategy. The essential feature is that firms invest in risk management before weighing the competition in the product market.

For instance, before launching a new product, firms in the final round may commit resources to pre-market research to more thoroughly evaluate potential risks associated with the product and make further product improvements if the research finds this to be necessary. These additional investments are intended to reduce potential post-sale operational risks. A natural question then arises: how many resources should they commit to such research? There is a trade-off between the cost of research and the expected benefits of research that enables firms to reduce potential risk exposures in the product market. We show how this trade-off determines the level of investment in risk management, and, more importantly, how that decision can be dependent upon the product market environment in which firms will compete.

We denote the firms' output levels as q_i and q_j, and, for simplicity, normalize their marginal production costs to zero. The (inverse) market demand is given by $p(q_i, q_j) = a - bQ = a - b(q_i + q_j)$, where $a, b \in \mathbb{R}_{++}$ are constants, and Q is the aggregate output level in the market. The firm's operating profit is $\pi_i(q_i, q_j) = p(q_i, q_j)q_i$. We use a conjectural variations framework that captures varying degrees of product market competition from perfect competition to complete collusion.[7] Specifically, firm i acts as if it believes that firm j will respond to its choice of output, q_i, such that $\partial q_j / \partial q_i = v$, which varies between –1 and 1.[8] Firm i's conjecture regarding the variation in the rival firm's output choice with a one-unit change in its own output, v, is referred to as the *conjectural variations* (CV) parameter. In other words, firm i acts as if it faces a demand curve with slope, $\frac{dp}{dq_i} = \frac{\partial p}{\partial q_i} + \frac{\partial p}{\partial q_j} \times \frac{\partial q_j}{\partial q_i} = p'(Q) \times (1 + v) = -b(1+v)$.

Different values of v capture a broad range of market environments. Cournot competition, for example, corresponds to zero CV ($v = 0$). When v approaches -1, each firm expects that its output expansion will be almost exactly absorbed by the corresponding output contraction by the other firm, leaving the aggregate output level and, thus, the market price, unchanged. In this case, each firm is essentially a price taker in a perfectly competitive market with its price being equal to the marginal production cost of zero. When v approaches 1, the market is collusive and firms behave like a single entity to maximize their joint profits. In other words, a lower v implies a

[7] See, for example, Bresnahan (1981), Perry (1982), Tirole (1988), and Cabral (1995).

[8] More generally, we can consider an n-firm conjectural variations setting in which v is assumed to vary between –1 and $n - 1$ (Cabral, 1995). In this general setting, our main implication remains unchanged.

more competitive product market environment faced by operating firms. With this CV approach, instead of assuming a specific form of market competition, we can examine the implications of product market competition for corporate demand for insurance.

Each firm faces a potential loss that is random and dependent upon its output level. Specifically, we assume that firm i's random loss is $L_i(q_i) \equiv k\theta q_i$, where $k > 0$ represents the constant sensitivity of the loss to the production scale and θ is a random variable that is normally distributed: $\theta \sim N(\mu, \sigma^2)$ with $\mu \in \mathbb{R}_{++}, \sigma \in \mathbb{R}_{++}$.[9] Intuitively, one can think of potential losses caused by a product recall because of the discovery of a product defect[10] or losses that occur because of environmental damage caused by the use of a particular product and consequent litigations.[11] These losses typically are proportional to the scale of production. In other words, the risk exposures in our model can refer to risks of employee injury, commercial liability, product liability, or business interruption,[12] which are closely related to the scale of business operations.

By anticipating its potential loss at the end of the second stage, firm i chooses a level of insurance coverage, $\alpha_i \in [0, 1]$, at the first stage before engaging in product market competition. We examine firms' optimal insurance choices in the case of risk-neutral firms in Section 3, and then, in Section 4, we assume that firms have constant absolute risk aversion (CARA) preferences with a common risk aversion parameter, $\gamma \geq 0$. The treatment of risk-neutral firms is based on the view that the owners of public firms can generally diversify unsystematic risk, such as the firm-specific operational risk in our model. In the case of risk-averse firms, we can interpret firm risk aversion as the ex-ante costs of risk borne by shareholders that may arise

[9]The linearity of the insurable loss in the production scale is not restrictive in that our main implication from the model remains unchanged even with a more general (e.g. convex) loss function of output.
[10]Some recent examples of a (costly) product recall are as follows: (i) In 2004, after a study revealed that the drug "more than doubled the risk of heart attacks and death," Merck withdrew Vioxx (the then-popular drug with around 80 million patient consumers) from the market just a few years following Federal Drug Administration (FDA) approval (see http://www.drugwatch.com/vioxx/); (ii) In 2008, Bridgestone Firestone initiated a voluntary field action in the US and Canada to replace approximately 135,000 Firestone tires and approximately 27,000 LeMans Champion tires (see https://www.firestonetire.ca/content/dam/bst/about/recalls/FR380_LeMans_en.pdf); (iii) In 2012, Toyota recalled over seven million vehicles because of faulty window switches, which constituted the "world's biggest car recall in 16 years" (see http://www.nbcnews.com/business/toyota-hold-worlds-biggest-car-recall-16-years-1C6374378).
[11]A most notable example is the "Deepwater Horizon disaster" in the Gulf of Mexico. BP has paid out billions of dollars to cover stopping the leak, cleaning up the oil, criminal and civil penalties, damages, and compensation.
[12]For example, see http://www.aiadc.org/AIAdotNET/docHandler.aspx?DocID=287081. *USA Today* documented that business interruption insurance claims loom following Hurricane Sandy in 2012 (see http://www.usatoday.com/story/money/business/2012/10/31/sandy-business-interruption-insurance/1672161/).

through the risk aversion of non-diversified corporate top executives or large shareholders, nonlinear tax systems, and/or costly financial distress. The risk aversion case is more general as it contains risk neutrality as a special case with $\gamma = 0$.

We solve for the two-stage game by backward induction. Given the insurance coverage α_i chosen in the first stage, firm i chooses its output quantity simultaneously with firm j in the second stage to maximize its expected utility over the gross profit net of loss not covered by insurance, which will be realized at the end of the second stage: $\pi_i(q_i, q_j) - (1-\alpha_i)L(q_i)$. Because of the CARA preferences and normality of the insurable loss, we can characterize firm i's objective function for an optimal output level in the second stage by its certainty equivalent (or mean-variance characterization):

$$V_i\left(q_i, q_j, \alpha_i\right) = \mathbb{E}_\theta\left[\pi_i(q_i, q_j) - (1-\alpha_i)L(q_i)\right] - \frac{1}{2}\gamma Var_\theta\left[\pi_i(q_i, q_j) - (1-\alpha_i)L(q_i)\right]$$
$$= \pi_i(q_i, q_j) - (1-\alpha_i)k\mu q_i - \frac{1}{2}\gamma(1-\alpha_i)^2 k^2\sigma^2 {q_i}^2, \quad (1)$$

where the last term represents the firm's costs of risk. We denote firm i's optimal output choice that maximizes the above objective function as q_i^*.

In the first stage, firms simultaneously decide their optimal insurance coverage. Firm i maximizes its expected utility incorporating the cost of insurance. In the CARA-normality framework, that is equivalent to maximizing its certainty equivalent net of the cost of insurance:

$$W_i(\alpha_i, \alpha_j) = V_i\left(q_i^*, q_j^*, \alpha_i\right) - (1+\lambda)\alpha_i k\mu q_i^*. \quad (2)$$

The insurance premium payment exceeds the expected loss coverage by a proportional premium loading factor λ to cover the insurer's administrative and risk costs.

3. Product market competition and corporate demand for insurance: The case of risk-neutral firms

In this section, we consider the case of risk-neutral firms first so that we can disentangle strategic dimensions related to output market competition from the effects of firm risk aversion (or costs of risk) on their insurance choices.

3.1. Second stage: Output choices

As outlined above, we begin with the simultaneous output choices by two firms in the second stage. By (1), where $\gamma = 0$, firm i's optimal output choice, given its insurance coverage α_i, maximizes its expected payoff as follows:

$$Max_{q_i} V_i\left(q_i, q_j, \alpha_i\right) = \pi_i(q_i, q_j) - (1-\alpha_i)k\mu q_i = p(q_i, q_j)q_i - (1-\alpha_i)k\mu q_i. \tag{3}$$

The first-order condition (FOC) for the expected payoff maximization is:

$$\partial V_i/\partial q_i = p + \frac{dp}{dq_i}q_i - (1-\alpha_i)k\mu = p - (1+v)bq_i - (1-\alpha_i)k\mu$$

$$= a - (2+v)bq_i - bq_j - (1-\alpha_i)k\mu = 0, \tag{4}$$

where v is the CV parameter that represents firm i's conjecture of firm j's response to its own output change. Similarly, the FOC for firm j's output choice is given by:

$$\partial V_j/\partial q_j = a - (2+v)bq_j - bq_i - \left(1-\alpha_j\right)k\mu = 0, \tag{5}$$

where we implicitly assume that firms, which are ex-ante identical, hold symmetric CV as is standard in CV models: $\partial q_j/\partial q_i = \partial q_i/\partial q_j = v$. The necessary conditions for optimal output market choices, (4) and (5), are linear so that the equilibrium, if it exists, is unique.

We make the following assumptions throughout the paper:

Assumption 1: $v \in (-1,1]$.

Assumption 2: $a > (1+\lambda)k\mu\left(\frac{3+v}{1+v}\right)$.

Assumption 1 represents the standard support for the CV parameter in a two-firm setting, in which we exclude $v = -1$ as this case is immediately ruled out according to Assumption 2. Assumption 2 ensures that the market size (represented by parameter a in the market demand function) and thus the market price, is sufficiently large compared with the size of the expected loss and the insurance premium loading factor. In other words, this condition guarantees positive expected profits to the firms in equilibrium.[13]

[13]For example, if v is close to -1, firms almost hold the Bertrand competitive conjecture. In this case, if firms produce in a non-cooperative way in the CV model, the market price is close to zero, so that their expected gross profits in the second stage are close to zero. When considering the expected loss related to their operation, positive production implies a negative expected payoff to firms. By anticipating the consequence, it is optimal for firms to choose no insurance in the first stage and no production in the second stage unless the market size is sufficiently large. We rule out such a case ($v \approx -1$) as it is not particularly relevant for our main discussion.

By (4) and (5), we obtain the following unique equilibrium solutions for optimal output levels:

$$q_i^*(\alpha_i, \alpha_j) = \max\left(\frac{(2+v)[a-(1-\alpha_i)k\mu]-[a-(1-\alpha_j)k\mu]}{b(1+v)(3+v)}, 0\right), \tag{6}$$

$$q_j^*(\alpha_i, \alpha_j) = \max\left(\frac{(2+v)[a-(1-\alpha_j)k\mu]-[a-(1-\alpha_i)k\mu]}{b(1+v)(3+v)}, 0\right). \tag{7}$$

For the symmetric case with $\alpha_i = \alpha_j = \alpha$, both firms choose the following output levels:

$$q_i^* = q_j^* = q^*(\alpha) = \frac{a-(1-\alpha)k\mu}{b(3+v)}; \text{ and } Q^*(\alpha) = \frac{2[a-(1-\alpha)k\mu]}{b(3+v)}. \tag{8}$$

Based on above optimal solutions, the following lemma states the effects of first-stage insurance coverage choices on the equilibrium output levels in the second stage.

Lemma 1 *Suppose that firms are risk neutral. Let α_i denote the insurance coverage chosen by firm i in the first stage.*

(a) Firm i's optimal output level increases with its insurance coverage, but decreases with the rival firm's insurance coverage ($\partial q_i^*/\partial \alpha_i \geq 0$ and $\partial q_i^*/\partial \alpha_j \leq 0$). In particular, if its insurance coverage is sufficiently higher than that chosen by its rival $\left(\alpha_i > (2+v)\alpha_j + (1+v)\frac{a-k\mu}{k\mu}\right)$, it can effectively drive the rival firm out of the product market ($q_j^* = 0$).

(b) The effect of firm i's own insurance coverage on its output level increases with the intensity of product market competition ($\partial q_i^*/\partial \alpha_i$ is decreasing in v), but the effect of its rival's insurance coverage on its output level decreases ($\partial q_i^*/\partial \alpha_j$ is increasing in v).

(c) For the symmetric case with $\alpha_i = \alpha_j = \alpha$, the aggregate output level increases with the insurance coverage ($\partial Q^*/\partial \alpha > 0$) and the intensity of product market competition ($\partial Q^*/\partial v < 0$). *Moreover, $\partial Q^*/\partial \alpha$ is strictly decreasing in v.*

Proof: See Appendix A.

Lemma 1(a) demonstrates the strategic effect of insurance on product market behavior, as addressed by Seog (2006). That is, a firm's higher insurance coverage induces the firm to pursue a more aggressive output strategy, and, at the same time, induces its rival firm to behave less aggressively. An increase in output level increases the firm's operating profit as well as its operational risk exposure. With higher insurance coverage, the firm can mitigate the effect of the increased risk exposure, thus expanding its ability to increase its output level for any given output level chosen by its rival. The firm's increased aggressiveness and the resulting negative effect on the market price lower its rival's marginal profits, thereby implying a lower output level by the rival in the output market equilibrium. In particular, when the firm has sufficiently higher insurance coverage relative to its rival firm, it can successfully drive the rival out of the market. This observation suggests that insurance purchases or risk management strategies can be used as exclusionary devices by incumbent firms to prevent entry or induce exit of rivals if firms are subject to differential liquidity constraints (see the "long-purse" or "deep-pockets" story of predation in the industrial organization literature; e.g. Tirole (1988) and Telser (1966)).

More importantly, Lemma 1(b) links the strategic effect of insurance to the intensity of product market competition. In a more competitive product market, an increase in the firm's output level would be expected to have a smaller negative effect on the market price. The firm can thus be more aggressive with a one-unit increase in its insurance coverage in such a market environment as it can increase its output level without much negative effect on the product price. This in turn implies that the same increase in the firm's insurance coverage can lower the competitor's output level to a larger degree in a more competitive market. In other words, higher intensity of product market competition makes the strategic effect of insurance stronger.

Lemma 1(c) describes the symmetric case in which both firms choose the same level of insurance coverage. In this case, if the firms increase their insurance coverage simultaneously, both will increase their output levels in the second stage. The commitment effect of insurance—that is, higher output choices (i.e. tougher output market competition) arising from the choice of higher insurance coverage—is even stronger in a more competitive market. We also observe that, in the symmetric equilibrium, the aggregate output level is larger in a more competitive market environment.

3.2. First stage: Insurance choices

We now turn to the optimal choice of insurance coverage by firms in the first stage prior to their output market decisions. As shown in (2), firm i selects its level of insurance coverage α_i to maximize its certainty equivalent including the insurance premium payment:

$$Max_{\alpha_i} W_i(\alpha_i, \alpha_j) = V_i\left(q_i^*(\alpha_i, \alpha_j), q_j^*(\alpha_i, \alpha_j), \alpha_i\right) - (1+\lambda)\alpha_i k\mu q_i^*(\alpha_i, \alpha_j), \tag{9}$$

where we explicitly denote the dependence of the optimal output choices made in the second stage on the insurance coverage. The optimal solution for (9) will satisfy the following FOC:

$$\partial W_i/\partial \alpha_i = \frac{\partial V_i}{\partial q_j}\frac{\partial q_j^*}{\partial \alpha_i} + \frac{\partial V_i}{\partial \alpha_i} - (1+\lambda)k\mu q_i^* - (1+\lambda)\alpha_i k\mu \frac{\partial q_i^*}{\partial \alpha_i} = 0, \tag{10}$$

where, by the envelop theorem, we omit a term $\frac{\partial V_i}{\partial q_i}\frac{\partial q_i^*}{\partial \alpha_i}$ (see (4)). The first two terms in (10) represent firm i's marginal benefit from a one-unit increase in its insurance coverage. The first term captures the strategic benefits to firm i of raising α_i as the increased insurance coverage leads to a decrease in the rival's output level, q_j^*, which in turn increases firm i's expected operating profit through its positive effect on the market price. The second term represents a direct benefit to firm i of increasing α_i that comes from a reduction in its expected uncovered loss. The last two terms in (10) represent firm i's marginal costs of a one-unit increase in its insurance coverage due to the increased premium payment. Specifically, the third term reflects the increase in firm i's premium costs (assuming no change in the output level), and the last term captures the increase in the premium costs due to the firm's increased output level after increasing its insurance coverage.

Using the definition of V_i in (3) and optimal output levels, q_i^* and q_j^* in (6) and (7), we can simplify (10) to:

$$\partial W_i/\partial \alpha_i = bq_i^* - b\lambda(3+v)(1+v)q_i^* - (1+\lambda)(2+v)\alpha_i k\mu = 0, \tag{11}$$

which is linear in α_i and α_j. Similarly, we obtain the FOC for firm j's optimal insurance choice, which, together with (11), leads to the following unique equilibrium solution for insurance coverage that is symmetric between the firms:

$$\alpha_i^* = \alpha_j^* = \alpha^* = \min\left(\max\left(\frac{1-\lambda(3+v)(1+v)}{v^2+5v+5+\lambda(3+v)(3+2v)}\frac{a-k\mu}{k\mu}, 0\right), 1\right). \tag{12}$$

The symmetric equilibrium insurance choices made by firms also imply their symmetric output choices in the second stage: $q_i^* = q_j^* = q^*(\alpha^*) = \frac{a-(1-\alpha^*)k\mu}{b(3+v)}$.

Let us denote:

$$g(v) \equiv \frac{1}{(3+v)(1+v)} \text{ and } v^* \equiv \frac{\sqrt{1+4(a/k\mu)}-5}{2}. \tag{13}$$

The following proposition further characterizes the firms' optimal insurance choices in the first stage.

Proposition 1 *With risk-neutral firms, we have the following:*

(a) Given the intensity of product market competition as represented by the conjectural variations parameter v, firms acquire insurance when $\lambda < g(v)$, that is, when the cost of insurance as captured by the premium loading factor λ is low enough compared with the strategic commitment effect of insurance.

(b) Suppose that $\lambda < g(v)$. There is a cutoff level of the intensity of product market competition such that firms choose to only partially insure their potential losses if $v > v^*$. If $v \leq v^*$, then the level of insurance coverages purchased by the firms depends on the intensity of product market competition and the cost of insurance: i) if $\lambda > \underline{\lambda}(v)$, firms select partial insurance; ii) if $\lambda \leq \underline{\lambda}(v)$, firms select full insurance, where

$$\underline{\lambda}(v) \equiv \frac{a - k\mu(2+v)(3+v)}{(3+v)[a(1+v)+k\mu(2+v)]}. \tag{14}$$

Proof: See Appendix A.

Proposition 1(a) shows that, even when firms are risk neutral, they may acquire insurance in pursuit of the strategic effect of insurance choice on their second-stage product market decisions. As long as the insurance cost is small enough relative to the strategic benefit from purchasing insurance, firms will choose positive insurance coverage against their risk exposure. Proposition 1(b) additionally shows two cutoff levels that determine whether firms will obtain partial or full insurance coverage. Only when the market is competitive enough ($v \leq v^*$) and the cost of insurance is even smaller ($\lambda \leq \underline{\lambda}(v) < g(v)$), that is, when the strategic benefit of insurance is sufficiently strong relative to the cost of insurance, it is optimal for firms to choose full insurance coverage. The following proposition demonstrates the effects of product market characteristics on firms' optimal insurance choices.

Proposition 2 *Suppose that firms are risk neutral. Their optimal insurance coverage choices show the following properties:*

(a) The more competitive the product market, the more likely it is that firms will purchase insurance.

(b) *Given that firms choose to purchase insurance, their insurance coverage increases with the intensity of product market competition and the size of the product market* ($\partial\alpha^*/\partial\nu \leq 0$ *and* $\partial\alpha^*/\partial a \geq 0$).

Proof: See Appendix A.

Given a certain degree of competition in the product market, a risk-neutral firm's optimal demand for insurance is determined by the trade-off between the strategic benefit of insurance and the cost of insurance. As discussed following the necessary condition (10) for the firm's optimal insurance coverage, the strategic benefit of insurance represents the operating benefits the firm can achieve with a one-unit increase in its insurance coverage, through the effect of increasing its own output level and, at the same time, lowering the rival firm's output level in product market competition.

Unlike the cost of insurance (which is fixed), the magnitude of the strategic effect depends on the competitive nature of the product market. If the firm perceives that the market price would not change much with its increase in output (i.e. when it operates in a more competitive market), it can be relatively more aggressive with a one-unit increase in its insurance coverage because the negative price impact is of less concern in such a market. The firm's greater aggressiveness (i.e. increasing its output level to a greater degree) implies a larger reduction in the rival's output level in equilibrium and, thus, a stronger strategic benefit of insurance in a more competitive product market. For that reason, firms are more likely to purchase insurance and will choose a higher level of coverage in a more competitive product market.

In addition, we also find that the size of the product market (captured by parameter a in the market demand) is positively associated with the optimal insurance coverage chosen by firms operating in the market. The size of the market also amplifies the strategic benefit of insurance, which, however, can be distinguished from the effect of competition intensity. As shown in (10), the strategic benefit of insurance purchase comes from the lowered output level by its rival that, in turn, increases the firm's expected operating profit. The marginal increase in the firm's profit with respect to a one-unit reduction in the rival's output level is proportional to the firm's production scale. A larger product market implies that firms produce on a larger scale, so that the strategic benefit of insurance is stronger in a larger market, thereby leads to greater strategic demand for insurance.

4. Product market competition and corporate demand for insurance: The case of risk-averse firms

In this section, we examine the equilibrium of the two-stage game by assuming that firms are risk averse and thus take into account the ex-ante costs arising from their operational risk. As shown in (1) and (2), a firm's optimal insurance and output choices now include the additional term capturing its costs (or disutility) of risk, $\frac{1}{2}\gamma(1-\alpha_i)^2k^2\sigma^2{q_i}^2 > 0$. In other words, the firm considers both the mean and variance of its future payoff. The additional term increases with risk aversion (or unit cost of risk) ($\gamma > 0$), and the variance of random loss not covered by insurance ($(1-\alpha_i)L(q_i)$). In a similar manner to the risk-neutral case (Section 3), we work backwards by solving first for optimal output levels and then for optimal insurance choices.

4.1. Second stage: Output choices

Conditional on their insurance choices in the first stage, firms maximize their certainty equivalent, $V_i\left(q_i, q_j, \alpha_i\right)$, in (1) by choosing their optimal output levels at:

$$q_i^*(\alpha_i, \alpha_j) = \max\left(\frac{AC-bD}{BC-b^2}, 0\right);\ q_j^*(\alpha_i, \alpha_j) = \max\left(\frac{BD-bA}{BC-b^2}, 0\right), \tag{15}$$

where, for ease of notation, we denote $A \equiv a-(1-\alpha_i)k\mu$; $B \equiv (2+v)b+\gamma(1-\alpha_i)^2k^2\sigma^2$; $C \equiv (2+v)b+\gamma\left(1-\alpha_j\right)^2k^2\sigma^2$; and $D \equiv a-\left(1-\alpha_j\right)k\mu$.[14] We obtain the following lemma by analyzing firms' optimal output choices in the second stage.

Lemma 2 *Consider risk-averse firms with CARA preferences ($\gamma > 0$). Given the insurance coverage chosen by firms in the first stage, the equilibrium output levels have the following properties:*

(a) Firm i's optimal output level increases with its insurance coverage, but decreases with the rival firm's insurance coverage ($\partial q_i^*/\partial\alpha_i \geq 0$ and $\partial q_i^*/\partial\alpha_j \leq 0$).

(b) For the symmetric case with $\alpha_i = \alpha_j = \alpha$, the aggregate output level increases with insurance coverage ($\partial Q^*/\partial\alpha > 0$) and the intensity of market competition ($\partial Q^*/\partial v < 0$). Moreover, $\partial Q^*/\partial\alpha$ is strictly decreasing in v.

[14] As in the case of risk-neutral firms, given the insurance choices made by the firms in the first stage, the equilibrium solution for optimal output choices, specified in (15), is unique.

Proof: See Appendix A.

The main implications of Lemma 2 are similar to those of Lemma 1. A firm's positive insurance coverage induces the firm to commit to a more aggressive operating strategy in the product market than it would with no purchase of insurance. The increased aggressiveness of the firm lowers the rival firm's marginal profits and, thereby, the equilibrium output level of the rival. We also find that, in the symmetric equilibrium, when firms are insured to a larger degree, both firms will choose to be more aggressive so that the aggregate output level will increase. Moreover, as firms perceive a less sensitive price movement with an increase in their output level in a more competitive product market, the commitment effect of insurance, that is, more aggressive output market behavior of firms is strictly increasing with the intensity of product market competition.

4.2. First stage: Insurance choices

By considering the trade-off between the strategic benefit of insurance and the cost of insurance, firms choose their insurance coverage by maximizing their certainty equivalents defined in (2). We rewrite (2) as

$$Max_{\alpha_i}\, W_i(\alpha_i, \alpha_j) = \pi_i\left(q_i^*, q_j^*\right) - (1 + \lambda\alpha_i)k\mu q_i^* - \frac{1}{2}\gamma(1 - \alpha_i)^2 k^2\sigma^2 q_i^{*2}. \tag{16}$$

Given that a firm's certainty equivalent (16) has a quadratic form of α_i because of the variance term of its future payoff uncovered by insurance, and the fact that q_i^* and q_j^* (given by (15)) are non-linear in α_i, the necessary condition for (16) is non-linear in α_i, in contrast to the case of risk-neutral firms. We thus do not have closed-form characterizations of the optimal insurance coverage for risk-averse firms. Although it is plausible to obtain an asymmetric equilibrium in the case of risk-averse firms, we will focus on a symmetric equilibrium to at least characterize firms' equilibrium insurance choices and examine their properties analytically. In the symmetric case ($\alpha_i = \alpha_j = \alpha$), we simplify the second-stage equilibrium solution (15) to

$$q_i^* = q_j^* = q^* = \frac{\widetilde{A}}{\widetilde{B}+b}, \text{ where } \widetilde{A} \equiv a - (1-\alpha)k\mu \text{ and } \widetilde{B} \equiv (2+v)b + \gamma(1-\alpha)^2k^2\sigma^2. \tag{17}$$

We then obtain the necessary condition of (16) for optimal insurance coverage in the symmetric case as

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

$$+\gamma k^2\sigma^2(1-\alpha)\tilde{A}^2(\tilde{B}^2+b^2)=0, \tag{18}$$

which is a sixth-degree polynomial equation of α by the definition of two parameters $\widetilde{A}$ and $\widetilde{B}$ in (17). Because it is, in general, impossible to find algebraic solutions of a polynomial equation of degree five or higher according to the Abel–Ruffini Theorem, we cannot obtain a closed-form solution for α in this symmetric case either. Also, it is plausible to have multiple symmetric equilibria.[15] Similar to Proposition 1, the following proposition characterizes risk-averse firms' symmetric insurance choices in the first stage.

Proposition 3 *Consider risk-averse firms with CARA preferences ($\gamma > 0$) and their symmetric insurance choices, $\alpha_i = \alpha_j = \alpha$.*

(a) The optimal insurance coverage is positive if and only if the insurance premium loading factor λ is lower than the following cutoff level,

$$\bar{\lambda}(v,\gamma) \equiv \frac{\gamma k\sigma^2(a-k\mu)\left[(2+v)b+\gamma k^2\sigma^2\right]^2+b^2[(3+v)b\mu+a\gamma k\sigma^2]}{\mu[(3+v)b+\gamma k^2\sigma^2]\{[(2+v)b+\gamma k^2\sigma^2]^2-b^2\}}. \tag{19}$$

(b) Suppose that $\lambda \leq \bar{\lambda}(v,\gamma)$. There is a cutoff level of the intensity of product market competition v such that firms choose to partially insure their potential losses if $v > v^*$, where v^* is specified by (13). If $v \leq v^*$, then the level of insurance coverage firms choose depends on the intensity of product market competition and the cost of insurance: i) if $\lambda > \underline{\lambda}(v)$, firms select partial insurance; ii) if $\lambda \leq \underline{\lambda}(v)$, firms select full insurance, where $\underline{\lambda}(v)$ is specified by (14).

Proof: See Appendix A.

Proposition 3 describes how the cost of insurance (λ), the level of risk aversion (γ), and the intensity of product market competition (v) jointly shape risk-averse firms' optimal insurance decisions in a symmetric equilibrium. There are three cutoff levels. The first one, $\bar{\lambda}(v,\gamma)$, is the cutoff level of insurance cost that determines whether or not firms will purchase insurance against their operational risk prior to the product market competition.[16] Note that this

---

[15]We do, numerically, find a unique interior solution for α within (0, 1) from equation (18), using reasonable parameter constellations.

[16]We obtain $\lim_{\gamma\to 0}\bar{\lambda}(v,\gamma) = \frac{1}{(1+v)(3+v)} = g(v)$, which is consistent with the cutoff level of the cost of insurance in the risk-neutral case as shown in Proposition 1(a).

cutoff level depends both on the firm risk aversion parameter and the intensity of product market competition. This suggests that when making the decision about whether or not to obtain positive insurance coverage, firms take into account both the traditional motive (that is, reducing the ex-ante costs of risk as reflected in the last term of (16)) and the strategic motive (that is, achieving operating benefits from committing to a more aggressive output market strategy). To illustrate this point more clearly, suppose that there was no strategic effect of insurance, that is, the firm's insurance coverage choice did not affect its equilibrium output level and operating profit. Then, the first-order derivative of the firm's certainty equivalent (16) with respect to its insurance coverage in a symmetric case would be

$$\frac{\partial W}{\partial \alpha} = -\lambda k \mu q^{*} + \gamma(1-\alpha)k^{2}\sigma^{2}q^{*2}\,. \tag{20}$$

When $\alpha = 0$, this derivative can never be positive unless $\gamma > 0$. This confirms that, as discussed in Section 3, risk-neutral firms (with $\gamma = 0$) would not purchase insurance at all without considering its strategic effect. In contrast, risk-averse firms might still demand insurance only for the benefit of reducing their ex-ante costs of risk. From (20), the optimal insurance coverage based only on the traditional motive is given by

$$\tilde{\alpha} = 1 - \frac{\lambda\mu}{\gamma k \sigma^{2} q^{*}}, \tag{21}$$

which increases with firm risk aversion γ and the production scale q^{*}. If q^{*} is larger, the size of potential loss is larger, thereby increasing the optimal insurance coverage for the purpose of reducing the costs of risk. Now additionally consider a firm's strategic motive for insurance purchases, that is, achieving operating profits by credibly committing to increasing its output level. With this motive, the firm's equilibrium output level would be higher. Together with (21), this implication of the strategic motive suggests that risk averse firms' demand for insurance would be even higher when considering both motives for insurance purchases.

The two cutoff levels in Proposition 3(b) are identical to those in the risk-neutral case as shown in Proposition 1(b), indicating that the risk aversion parameter does not affect whether firms select partial or full insurance coverage. This finding implies that, in our model, the choice between full or partial coverage is only determined by the strategic motive for insurance, not by the traditional motive. In other words, it is never optimal for firms even with a sufficiently high risk-aversion level to choose full coverage when only considering the traditional motive for insurance demand.[17] This seemingly counterintuitive observation is known as Mossin's (1968) Theorem in the insurance literature. If risk aversion is the only reason for insurance purchases, less-than-full coverage is optimal at an actuarially unfair insurance price (i.e., a positive premium loading factor, $\lambda > 0$) because risk-aversion is a second-order phenomenon (Eeckhoudt, Gollier, and Schlesinger, 2005). When insurance coverage tends to unity, the first-order effect of insurance cost dominates the second-order effect of increasing the retained risk. To the contrary, our results suggest that, if the strategic effect of insurance is sufficiently large, it can be optimal for firms to choose full coverage.

Based on the results in Proposition 3, the following proposition establishes the relation between firms' insurance choices and product market characteristics.

Proposition 4 *Consider risk-averse firms with CARA preferences ($\gamma > 0$). The more competitive the product market (smaller v), the more likely firms are to insure against their operational risk. Moreover, firms are more likely to choose full insurance coverage when the market is more competitive and/or larger.*

Proof: See Appendix A.

As shown in Lemma 2, the strategic effect of insurance is larger when a firm can commit to a more aggressive output market strategy if the resulting negative effect on the market price is of less concern, which is the case in a more competitive product market. The stronger strategic effect implies that firms are more likely to purchase insurance and, if they choose, more likely to choose full insurance when faced with more intense competition. Also, when the market is larger, the equilibrium production scale of a firm is larger. As discussed following Proposition 2, this amplifies the strategic benefits of insurance, thereby inducing the firm to choose full coverage, because a one-unit reduction in the rival's output level benefits the firm more significantly.

In sum, Proposition 4 suggests that our main predictions still hold in the case of risk-averse firms. The additional effect brought by firm risk aversion is the increased demand for insurance for the purpose of reducing the ex-ante costs of risk. Although the risk aversion parameter γ does not affect the choice between full and partial insurance coverage, it affects the firm's decision

[17]One can also see this point from equation (21): $\tilde{\alpha} < 1$ for any positive λ, in which we assume that firms only have the traditional motive (i.e. reducing the costs of risk) for insurance purchases.

regarding whether or not to purchase insurance, as well as the optimal (partial) insurance coverage.[18]

More importantly, incorporating firm risk aversion (or costs of risk) reinforces our main prediction regarding the effect of competition intensity in the product market. As we find in the case of risk-neutral firms, when the product market is more competitive (smaller v), the strategic motive is stronger, so that firms would demand higher insurance coverage and show more aggressive output market behavior (i.e. choose a higher output level). As discussed above (also, shown by (21)), the traditional motive suggests that firms would demand more insurance when facing larger costs of risk (i.e. larger potential loss). Taken together, the above arguments imply that, considering both the traditional motive and the strategic motive for insurance can lead to an even stronger effect of competition intensity in the product market on corporate demand for insurance because risk aversion (or costs of risk) strengthens the association between the size of insurable loss (i.e. the production scale) and the insurance demand.

5. Discussion

In this section, we discuss the results of several extensions of the main model, and examine the robustness of our main implications under the extensions. For the simplicity of exposition, we consider risk-neutral firms in the extensions.

5.1. Unobservable insurance choices

In the main model, we assume that the first-stage insurance choice made by a firm is observable to its rival before both decide on their output levels in the second stage. This observability assumption is standard in the literature that emphasizes the use of financial decisions (such as debt financing, compensation contracts, or risk management decisions) as a strategic commitment device to draw some desired outcomes from rival firms in output market competition (see, e.g., Brander and Lewis, 1986; Aggarwal and Samwick, 1999; Seog, 2006). In reality, however, it may not be the case that competing firms credibly communicate their financial decisions with each other. This naturally raises the question of to what extent the

[18]Although we do not have a closed-form solution for optimal insurance coverage, we can see that γ affects the level of (partial) insurance coverage in the necessary condition for the symmetric case (18) as well as (20) where we assume no strategic effect of insurance.

observability of insurance contracts is necessary for first-stage insurance choices to serve as a commitment device in our model. In Appendix B, we present an extension with unobservable insurance choices to examine the robustness of our main results—particularly, the positive effect of competition intensity in the product market on corporate demand for insurance—to relaxing the assumption of observable insurance choices.

Specifically, we incorporate the signaling approach employed in Aggarwal and Samwick (1999) into our two-stage game for insurance and output market choices.[19] We assume that, in the first stage, each firm chooses its insurance coverage (which is unobservable to its rival) and then decides whether to signal such coverage to the rival (while incurring a signaling cost) before engaging in the second-stage product market competition. We show that, under certain conditions, there exists a signaling equilibrium in which firms strategically purchase insurance and then signal such a decision to achieve desirable product market outcomes by credibly committing to a more aggressive strategy.

What is important is that when the product market is more competitive (smaller v), it is more likely that the conditions that ensure the existence of a signaling equilibrium will be satisfied. Further, provided that such a signaling equilibrium exists, the key implication of our main model still holds: that is, the corporate demand for insurance is positively associated with the intensity of market competition.

5.2. Strategic insurance choices in a dynamic setting

In the unique equilibrium of our main model with a reasonable level of insurance cost, firms choose positive insurance coverage and then engage in tough product market competition. The resulting expected payoffs to the firms are obviously lower than those that could be obtained in a collusive outcome where firms coordinate to choose no insurance and thus soften their competition in the output market. One may thus argue that the equilibrium with positive insurance coverage could be the result of our static setting. To address this possibility, we present an infinitely repeated game that allows for such tacit collusion.

[19] Aggarwal and Samwick (1999) study optimal managerial contracts under imperfect product market competition in a two-stage duopoly framework, in which two firms first determine executive compensation contracts and then compete in the output market after observing the contracts. In their appendix, the authors show the robustness of their main results using a signaling framework where contracts are not directly observable, as we adopt in our extension.

As detailed in Appendix C, in each period, each firm follows the coordination of no insurance purchase and engages in product market competition. If one firm unilaterally deviates from the no insurance scheme in any period, the firm will be "minimaxed" in the following period; that is, it will receive a payoff of zero in the next period as implemented in some repeated games (e.g. Cabral, 1995). After the period of punishment, the coordination cannot be sustained and both firms will go back to the competitive two-stage game (as in our main model) in each period in which they purchase insurance and compete more aggressively in the product market. In this one-period minimax-punishment setting, we show that, under reasonable parameter constellations, firms are willing to deviate from the collusive agreement with no insurance policy and strategically purchase insurance prior to competition in the output market; more importantly, their willingness to deviate is stronger when the product market is more competitive, which reinforces the implication of our main model concerning the positive relation between the insurance demand and the intensity of product market competition.

5.3. Premium loading factor and product market competition

In the main model, we assume that the insurance premium loading factor λ is independent of the level of the expected loss or the insurance coverage chosen by firms. However, insurers may price commercial insurance contracts by considering the competitive landscape faced by the insured firms. As we describe in Appendix D, there are two potential ways in which the insurance loading factor depends upon the structure of the product market in which firms will operate after being insured.

On one hand, the insurance loading may be lower in a more competitive product market. The rationale here is that a more competitive product market environment accompanies more firms, which naturally implies a higher aggregate demand for insurance. Providing the same insurance service to many firms enables insurers to operate more efficiently because of economies of scale, which potentially leads to a lower expense loading in the insurance premium. On the other hand, insurers may take into account firms' output market behavior in advance when determining insurance premiums. If they understand the insured firms' strategic interaction with other firms competing in the product market, insurance companies may charge a higher premium loading for firms operating in a more competitive market because these firms are likely to engage in more aggressive output market strategies after transferring their increased risk to the insurers.

As in our main model, firms' optimal insurance demand is determined by the trade-off between the strategic effect of insurance and the cost of insurance. In contrast to the main model, both the strategic effect of insurance and the cost of insurance vary with the intensity of market competition, which may alter our main prediction regarding the positive relation between firms' demand for insurance and the intensity of product market competition. In the first case when the insurance cost is lower for firms operating in a more competitive product market, our prediction is reinforced by the new assumption. In the second case when a higher premium loading is charged to firms operating in a more competitive market, however, our main result may or may not hold, depending on the relative magnitude of the effect of competition intensity on the premium loading factor relative to its effect on the strategic effect of insurance. As long as more intense competition implies a larger strategic effect relative to higher insurance costs, our main prediction continues to hold. If we consider potential competition among insurers, the incentives of an insurer charging a higher premium for potential opportunistic behavior of insured firms may not be that strong. In addition, given that, in reality, both of the two contrasting cases we have discussed are plausible, the net effect of competition on the cost of insurance may be relatively marginal, as compared to its effect on the strategic effect of insurance. Taken together, it is clear that the cost of insurance, as well as the operating characteristics of the product market in which the insured firms will operate, jointly shape firms' insurance decisions.

6. Empirical analysis

In this section, we empirically explore the implications of our model that relate product market characteristics to the corporate demand for insurance. Specifically, we test whether the amount of insurance purchased is higher (a) when firms operate in a more competitive product market; (b) when firms operate in a larger product market; or (c) when firms face a higher operational risk, controlling for the cost of insurance.

6.1. Data and descriptive statistics

We test our theoretical predictions by focusing on the US property and liability (PL) insurance industry in which firms are required to report details of their insurance transactions in their annual regulatory statements. It would be ideal to provide evidence on the insurance demand by firms operating in a variety of industrial and service sectors that have substantial heterogeneity in product market factors. However, because of firms' discretion in the disclosure of risk management activities (including insurance purchases), researchers usually do not obtain detailed information of insurance purchases by non-financial corporations. Hence, only a handful of recent empirical studies analyze corporate insurance purchases, using a sample of non-US public companies[20] or proprietary data for a small subset of US companies.[21]

Our aim in this section is to provide empirical evidence regarding the implications of our model for corporate insurance demand, rather than providing a comprehensive empirical test for existing theories. We thus follow the common approach in the literature that examines the motives for reinsurance purchases by a large panel of US PL primary insurance companies (e.g. Mayers and Smith, 1990).[22] Reinsurance contract is an insurance policy purchased by a primary insurance company from another insurance company (usually a reinsurer). As pointed out by Mayers and Smith (1990), within the insurance industry, reinsurance purchases are thus akin to traditional insurance purchases by non-financial corporations. In addition, as we detail further below, the US PL primary insurance industry provides a reasonable laboratory for the test of our model as this industry is distinguished by 26 lines of business and 50 geographic areas (states), which differ in terms of the intensity of competition, market size, and underwriting risk; and thereby serve as individual markets (Cummins and Weiss, 1992; Suponcic and Tennyson, 1998). Further, PL insurers must report details of their reinsurance transactions in their annual statements, including reinsurance partners and the amount of reinsurance purchased, from which we capture *firm-specific* reinsurance supply-side factors to control for the costs of reinsurance.

To construct our sample, we obtain financial and reinsurance transaction information for all US PL primary insurers and reinsurers, from the National Association of Insurance

[20]For example, Zou, Adams, and Buckle (2003) analyze the decision to purchase property insurance using a sample of 235 publicly listed Chinese companies over the period of 1997–1999, and Regan and Hur (2007) examine the property-casualty insurance expenditures by 433 publicly listed Korean manufacturing firms for the period 1990 through 2001.
[21]Aunon-Nerin and Ehling (2008) analyze property insurance contracts of 73 publicly traded US firms that come from SwissRe over the period of from January 1991 to September 2002, and Michel-Kerjan, Raschky, and Kunreuther (2015) compare property and terrorism insurance policies purchased by 141 large US companies using the data from Marsh in 2007.
[22]See also Garven and Lamm-Tennant (2003), Cole and McCullough (2006), Powell and Sommer (2007), and Lin, Yu and Peterson (2015).

Commissioners (NAIC) database. To avoid any effects of extraordinary operating activities (e.g. firms exiting an insurance market), we exclude firms with non-positive assets, surpluses, or premiums; firms with reinsurance ratios that are not between zero and one; and firms identified as being inactive. As our analysis examines reinsurance decisions by primary insurers, we do not include professional US reinsurers identified by the NAIC definition or the A.M. Best definition in our regression analysis.[23] Nonetheless, we use the financial information of those identified reinsurers to capture the variation in reinsurance costs faced by primary insurers. We also collect financial information for large non-US reinsurers from Standard and Poor's *Global Reinsurance Highlights*.[24] Our final sample is an unbalanced panel containing 18,931 firm–year observations (2,345 distinct primary insurers) for the period 1996–2008.

We estimate the following ordinary least squares (OLS) regression of the demand for reinsurance by primary US PL insurers:

$$REINS_{it} = \alpha + \sum\beta\times InsMkt_{it-1} + \sum\gamma\times ReinsSupply_{it-1} + \sum\delta\times X_{it-1} + \mu_i + \nu_t + \varepsilon_{it}, \qquad (22)$$

where $REINS_{it}$ represents the level of reinsurance usage by primary insurer i in year t. Our main interest is in the relation between a primary insurer's reinsurance activity and its primary insurance market factors ($InsMkt_{it-1}$), such as the intensity of market competition, market size, and underwriting risk, controlling for reinsurance supply-side factors ($ReinsSupply_{it-1}$) and other firm-specific factors (X_{it-1}). These explanatory variables are lagged by one year in an effort to mitigate potential effects of endogeneity.[25] In all regressions, we include year and firm fixed effects (ν_t and μ_i) to control for macroeconomic effects and unobserved firm heterogeneity, respectively, and cluster standard errors at the firm and year level to account for correlations among error terms within the firm and within the year (Petersen, 2009). Appendix E provides

[23]NAIC defines a reinsurer as any firm whose reinsurance assumed from non-affiliates is more than 75 percent of reinsurance assumed from non-affiliates plus direct business written. A.M. Best is a US-based rating agency that specializes in the insurance industry. It defines a reinsurer as any firm whose reinsurance assumed from non-affiliates is more than 75 percent of reinsurance assumed from affiliates plus direct business written.

[24]These publications report the list of the top 100–150 reinsurers around the world that are ranked based on the net reinsurance premiums written. As Cole and McCullough (2006) state, these top reinsurers accounted for almost 95 percent of the global reinsurance market in 1999.

[25]Although our main results also hold using contemporaneous explanatory variables, it is a common approach in empirical research to lag explanatory variables rather than use contemporaneous explanatory variables in an effort to purge their estimates of endogeneity by reducing the correlation between the explanatory variables and the error term (Angrist and Pischke, 2009). However, as addressed by Roberts and Whited (2013), the use of lagged explanatory variables does not fully address endogeneity problems. We acknowledge that our empirical tests are simply to show correlations between reinsurance demand by primary insurers and their primary insurance market factors as implied by our theory, rather than identifying causal effects of primary insurance market factors on reinsurance demand.

detailed definitions of the variables employed in our empirical analysis.

[Insert Table 1 here]

Table 1 provides descriptive statistics for our empirical measures. We winsorize all ratio variables at the 2nd and 98th percentiles to mitigate any effect of outliers. Panel A of Table 1 presents means, medians, standard deviations, and 25th and 75th percentiles for our dependent variables that measure a primary insurer's reinsurance activity. Primary insurers are often affiliated members of insurance groups so that they cede premiums to (or assume from) their affiliates (including professional reinsurers and other primary insurers within the group), in addition to making reinsurance transactions with unaffiliated companies. Based on previous studies (e.g. Cole and McCullough, 2006), our main dependent variable (REINS) represents a total reinsurance ratio defined as the ratio of total reinsurance premiums ceded to total business premiums. Total business premiums represent the sum of premiums from a firm's direct business (i.e. gross premiums (policy and membership fees written and renewed during the year) less return premiums) and reinsurance assumed (premium income from supplying reinsurance services). This measure thus represents the proportion of the underwriting risk laid off by a primary insurer to its reinsurance providers, including both affiliated and unaffiliated companies.

As an alternate measure for robustness check, we also consider a measure of net reinsurance activity (NET_REINS). This measure represents the ratio of the net amount of reinsurance purchased (i.e. reinsurance purchased (ceded) minus reinsurance assumed) to direct business premiums by treating reinsurance assumed simply as the negative of reinsurance purchased.[26] In addition, we further estimate the regression equation (22) using the ratio of reinsurance premiums ceded only to external companies (EXT_REINS). This additional test addresses the possibility that primary insurers may have different incentives when their reinsurance partners are unaffiliated reinsurers (external reinsurance) and when their partners are affiliated insurers (internal reinsurance) (Powell and Sommer, 2007). In our sample of primary insurers, the average total reinsurance ratio (including both internal and external reinsurance) is 0.406, and the average external reinsurance ratio 0.167. The difference between these means suggests that the bulk of reinsurance transactions occur between affiliated insurers. The statistics

[26]As Mayers and Smith (1990) point out, however, a caveat concerning the use of net reinsurance activity is that we cannot distinguish between a firm with positive reinsurance purchased but similar positive reinsurance assumed, and a firm with no participation in the reinsurance market.

for these reinsurance ratios are largely comparable to those in related studies.

As shown in Table 1, we classify our explanatory variables into three categories: insurance market-related variables, reinsurance supply-side variables, and other firm-specific controls. First, insurance market-related variables are explanatory variables of our main interest. Previous insurance market structure studies document that concentration and market shares can vary substantially with insurance lines of business in the same state or across different states for the same business line (Cummins and Weiss, 1992; Suponcic and Tennyson, 1998; Choi and Weiss, 2005). We thus define individual PL primary insurance markets by line of business and by state, and then measure the intensity of competition, size, and underwriting risk for each specific market. Using detailed information concerning direct business premiums and losses for companies operating in a particular primary market, we obtain different proxies of the intensity of market competition. Our first three measures of competition are market concentration variables such as the Herfindahl–Hirschman Index (HHI), and four-firm and eight-firm concentration ratios (CR4 and CR8, respectively). These variables are widely used proxies for product market competition based on industrial organization theory (see Tirole, 1988).

We compute these variables using the market shares of primary insurers based on their direct premiums written in the market. A higher HHI or concentration ratio implies less competition among firms in the market. The final proxy for market competition is the average price measure. The price charged by a firm in the insurance market is estimated as premiums earned divided by losses incurred (i.e. the inverse of a loss ratio). This measure is a standard measure of underwriting returns in PL insurance (see, e.g., Winter, 1994; Cummins and Danzon, 1997; Choi and Weiss, 2005). To the extent that price (or underwriting performance) is associated with the market structure—that is, it reflects the market power that firms have according to the nature of market competition—the average price across firms in the market can be another proxy for market competition. That is, a higher average price generally implies less competition that firms face in the market. In addition to these market competition measures, we measure the size of the market as the sum of direct premiums of firms operating in the market, and the market risk as the average underwriting risk across firms that we estimate as the standard deviation of loss ratios across firms over the previous three years (e.g. Lamm-Tennant and Starks, 1993).

After we measure these variables at the primary insurance market level, we convert them into firm-specific insurance market-related variables. Most primary insurers tend to operate in multiple markets rather than concentrating on one particular market mainly for the purpose of risk diversification. In our sample, the average (median) number of business lines an insurer operates is seven (six), and that of states is seventeen (six). To capture the overall level of insurance market variables faced by an insurer operating in multiple states across different lines of business, we compute the weighted averages of insurance market variables for the firm. For the weights, we use the percentage of direct premiums that the company underwrites in the specific market over its total direct premiums across all markets. Panel B of Table 1 presents summary statistics for the firm-specific insurance market-related variables. The firm-specific HHI has an average (median) of 0.065 (0.052), generally implying a low level of market concentration.[27] The concentration ratios (CR4 or CR8) imply that the largest four (eight) firms, on average, take a market share of 37% (49.5%).

[Insert Figure 1 here]

Figure 1 illustrates the descriptive relation among the firm-specific proxies of market competition. Intuitively, these alternate proxies correlate positively with each other. Table 2 provides the pairwise correlation coefficients between the reinsurance ratio (REINS) and firm-specific insurance market variables. Reinsurance activity positively correlates with the intensity of market competition (captured by lower HHI, lower concentration ratios, or lower average price), and also positively correlates with the market size. Although the pairwise correlation between the reinsurance ratio and the market risk is slightly negative, their relation turns out to be positive in a multivariate analysis as we show below.

[Insert Table 2 here]

We now describe the measures that capture the status of reinsurance partners and, therefore, the reinsurance supply-side factors related to a primary insurer's reinsurance choice. Cole and McCullough (2006) highlight the importance of incorporating reinsurance industry factors in assessing the demand for reinsurance by primary insurers. In contrast to their study assuming that the overall state of the reinsurance market influences all primary insurers identically, we

[27] According to the Antitrust Division of the Department of Justice, HHI between 0.15 and 0.25 are considered moderately concentrated, and indices above 0.25 are considered highly concentrated.

consider the fact that firms have different sources of reinsurance supply, including their affiliates, US unaffiliated reinsurers, and non-US reinsurers. If there are variations in the status of their different reinsurance supply groups, primary insurers will take into account those changes when they decide the amount of reinsurance purchased.

To capture the reinsurance supply-side factors facing a primary insurer, we consider the average combined ratios of its reinsurance partner groups. The combined ratio of a reinsurer, which is the sum of its underwriting expense and loss ratios, provides information about the reinsurer's underwriting performance, as well as the price of reinsurance (Cole and McCullough, 2006). A higher combined ratio indicates either that the reinsurer charges a lower price, leading to lower underwriting performance, or that the reinsurer's underwriting profitability is poor because of higher expenses. Depending on which of these is of primary concern for the primary insurer—lower reinsurance price or higher reinsurer quality—the insurer's demand for reinsurance will correlate positively or negatively with the reinsurer's combined ratio.

Using the reinsurance transaction data (provided by Schedule F (Part 3) of the NAIC database), we can identify a primary insurer's reinsurance partners and the amount of reinsurance premiums transferred to them. As indicated by dummy variables (AFF, US_UNAFF, NONUS) in Panel C of Table 1, of 18,931 firm–year observations for primary insurers, 61 percent are affiliated insurers that engage in internal reinsurance activity, 79 percent transfer premiums to US unaffiliated insurers, and 56 percent make transactions with non-US reinsurers. To capture the status of a primary insurer's reinsurance partner groups, we compute the weighted averages of combined ratios of affiliated and unaffiliated reinsurance partners (AFF_COMB and US_COMB) to which the primary insurer transfers risk (i.e. cedes reinsurance) by placing a higher weight on the partner assuming more reinsurance from the insurer. Using the fraction of reinsurance ceded to a particular reinsurance partner for the weight on the partner's combined ratio captures the importance of the partner to the primary insurer. As limited information is available for non-US reinsurers with which US primary insurers in our sample make a transaction, we only measure the average combined ratio of the top 100–150 reinsurers around the world (NONUS_COMB). We apply the average information for these top global reinsurers to all primary insurers that have risk transfer relationships with non-US reinsurers. From Panel C, we note that the mean and median values of these firm-specific combined ratios of reinsurance partner groups are relatively similar, which is consistent with Cole and McCullough (2006), who document no statistical differences in the average combined ratios between the aggregate US and international reinsurance markets. We incorporate these variables to control for reinsurance supply-side factors capturing either reinsurance cost or reinsurer profitability that primary insurers may consider in deciding reinsurance coverage.

In addition to the insurance market-related variables and reinsurance supply-side variables, we include firm-specific control variables suggested in the literature (e.g. Mayers and Smith, 1990; Cole and McCullough, 2006; Lin, Yu, and Peterson, 2015). We include size, profitability, leverage, and cash-flow volatility as they control for a primary insurer's probability of encountering financial distress, which is positively correlated with its incentives to purchase reinsurance. The percentage of investment income generated from tax-favored assets addresses the insurer's incentive to smooth earnings and thus purchase a higher level of reinsurance. We also consider the insurer's catastrophe exposure and business mix concentration (overall, business line, and geographic concentrations), as well as proxies for information asymmetry between the insurer and reinsurers, such as firm age and organizational form (if the company is a publicly traded company). Affiliation-related variables such as the number of firms within the group and the insurer's size relative to its affiliates control for the insurer's different incentives for internal and external reinsurance, which may vary with its status within the group. Finally, following previous studies, we control for different underwriting risk levels across lines of business by including the insurer's percentage of direct business written in each of 26 lines as additional control variables.

6.2. Empirical results

Table 3 reports the estimation results for the regression equation (22) that models the reinsurance activity of primary insurers. The table contains five regressions mainly distinguished by alternate measures of market competition that primary insurers face. As noted earlier, we capture the intensity of market competition using different market concentration proxies such as HHI, CR4 or CR8, and average price. A higher value for each of these proxies implies that firms face lower competition overall. Consistent with our main theoretical prediction, the coefficients of market concentration proxies are negative and significant at the 5% or 1% confidence level depending on the alternate measures. These estimates are also economically meaningful. For example, based on the coefficient estimates in column (1), a one standard deviation increase

(0.052) in HHI is, on average, related to a decrease of around 0.83 percentage points (i.e. –0.159 × 0.052) in a firm's reinsurance ratio. Compared with the sample average reinsurance ratio of 0.406, this change represents a decrease of around 2.04%. The coefficient estimates for the alternate proxies of market competition in columns (3)–(5) also imply similar economic magnitudes, ranging between 1.53–6.48%.

[Insert Table 3 here]

In addition to the relation between reinsurance demand and market competition, our model implies that insurance coverage is positively associated with the size of the product market (MKTSIZE) and the underlying operational risk (MKTRISK). Consistent with intuition, the coefficients of these variables are both positive and significant at the 1% confidence level. Based on the estimates in column (1), a one standard deviation increase in these variables is related to a 6.91% and a 1.13% increase in reinsurance ratio (relative to the sample average reinsurance ratio), respectively.

We observe a significantly positive coefficient for the interaction between the reinsurance affiliate dummy variable (AFF) and the average combined ratio of its affiliated reinsurance partners. If the insurer has its affiliates as reinsurance partners, then its reinsurance demand should be related to their average combined ratio, which captures either the inverse of the average price charged by the reinsurance partners for reinsurance service or the inverse of their average underwriting performance. The positive sign of the coefficient implies that the demand for reinsurance by the insurer is positively related to lower reinsurance price offered by its affiliates. Along similar lines, we observe a significantly positive sign of the interaction between the reinsurance US unaffiliate dummy (US_UNAFF) and the average combined ratio of those reinsurance partners. However, we note that, as Cole and McCullough (2006) document in their comparison of the foreign and US reinsurance markets, the average combined ratio of non-US reinsurers is not significantly related to the reinsurance choice by primary insurers that utilize foreign reinsurance. We also note that the coefficients of the control variables have similar signs to those documented in previous reinsurance studies. Smaller firms and firms with higher leverage tend to transfer more risk to reinsurers to decrease their likelihood of financial distress. Firms widely diversified across different lines of business or different states use more reinsurance because more diversified primary insurers can benefit more from reinsurers that can provide real services with their comparative advantages and expertise in risk management.

[Insert Table 4 here]

We corroborate the main results using alternate measures of reinsurance activity. As discussed earlier, we consider a primary insurer's net reinsurance activity (NET_REINS) by treating reinsurance assumed by the firm as the negative of reinsurance purchased. The first four columns in Table 4 show the estimation results obtained by carrying out the same analysis with the net reinsurance ratio as the dependent variable. Our main results using market competition proxies are largely robust to using the alternate proxy for reinsurance activity. The last four columns in Table 4 report the results obtained by running the regression of external reinsurance (EXT_REINS) on the same set of explanatory variables. External reinsurance captures only a primary insurer's reinsurance activity with its unaffiliated reinsurance partners. This additional test addresses the possibility that our results may hold only for the use of reinsurance contracts among affiliated insurers (i.e. internal reinsurance activity), which may represent transactions in an internal capital market, rather than an active risk management strategy (Powell and Sommer, 2007). Although slightly weaker in terms of statistical significance, the coefficients for primary insurance market variables have the same signs and are economically important for external reinsurance. We also note that, in line with the results of Powell and Sommer (2007), the coefficient estimate for the company-to-affiliation size ratio is positive in the external reinsurance equation, in contrast to the negative sign in the total reinsurance equation (Table 3). This finding implies that a larger insurer relative to its affiliates tends to assume more reinsurance internally, but is able to transfer more risk to external reinsurers.

[Insert Table 5 here]

To further address potential differences in reinsurance activity between affiliated insurers and unaffiliated single insurers, we carry out the same analysis by including only unaffiliated single companies (Mayers and Smith, 1990; Garven and Lamm-Tennant, 2003). The first four regressions in Table 5 show that, consistent with our baseline results in Table 3, the reinsurance activity of unaffiliated single insurers is negatively associated with insurance market concentration measures. In contrast to our baseline results for both affiliated and unaffiliated insurers, an unaffiliated single insurer's catastrophe exposure, which measures the proportion of its property insurance business in eastern coastal states and earthquake insurance business in California, is significantly positively related to its demand for reinsurance.

As discussed earlier, a primary insurer typically diversifies its operations across different lines of business and across different states. In our baseline analysis, we employed firm-specific market competition measures (weighted average market competition measures across different market segments distinguished by 26 insurance lines and 50 states) to capture the overall level of market competition that the company faces. To further examine the robustness of our baseline results with the weighted average measures, we now focus on firms' major market segment (e.g. earthquake insurance in California) and link firms' reinsurance demand to the characteristics of the major market segment. We restrict the sample to primary insurers for which the major market segment represents at least 25 percent of their business operation. This sample restriction ensures that their firm-level risk management strategy tends to be more closely related to the characteristics of their major market segment, rather than their other smaller market segments. Columns (5)–(8) of Table 5 show the regression results for this subsample of firms. The intensity of competition and the size of a firm's primary market are positively associated with its demand for reinsurance. The underwriting risk of the major market segment is also positively related to the firm's reinsurance demand.

Taken together, our empirical results provide supporting evidence for the predictions of our model (in particular, the positive correlation between the intensity of market competition and the demand for insurance). Further, our empirical analysis complements prior empirical studies on reinsurance demand by taking into account primary insurance market factors and reinsurance supply-side factors.

7. Conclusion

This study presents a two-stage duopoly model of insurance and output choices by allowing for different degrees of product market competition. A firm's insurance choice is determined by the trade-off between the strategic effect of insurance and the cost of insurance. The strategic effect of insurance reflects the firm's operating benefits from the strategic commitment aspect of the insurance choice in relation to output markets. In a more competitive product market, the strategic effect of commitment to a more aggressive output market strategy is stronger as the firm can be even more aggressive by perceiving a smaller negative effect on the product price. The model thus demonstrates a positive relation between firms' insurance purchases—or more broadly, risk management decisions—and the intensity of product market competition faced by those firms. This main prediction holds true regardless of whether firms are risk neural or risk averse, as well as in an extended model in which insurance choices are not publicly observable. We provide robust support for the model in an empirical analysis of reinsurance purchases by US PL primary insurers. For future research, it would be interesting to examine the model predictions using data for corporate insurance purchases by non-financial firms in other industries (if available), rather than restricting to the insurance industry.

References

Adam, T., Dasgupta, S., Titman, S., 2007. Financial constraints, competition, and hedging in industry equilibrium. Journal of Finance 62, 2445-2473.

Aggarwal, R. K., Samwick, A. A., 1999. Executive compensation, strategic competition, and relative performance: Theory and evidence. Journal of Finance 54, 1999-2043.

Angrist, J. D., Pischke, J-S., 2009. Mostly Harmless Econometrics. Princeton: Princeton University Press.

Ashby, S. G., Diacon, S. R., 1998. The corporate demand for insurance: A strategic perspective. Geneva Papers on Risk and Insurance 23, 34-51.

Aunon-Nerin, A., Ehling, P., 2008. Why firms purchase property insurance? Journal of Financial Economics 90, 298-312.

Brander, J.A., Lewis, T.R., 1986. Oligopoly and financial structure: The limited liability effect. American Economic Review 76, 956-970.

Bresnahan, T., 1981. Duopoly models with consistent conjectures. American Economic Review 71, 934-945.

Bulow, J. I., Geanakoplos, J. D., Klemperer, P. D., 1985. Multimarket oligopoly: Strategic substitutes and complements. Journal of Political Economy 93, 488-511.

Cabral, L. M. B., 1995. Conjectural variations as a reduced form. Economics Letters 49, 397-402.

Cheyne, B., Nini, G., 2010. Creditor mandated purchases of corporate insurance. Working paper, Wharton School, University of Pennsylvania.

Choi, B. P., Weiss, M. A., 2005. An empirical investigation of market structure, efficiency, and performance in property-liability insurance. Journal of Risk and Insurance 72, 635-673.

Cole, C.R., McCullough, K.A., 2006. A reexamination of the corporate demand for reinsurance. Journal of Risk and Insurance 73, 169-192.

Cummins, J.D., Danzon, P.M., 1997. Price, financial quality, and capital flows in insurance markets. Journal of Financial Intermediation 6, 3-38.

Cummins, J. D., Weiss, M. A., 1992. The Structure, Conduct, and Regulation of the Property-Liability Insurance Industry. In: Kopcke, A.W., Randall, R. E. (Eds.), The Financial Condition and Regulation of Insurance Companies. Boston: Federal Reserve Bank of Boston.

Doherty, N. A., Schlesinger, H., 1983. Optimal insurance in incomplete markets. Journal of Political Economy 91, 1045-1054.

Doherty, N. A., Smith, C. W., 1993. Corporate insurance strategy: The case of British Petroleom. Journal of Applied Corporate Finance 6, 4-15.

Eeckhoudt, L., Gollier, C., Schlesinger, H., 2005. Economic and Financial Decisions under Risk. Princeton University Press.

Garven, J.R., Lamm-Tennant, J., 2003. The demand for reinsurance: Theory and empirical tests. Assurances 71, 217-238.

Lamm-Tennant. J., Starks, L. T., 1993. Stock Versus Mutual Ownership Structures: The Risk Implications. Journal of Business 66, 29-46.

Léautier, T-O., Rochet, J-C., 2014. On the strategic value of risk management. International Journal of Industrial Organization 37, 153-169.

Lin, Y., J. Yu, Peterson, M. O., 2014. Reinsurance networks and their impact on reinsurance decisions: Theory and empirical evidence. Journal of Risk and Insurance 82, 531-569.

Mayers, D., Smith, C. W., 1982. On the corporate demand for insurance. Journal of Business, 55, 281-296.

Mayers, D., Smith, C. W., 1990. On the corporate demand for insurance: Evidence from the reinsurance market. Journal of Business 63, 19-40.

Mello, A.S., Ruckes, M. E., 2005. Financial hedging and product market rivalry. Working paper, University of Wisconsin - Madison.

Michel-Kerjan, E., Raschky, P.A., Kunreuther, H. C., 2015. Corporate Demand for Insurance: New Evidence From the U.S. Terrorism and Property Markets. Journal of Risk and Insurance 82, 505–530.

Mossin, J., 1968. Aspects of Rational Insurance Purchasing. Journal of Political Economy, 76, 553-568.

Perry, M., 1982. Oligopoly and consistent conjectural variations. Rand Journal of Economics 13, 197-205.

Powell, L.S., Sommer, D. W., 2007. Internal versus external capital markets in the insurance industry: The role of reinsurance. Journal of Financial Services Research 31, 173-188.

Petersen, M.A., 2009. Estimating standard errors in finance panel data sets: comparing approaches. Review of Financial Studies 22, 435–480.

Regan, L., Hur, Y., 2007. On the corporate demand for insurance: The case of Korean nonfinancial firms. Journal of Risk and Insurance 74, 829-850.

Roberts, M. R., Whited, T. M., 2013. Endogeneity in empirical corporate finance. In: Constantinides, G. M., Harris, M., Stulz, R. M. (Eds.), Handbook of the Economics of Finance, Vol. 2 (Part A), 493-572. North Holland.

Seog, S. H., 2006. Strategic demand for insurance. Journal of Risk and Insurance 73, 279-295.

Servaes, H., Tamayo, A., Tufano, P., 2009. The theory and practice of corporate risk management. Journal of Applied Corporate Finance 21, 60-78.

Smith, C., Stulz, R., 1985. The determinants of firms' hedging policies. Journal of Financial and Quantitative Analysis, 20, 391-405.

Suponcic, S. J., Tennyson, S., 1998. Rate Regulation and the Industrial Organization of Automobile Insurance. In: Bradford, D. F. (Eds.), The Economics of Property Casualty Insurance. Chicago: University of Chicago Press.

Telser, L.G., 1966. Cutthroat competition and the long purse. Journal of Law and Economics 9, 259-277.

Tirole, J., 1988. The Theory of Industrial Organization. Cambridge, MA: MIT Press.

Tufano, P., 1996. Who manages risk? An empirical examination of risk management practices in the gold mining industry. Journal of Finance 51, 1097–1137.

Winter, R., 1994. The dynamics of competitive insurance markets. Journal of Financial Intermediation 3, 379-415.

Zou, H., Adams, M. B., Buckle, M. J., 2003. Corporate risks and property insurance: Evidence from the People's Republic of China. Journal of Risk and Insurance 70, 289-314.

Appendix A. Proofs.

Proof of Lemma 1

Proof: (a) Using equation (6), it is straightforward to verify that $\partial q_i^*/\partial\alpha_i \geq 0$; and $\partial q_i^*/\partial\alpha_j \leq 0$. Moreover, from equation (7) we know that if $\alpha_i > (2+v)\alpha_j + (1+v)\frac{a-k\mu}{k\mu}$, we have $q_j^* = 0$. In particular, since $v \in (-1, 1]$, 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, when $\alpha_i > (2+v)\alpha_j + (1+v)\frac{a-k\mu}{k\mu}$, we have $a - (1-\alpha_j)k\mu < (2+v)[a-(1-\alpha_j)k\mu] < a - (1-\alpha_i)k\mu < (2+v)[a-(1-\alpha_i)k\mu]$, which further implies that $q_i^* > 0$ according to equation (6).

(b) From equation (6), $\partial q_i^*/\partial\alpha_i = \frac{(2+v)k\mu}{b(3+v)(1+v)}$; $\partial q_i^*/\partial\alpha_j = -\frac{k\mu}{b(1+v)(3+v)}$. Therefore, $\frac{\partial(\partial q_i^*/\partial\alpha_i)}{\partial v} = \frac{(3+v)(1+v)-2(2+v)^2}{b(1+v)^2(3+v)^2}k\mu < 0$; and $\frac{\partial(\partial q_i^*/\partial\alpha_j)}{\partial v} = \frac{2(2+v)}{b(1+v)^2(3+v)^2}k\mu > 0$.

(c) Under the symmetric equilibrium characterized by equation (8), we have $\partial Q^*/\partial\alpha = \frac{2k\mu}{b(3+v)} > 0$; and $\partial Q^*/\partial v = -\frac{2[a-(1-\alpha)k\mu]}{b(3+v)^2} < 0$. Furthermore, $\frac{\partial(\partial Q^*/\partial\alpha)}{\partial v} = \frac{-2k\mu}{b(3+v)^2} < 0$.

Proof of Proposition 1

Proof: (a) From equation (12), we have $\alpha^* = \frac{1-\lambda(1+v)(3+v)}{v^2+5v+5+\lambda(3+v)(3+2v)}\frac{a-k\mu}{k\mu} > 0$ When $\lambda < g(v)$ for a given v.

(b) With $\lambda < g(v)$, again, from equation (12), firms choose to be fully insured when $\frac{1-\lambda(3+v)(1+v)}{v^2+5v+5+\lambda(3+v)(3+2v)}\frac{a-k\mu}{k\mu} \geq 1 \Leftrightarrow (1-\lambda(3+v)(1+v))(a-k\mu) \geq (v^2+5v+5+\lambda(3+v)(3+2v))k\mu \Leftrightarrow \lambda \leq \underline{\lambda}(v) \equiv \frac{a-k\mu(2+v)(3+v)}{(3+v)[a(1+v)+k\mu(2+v)]}$. When $\lambda > \underline{\lambda}(v)$, firms choose to only partially insure their potential losses. In particular, a sufficient condition for firms to only choose partial insurance is when $v > v^* \equiv \frac{\sqrt{1+4(a/k\mu)}-5}{2}$, under which we further derive $a - k\mu(2+v)(3+v) < 0$ and $\underline{\lambda}(v) < 0$, meaning that the full insurance condition ($\lambda \leq \underline{\lambda}(v)$) cannot be satisfied with any non-negative insurance premium loading.

An illustration for the cutoff level v^* is further provided in Figure A.1. Define $f(v) \equiv (3+v)(2+v)$. It is then easy to verify that $f(v^*) = a/k\mu$. If $v > v^*$, $\underline{\lambda}(v) < 0$, so firms will select only partial, or maybe no insurance cover for their potential losses. If $v \leq v^*$, $\underline{\lambda}(v) \geq 0$. In this case the equilibrium insurance cover purchased by firms 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 insurance; when $\lambda \leq \underline{\lambda}(v)$, firms will select full insurance.

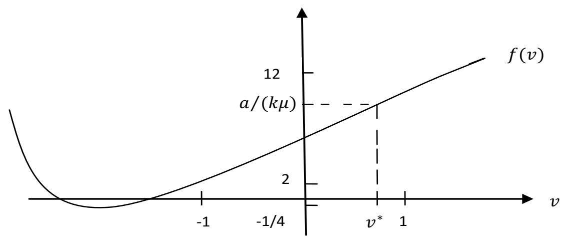

Figure A.1 Critical Value v^* for Insurance Coverage Choice

Proof of Proposition 2

Proof: (a) From equation (13), $g'(v) = \frac{-(3v^2+10v+11)}{[(1+v)(3+v)]^2} < 0$. This implies that a lower v (a more competitive product market) leads to a higher $g(v)$. Thus, it is more likely that $\lambda < g(v)$ will be satisfied, which implies that firms are more likely to purchase insurance, according to Proposition 1(a).

(b) When $\lambda < g(v)$, from equation (12) we have

$$\frac{\partial \alpha^*}{\partial v} = \frac{-2\lambda(2+v)[v^2+5v+5+\lambda(3+v)(3+2v)]-[1-\lambda(1+v)(3+v)][2v+5+\lambda(9+4v)]}{[v^2+5v+5+\lambda(3+v)(3+2v)]^2}\frac{a-k\mu}{k\mu} \leq 0.$$

Therefore, firms' insurance coverage increases with the intensity of product market competition. Moreover, when $\lambda < g(v)$, again from equation (12) we have $\frac{\partial \alpha^*}{\partial a} = \frac{1-\lambda(3+v)(1+v)}{v^2+5v+5+\lambda(3+v)(3+2v)}\frac{1}{k\mu} \geq 0$, that is, firms' insurance coverage increases with the size of the product market.

Proof of Lemma 2

Proof: (a) Given the assumptions and the support of parameter values, it is straightforward to verify that $A, B, C,$ and D defined below equation (15) are all positive. We can also obtain following equations:

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

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

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

Therefore, from equation (15), we have

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

Similarly, when $BD - bA \leq 0$, $\partial q_i^*/\partial \alpha_j = 0$; otherwise from equation (15):

$$\partial q_i^*/\partial \alpha_j = \frac{-(BC-b^2)\left[2\gamma k^2\sigma^2(1-\alpha_j)A+bk\mu\right]+2(AC-bD)\gamma k^2\sigma^2(1-\alpha_j)B}{(BC-b^2)^2}$$
$$= -\frac{2b\gamma k^2\sigma^2(1-\alpha_j)(BD-bA)+bk\mu(BC-b^2)}{(BC-b^2)^2}$$
$$= -\frac{1}{(BC-b^2)}\left[2b\gamma k^2\sigma^2\left(1-\alpha_j\right)q_j^* + bk\mu\right] < 0.$$

(b) For the symmetric case with $\alpha_i = \alpha_j = \alpha$, we denote

$A|_{\alpha_i=\alpha_j=\alpha} = D|_{\alpha_i=\alpha_j=\alpha} = a - (1-\alpha)k\mu \equiv \tilde{A};$

$B|_{\alpha_i=\alpha_j=\alpha} = C|_{\alpha_i=\alpha_j=\alpha} = (2+v)b + \gamma(1-\alpha)^2k^2\sigma^2 \equiv \tilde{B}.$ (A.1)

We then have $q_i^* = q_j^* = q^* = \frac{\tilde{A}}{\tilde{B}+b}$; $Q^* = 2q^*$; $\partial Q^*/\partial\alpha = \frac{2k\mu(\tilde{B}+b)+4\gamma k^2\sigma^2(1-\alpha)\tilde{A}}{(\tilde{B}+b)^2} > 0$; 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 Proposition 3

Proof: (a) In the symmetric setup, firms' decision to obtain positive optimal insurance coverage or not depends on the behavior of the necessary condition (18) at $\alpha = 0$. Denote: $\tilde{A}_0 \equiv \tilde{A}\big|_{\alpha=0} = a - k\mu$, and $\tilde{B}_0 \equiv \tilde{B}\big|_{\alpha=0} = (2+v)b + \gamma k^2\sigma^2$. We have:

$$\begin{aligned}
(18)|_{\alpha=0} &= \left[k\mu\tilde{A}(\tilde{B}+b)[(1+\lambda)b^2 - \lambda\tilde{B}^2] + \gamma k^2\sigma^2\tilde{A}^2(\tilde{B}^2+b^2)\right]\Big|_{\alpha=0} \\
&= k\mu\tilde{A}_0(\tilde{B}_0+b)\left[(1+\lambda)b^2 - \lambda{\tilde{B}_0}^{\,2}\right] + \gamma k^2\sigma^2{\tilde{A}_0}^{\,2}({\tilde{B}_0}^{\,2}+b^2) \\
&= k\mu\tilde{A}_0(\tilde{B}_0+b)\left[\frac{\gamma k^2\sigma^2\tilde{A}_0({\tilde{B}_0}^{\,2}+b^2)}{k\mu(\tilde{B}_0+b)} + b^2 - \lambda({\tilde{B}_0}^{\,2} - b^2)\right] \\
&= k\mu(a-k\mu)[(3+v)b+\gamma k^2\sigma^2]\{[(2+v)b+\gamma k^2\sigma^2]^2 - b^2\}\left[\bar{\lambda}(v,\gamma) - \lambda\right], \qquad \text{(A.2)}
\end{aligned}$$

where

$$\bar{\lambda}(v,\gamma) \equiv \frac{\gamma k\sigma^2(a-k\mu)\left[(2+v)b+\gamma k^2\sigma^2\right]^2 + b^2[(3+v)b\mu + a\gamma k\sigma^2]}{\mu[(3+v)b+\gamma k^2\sigma^2]\{[(2+v)b+\gamma k^2\sigma^2]^2 - b^2\}}. \qquad \text{(A.3)}$$

It is obvious from equation (A.3) that $\bar{\lambda}(v) > 0$. From equation (A.2), we know that if $\lambda > \bar{\lambda}(v,\gamma)$, $FOC(18)|_{\alpha=0} < 0$, which implies that firms will not obtain insurance at all; when $\lambda \le \bar{\lambda}(v,\gamma)$, firms will obtain positive insurance coverage. Therefore, $\bar{\lambda}(v,\gamma)$ is the cutoff level of the insurance premium loading that determines whether firms will choose positive optimal insurance coverage prior to product market competition.

(b) Now assuming that $\lambda \le \bar{\lambda}(v,\gamma)$, so firms will choose to insure their potential losses. Given this, the condition of firms obtaining full or partial insurance coverage depends on the behavior of the necessary condition (18) at $\alpha = 1$. With $\alpha = 1$, from equation (17) we have $\tilde{A}\big|_{\alpha=1} = a$, and $\tilde{B}\big|_{\alpha=1} = (2+v)b$. Equation (18) can then be reduced to

$$\begin{aligned}
(18)|_{\alpha=1} &= k\mu(\tilde{B}+b)\left[(1+\lambda)[b^2\tilde{A} - k\mu\tilde{B}(\tilde{B}+b)] - \lambda\tilde{A}\tilde{B}^2\right]\Big|_{\alpha=1} \\
&= b^3k\mu(3+v)\{(1+\lambda)[a - k\mu(2+v)(3+v)] - \lambda a(2+v)^2\} \\
&= b^3k\mu(3+v)^2[a(1+v) + k\mu(2+v)]\left[\underline{\lambda}(v) - \lambda\right], \qquad \text{(A.4)}
\end{aligned}$$

where $\underline{\lambda}(v)$ is defined by (14). From equation (A.4) we know that the sign of $FOC(18)|_{\alpha=1}$ is the same as the sign of $\underline{\lambda}(v) - \lambda$. If $\lambda > \underline{\lambda}(v)$, we have $(18)|_{\alpha=1} < 0$, which implies that firms will choose partial insurance coverage. If $\lambda \le \underline{\lambda}(v)$, we have $(18)|_{\alpha=1} \ge 0$, which implies that firms will choose full insurance coverage.

A sufficient condition for firms to only choose partial insurance is when $a - k\mu(2+v)(3+v) < 0$, where from equation (14) we obtain $\underline{\lambda}(v) < 0 < \lambda$ for any non-negative insurance premium loading λ. Solving for v^* such that $(3+v^*)(2+v^*) = a/k\mu$, we have: $v^* = \frac{\sqrt{1+4(a/k\mu)}-5}{2}$. Therefore, if $v > v^*$, we have $\underline{\lambda}(v) < 0$, which implies that firms will select only partial insurance.

Proof of Proposition 4

Proof: From equation (A.3), we have:

$$
\begin{aligned}
\frac{\partial\bar{\lambda}(v,\gamma)}{\partial v} &= \frac{\mu(\tilde{B}_0+b)({\tilde{B}_0}^2-b^2)(2\gamma k\sigma^2\tilde{A}_0\tilde{B}_0 b+b^3\mu)-\left[\gamma k\sigma^2\tilde{A}_0{\tilde{B}_0}^2+(3+v)b^3\mu+ab^2\gamma k\sigma^2\right]\left[b\mu\left({\tilde{B}_0}^2-b^2\right)+2\mu(\tilde{B}_0+b)\tilde{B}_0 b\right]}{\left[\mu(\tilde{B}_0+b)({\tilde{B}_0}^2-b^2)\right]^2} \\
&= \frac{b\mu(\tilde{B}_0+b)\left\{({\tilde{B}_0}^2-b^2)(2\gamma k\sigma^2\tilde{A}_0\tilde{B}_0+b^2\mu)-\left[\gamma k\sigma^2\tilde{A}_0{\tilde{B}_0}^2+(3+v)b^3\mu+ab^2\gamma k\sigma^2\right][(\tilde{B}_0-b)+2\tilde{B}_0]\right\}}{\left[\mu(\tilde{B}_0+b)({\tilde{B}_0}^2-b^2)\right]^2} \\
&= \frac{b\left\{(\tilde{B}_0-b)\left[\gamma k\sigma^2\tilde{A}_0{\tilde{B}_0}^2+2\gamma k\sigma^2\tilde{A}_0\tilde{B}_0 b-ab^2\gamma k\sigma^2+b^2\mu(\tilde{B}_0-(2+v)b)\right]-2\tilde{B}_0\left[\gamma k\sigma^2\tilde{A}_0{\tilde{B}_0}^2+(3+v)b^3\mu+ab^2\gamma k\sigma^2\right]\right\}}{\mu(\tilde{B}_0+b)({\tilde{B}_0}^2-b^2)^2} \\
&= \frac{b\left\{(\tilde{B}_0-b)\gamma k\sigma^2\left(\tilde{A}_0{\tilde{B}_0}^2+2\tilde{A}_0\tilde{B}_0 b-ab^2+b^2\mu k\right)-2\tilde{B}_0\left[\gamma k\sigma^2\tilde{A}_0{\tilde{B}_0}^2+(3+v)b^3\mu+ab^2\gamma k\sigma^2\right]\right\}}{\mu(\tilde{B}_0+b)({\tilde{B}_0}^2-b^2)^2} \\
&= \frac{b\left\{\gamma k\sigma^2\left[(\tilde{B}_0-b)\tilde{A}_0\left({\tilde{B}_0}^2+2\tilde{B}_0 b-b^2\right)-2\tilde{A}_0{\tilde{B}_0}^3-2ab^2\tilde{B}_0\right]-2\tilde{B}_0(3+v)b^3\mu\right\}}{\mu(\tilde{B}_0+b)({\tilde{B}_0}^2-b^2)^2} \\
&= \frac{b\left\{\gamma k\sigma^2\left[-(\tilde{B}_0-b)\tilde{A}_0\left({\tilde{B}_0}^2+b^2\right)-2b^2\tilde{B}_0(\tilde{A}_0+a)\right]-2\tilde{B}_0(3+v)b^3\mu\right\}}{\mu(\tilde{B}_0+b)\left({\tilde{B}_0}^2-b^2\right)^2} \\
&< 0. \qquad\qquad \text{(A.5)}
\end{aligned}
$$

We obtain the inequality by 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 (14), we have:

$$
\begin{aligned}
\frac{\partial\underline{\lambda}(v)}{\partial v} &= \frac{-(3+v)[a(1+v)+k\mu(2+v)]k\mu(5+2v)-[a-k\mu(2+v)(3+v)][a(1+v)+k\mu(2+v)+(3+v)(a+k\mu)]}{\{(3+v)[a(1+v)+k\mu(2+v)]\}^2} \\
&= \frac{-(3+v)[a(1+v)+k\mu(2+v)]k\mu(5+2v)-[a-k\mu(2+v)(3+v)][2a(2+v)+k\mu(5+2v)]}{\{(3+v)[a(1+v)+k\mu(2+v)]\}^2} \\
&= \frac{-ak\mu(5+2v)(2+v)^2-2a(2+v)[a-k\mu(2+v)(3+v)]}{\{(3+v)[a(1+v)+k\mu(2+v)]\}^2} \\
&< 0,\ \text{when } v < v^*. \qquad\qquad \text{(A.6)}
\end{aligned}
$$

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 negative when $v < v^*$. From equation (14), we also have:

$$
\begin{aligned}
\frac{\partial\underline{\lambda}(v)}{\partial a} &= \frac{(3+v)[a(1+v)+k\mu(2+v)]-[a-k\mu(2+v)(3+v)](3+v)(1+v)}{\{(3+v)[a(1+v)+k\mu(2+v)]\}^2} \\
&= \frac{k\mu(2+v)^3(3+v)}{\{(3+v)[a(1+v)+k\mu(2+v)]\}^2} \\
&> 0. \qquad\qquad \text{(A.7)}
\end{aligned}
$$

Proof of Proposition 4 follows from the inequalities (A.5), (A.6) and (A.7), and Proposition 3. According to inequality (A.5), a lower v—which represents a more competitive product market—leads to a higher $\bar{\lambda}$; thus a higher likelihood of satisfying $\lambda < \bar{\lambda}$, which triggers insurance purchase according to Proposition 3(a). According to inequality (A.6), given $v < v^*$, a lower v leads to a higher $\underline{\lambda}$, thus a higher likelihood of satisfying $\lambda < \underline{\lambda}$, which triggers the selection of full coverage according to Proposition 3(b). Similarly, according to inequality (A.7), a higher a leads to a higher $\underline{\lambda}$, thus a higher likelihood of satisfying $\lambda < \underline{\lambda}$, which again triggers the selection of full coverage according to Proposition 3(b).

Appendix B. Unobservable insurance choices

In this appendix, we incorporate a signaling framework, employed in Aggarwal and Samwick (1999, hereafter AS), into our two-stage duopoly game for insurance and product market choices. For the simplicity of exposition and consistency with our main setup, we consider risk-neutral firms in a two-sided signaling framework, in which both firms make insurance and signaling choices in the first stage, and then engage in product market competition with each other in the second stage.

Our objectives in this appendix are first, to show that, under certain conditions, strategically purchasing insurance emerges in a signaling equilibrium, and second, to examine whether, given the existence of such an equilibrium, our main result regarding the positive effect of market competition on corporate demand for insurance continues to hold. Specifically, we do the following: First, we consider the case with no insurance choice by both firms. Second, we consider a symmetric case with which the insurance choice by either firm is publicly observable. Lastly, we show when the positive insurance choice can still appear in equilibrium even when we assume such a choice is not publicly observable, and whether the chosen insurance coverage positively responds to an increase in the intensity of product market competition.

We first consider the case in which both firms choose not to purchase insurance. In this case, we only need to determine the output levels in the second stage during which these firms engage in the product market competition before their operating loss is realized. That is, firm i will choose an output level to maximize its following expected payoff:

$$V_i(q_i, q_j, \alpha_i = 0) = (a - bq_i - bq_j)q_i - k\mu q_i \tag{A.8}$$

The first-order condition (FOC) entails

$$\partial V_i/\partial q_i = a - k\mu - (2 + v)bq_i - bq_j = 0. \tag{A.9}$$

From (A.9), we know firm i's *reaction function* under the no-insurance case is

$$q_i^*(q_j) = \frac{a-k\mu-bq_j}{(2+v)b}. \tag{A.10}$$

The (symmetric) equilibrium output levels and the expected payoff are as follows:

$$q_i^* = q_j^* = q^* = \frac{a-k\mu}{(3+v)b};\ V_i^* = V_j^* = V^* = \frac{(1+v)(a-k\mu)^2}{(3+v)^2 b}. \tag{A.11}$$

Second, we consider the case in which both firms have the opportunity to commit to insurance purchase before taking an output market strategy. Under the assumptions that the insurance choice is publicly observable and that firms are risk neutral, the optimal strategies for both firms become identical to what we describe in Section 3 of the main paper. That is, in the second stage, firm i's *reaction function* under insurance choice is:

$$q_i^{**}(q_j) = \frac{a-(1-\alpha_i)k\mu-bq_j}{(2+v)b}, \tag{A.12}$$

which further gives the equilibrium output levels as:

$$q_i^{**}(\alpha_i, \alpha_j) = \max\left(\frac{(1+v)[a-(1-\alpha_i)k\mu]+(\alpha_i-\alpha_j)k\mu}{(1+v)(3+v)b}, 0\right). \tag{A.13}$$

Anticipating the outcomes in the product market competition, both firms choose the same insurance coverage α^* in the unique and symmetric equilibrium:

$$\alpha_i^* = \alpha_j^* = \alpha^* = \min\left(\max\left(\frac{1-\lambda(1+v)(3+v)}{v^2+5v+5+\lambda(3+v)(3+2v)}\frac{a-k\mu}{k\mu}, 0\right), 1\right). \tag{A.14}$$

Substituting (A.14) into (A.13), we have:

$$q_i^{**} = q_j^{**} = q^{**} = \max\left(\frac{a-(1-\alpha^*)k\mu}{(3+v)b}, 0\right). \tag{A.15}$$

Third, we will now demonstrate that, when firms' first-stage insurance choice is not publicly observable, there may exist an equilibrium under which firms choose to purchase insurance and signal it to their rival firms before determining their output levels under market competition, given that insurance is not too expensive ($\lambda < g(v) = 1/(1+v)(3+v)$). Suppose that a firm—without loss of generality, namely, firm i—chooses insurance coverage α_i^* in the first stage. If it wants to signal such an insurance choice, it chooses an insurance signaling action $c = c^{is} \in [0, \infty)$ (which, for simplicity, also denotes the cost of this signaling action incurred by the firm). If firm i wants to signal that it has not purchased any insurance, it chooses a no insurance signaling action $c = c^{nis}$ (which also denotes the cost of the no insurance signaling action incurred by the firm). The incentive compatibility (IC) constraints for the two choices that firm i can undertake are[28]

$$
\begin{aligned}
&V_i(q^{**}, q^{**}, \alpha^*) - (1+\lambda)\alpha^* k\mu q^{**} - c^{is} \\
&\quad \geq V_i(q_i^{**}(q_j = E(q_j | c = c^{nis})), E(q_j | c = c^{nis}), \alpha^*) \\
&\qquad -(1+\lambda)\alpha^* k\mu q_i^{**}(q_j = E(q_j | c = c^{nis})) - c^{nis},
\end{aligned} \tag{A.16}
$$

and

$$V_i(q^*, q^*, 0) - c^{nis} \geq V_i(q_i^*(q_j = E(q_j | c = c^{is})), E(q_j | c = c^{is}), 0) - c^{is}. \tag{A.17}$$

Equation (A.16) ensures that, after purchasing insurance, firm i's expected payoff by signaling its insurance purchase to firm j while incurring c^{is} is greater than or equal to its expected payoff by lying (i.e., making firm j believe that it has not purchased any insurance) while incurring c^{nis}. Equation (A.17) ensures that, after choosing not to purchase insurance, firm i's expected payoff by signaling its choice of no insurance is greater than or equal to its expected profit by lying as if it has a positive insurance coverage.

In the above, the expected output of firm j conditional on observing firm i's action of c^{is} is q^{**}, and firm j's expected output conditional on observing firm i's action of c^{nis} is q^*, i.e.,

$$E(q_j | c = c^{is}) = q^{**}, \text{ and } E(q_j | c = c^{nis}) = q^*. \tag{A.18}$$

Using the reaction functions (A.10) and (A.12), and definitions of q^* and q^{**} in (A.11) and (A.15), respectively, we have

$$
\begin{aligned}
&q_i^{**}(q_j = q^*) \equiv \hat{q}_i^{**} = \frac{(2+v)(a-k\mu)+(3+v)\alpha^* k\mu}{(2+v)(3+v)b}, \text{ and} \\
&q_i^*(q_j = q^{**}) \equiv \hat{q}_i^* = \frac{(2+v)(a-k\mu)-\alpha^* k\mu}{(2+v)(3+v)b}.
\end{aligned} \tag{A.19}
$$

Recall that $V_i(q_i, q_j, \alpha_i) = (a - bq_i - bq_j)q_i - (1-\alpha_i)k\mu q_i$. Substituting (A.18) and (A.19) into the first IC constraint (A.16) yields

$$
\begin{aligned}
&(a - bq^{**} - bq^{**})q^{**} - (1-\alpha^*)k\mu q^{**} - (1+\lambda)\alpha^* k\mu q^{**} - c^{is} \\
&\quad \geq V_i\{\hat{q}_i^{**}, q^*, \alpha^*\} - (1+\lambda)\alpha^* k\mu \hat{q}_i^{**} - c^{nis} \\
&\quad = (a - b\hat{q}_i^{**} - bq^*)\hat{q}_i^{**} - (1-\alpha^*)k\mu \hat{q}_i^{**} - (1+\lambda)\alpha^* k\mu \hat{q}_i^{**} - c^{nis},
\end{aligned}
$$

which can be further expressed as

$$
\begin{aligned}
&c^{is} - c^{nis} \leq b[(\hat{q}_i^{**})^2 - (q^{**})^2] + b(\hat{q}_i^{**}q^* - (q^{**})^2) + [a - (1+\lambda\alpha^*)k\mu](q^{**} - \hat{q}_i^{**}), \iff \\
&c^{is} - c^{nis} \leq \frac{-\{2(1+v)(2+v)(a-k\mu) + [(v^2+2v-1) - \lambda(2+v)(3+v)]\alpha^* k\mu\}\alpha^* k\mu}{[(2+v)(3+v)]^2 b}.
\end{aligned} \tag{A.20}
$$

Similarly, the second IC constraint (A.17) implies that

$$
\begin{aligned}
&V_i(q^*, q^*) - c^{nis} = (a - bq^* - bq^*)q^* - k\mu q^* - c^{nis} \\
&\quad \geq V_i(\hat{q}_i^*, q^{**}) - c^{is} = (a - b\hat{q}_i^* - bq^{**})\hat{q}_i^* - k\mu \hat{q}_i^* - c^{is}, \qquad \iff \\
&c^{is} - c^{nis} \geq b[(q^*)^2 - (\hat{q}_i^*)^2] + b((q^*)^2 - \hat{q}_i^* q^{**}) - (a - k\mu)(q^* - \hat{q}_i^*), \quad \iff \\
&c^{is} - c^{nis} \geq \frac{(1+v)[\alpha^* k\mu - 2(2+v)(a-k\mu)]\alpha^* k\mu}{[(2+v)(3+v)]^2 b}.
\end{aligned} \tag{A.21}
$$

To satisfy both IC constraints (A.20) and (A.21), we need to show that the right-hand side (RHS) of (A.20) is greater than the RHS of (A.21). If this is indeed the case, there may exist a credible signaling game that supports the equilibrium in which firm i will purchase insurance in the first stage and signal that to firm j, even when such an insurance choice is not directly observable to firm j.

The RHS of (A.20) − the RHS of (A.21)

---

[28] Where $E(\cdot \mid \cdot)$ is the conditional expectation operator based on the counter party's belief, and $q_i^{**}(q_j)$ and $q_i^*(q_j)$ denote firm i's reaction function in the insurance commitment case (A.16) and non-commitment case (A.14), respectively.

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

$$= \frac{[\lambda(2+v)-v](\alpha^* k\mu)^2}{(2+v)^2(3+v)b}. \quad \text{(A.22)}$$

Hence, when $\lambda > v/(2+v) \equiv \varphi(v)$, the RHS of (A.20) is greater than the RHS of (A.21). This together with the condition for $\alpha^* > 0$, namely, $\lambda < g(v) \equiv 1/(1+v)(3+v)$, will support that a signaling equilibrium exists.

We have shown in the main text that $g'(v) < 0$. It is straightforward to verify that $\varphi'(v) > 0$. Therefore, as v becomes smaller (the product market becomes more competitive), the more likely the condition $\varphi(v) < \lambda < g(v)$ will be satisfied, i.e., the more likely a signaling equilibrium exists. It can be shown that for $-1 < v \leq 0.481$, $g(v) > \varphi(v)$, hence the two inequalities $\lambda > \varphi(v)$ and $\lambda < g(v)$ could be simultaneously satisfied, and therefore the signaling equilibrium may exist. When $v > 0.481$, $g(v) < \varphi(v)$, implying that such a signaling equilibrium with positive insurance purchase does not exist.

Given that a signaling equilibrium exists, the equilibrium insurance coverage α^* is given in equation (A.14), which is again the same as the α^* in Section 3. From the proof of Proposition 2(b), we know that $\partial\alpha^*/\partial v \leq 0$, when $\lambda < g(v)$. Therefore, our main result that firms competing in a more competitive product market tend to purchase more insurance still holds in the two-sided signaling model here.

Appendix C. Strategic insurance choices in a dynamic setting

In this appendix, we extend the main model with risk-neutral firms into a dynamic setting. Recall that the main model is a two-stage static game in which two firms choose insurance coverage and output strategies in a non-cooperative way. In equilibrium, firms thus commit ex ante to their positive insurance coverage and take a more aggressive output market strategy than they would with no insurance. In what follows, we consider an infinitely repeated game that allows for a collusive equilibrium in which firms coordinate a no-insurance policy with each other to soften their output market competition. We then examine firms' willingness to deviate from the designated policy and go back to the non-cooperative equilibrium, i.e., the static game in our main model, after the period of retaliation.

We first consider the collusive equilibrium outcome. Firms cooperate by committing to no use of insurance and then engage in product market competition based on the given market structure characterized by v. This is the same case as the first case in Appendix B, where we have shown that both firms choose a symmetric equilibrium output level $q^* = \frac{a-k\mu}{(3+v)b}$, which further gives them the following expected cooperation payoff: $W^* = V^* = p(q^*, q^*)q^* - k\mu q^* = \frac{(1+v)(a-k\mu)^2}{(3+v)^2 b}$.

We now consider a firm's incentive to deviate from above collusive agreement. Assume that firm j follows the designated action: $\alpha_j = 0$. If firm i deviates from the collusion by choosing $\alpha_i > 0$, this non-zero insurance purchase is observed by firm j when both firms choose their optimal output levels. In particular, given their insurance choices, $\alpha_i > 0$ and $\alpha_j = 0$, they maximize their respective expected payoff,

$$V_i(q_i, q_j, \alpha_i) = \pi_i(q_i, q_j) - (1-\alpha_i)k\mu q_i,$$

$$V_j(q_i, q_j) = \pi_j(q_i, q_j) - k\mu q_j. \quad \text{(A.23)}$$

The FOCs are

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

$$\partial V_j/\partial q_j = a - k\mu - (2+v)bq_j - bq_i = 0, \tag{A.24}$$

from which we first obtain $q_i^{**} = q_j^{**} + \frac{\alpha_i k\mu}{(1+v)b}$. This implies that positive insurance coverage enables firm i to produce more than its uninsured rival firm j. From (A.24), we further obtain the following equilibrium output levels:

$$q_i^{**} = \max\left(\frac{(1+v)(a-k\mu)+(2+v)\alpha_i k\mu}{(1+v)(3+v)b}, 0\right),\ q_j^{**} = \max\left(\frac{(1+v)(a-k\mu)-\alpha_i k\mu}{(1+v)(3+v)b}, 0\right). \tag{A.25}$$

Anticipating the above outcomes of the product market decisions, firm i will choose α_i in the first stage, to maximize its expected payoff:

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

The FOC is

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

$$\partial W_i/\partial \alpha_i = \frac{bq_i^{**}k\mu}{(1+v)(3+v)b} + k\mu q_i^{**} - (1+\lambda)k\mu\left[q_i^{**} + \frac{(2+v)\alpha_i k\mu}{(1+v)(3+v)b}\right] = 0,$$

which can be further simplified as:

$$\partial W_i/\partial \alpha_i = bq_i^{**} - \lambda b q_i^{**}(1+v)(3+v) - (1+\lambda)(2+v)\alpha_i k\mu. \tag{A.26}$$

Therefore, we have:

$$\alpha_i^{**} = \min\left(\max\left(\frac{(1+v)[1-\lambda(1+v)(3+v)]}{(2+v)[(1+2\lambda)(1+v)(3+v)-1]}\frac{a-k\mu}{k\mu}, 0\right), 1\right). \tag{A.27}$$

Finally, we calculate firm i's expected payoff in the deviation period as

$$\begin{aligned}
W_i^{**} &= p\left(q_i^{**}, q_j^{**}\right)q_i^{**} - (1-\alpha_i^{**})k\mu q_i^{**} - (1+\lambda)\alpha_i^{**}k\mu q_i^{**} \\
&= \left[p\left(q_i^{**}, q_j^{**}\right) - (1+\lambda\alpha_i^{**})k\mu\right]q_i^{**} \\
&= \left\{\frac{(1+v)(a-k\mu)-[1+\lambda(3+v)]\alpha_i^{*}k\mu}{(3+v)}\right\}\frac{(1+v)(a-k\mu)+(2+v)\alpha_i^{*}k\mu}{(1+v)(3+v)b} \\
&= \frac{(1+v)^2(a-k\mu)^2}{(3+v)b}\frac{\left\{(1+v)\left(v^2+5v+5\right)-2+\lambda(3+v)\left[2v^2+7v+4+\lambda(1+v)(3+v)\right]\right\}(1+\lambda)}{(2+v)[v^2+4v+2+2\lambda(1+v)(3+v)]^2}.
\end{aligned} \tag{A.28}$$

Following Cabral (1995), we consider a one-period minimax-punishment, i.e., firm i will receive a payoff of zero in the following period after deviating and achieving the deviation payoff as described in (A.28). After the period of punishment, both firms go back to their non-cooperative game in subsequent periods as the collusion cannot be sustained. Their payoffs from the non-cooperative game in each of the subsequent period are the same as in the main model based on $q^{***} = \frac{a-(1-\alpha)k\mu}{b(3+v)}$; $\alpha^{***} = \frac{1-\lambda(3+v)(1+v)}{v^2+5v+5+\lambda(3+v)(3+2v)}\frac{a-k\mu}{k\mu}$, and can be calculated as:

$$\begin{aligned}
W^{***} &= p(q^{***}, q^{***})q^{***} - (1-\alpha^{***})k\mu q^{***} - (1+\lambda)\alpha^{***}k\mu q^{***} \\
&= \frac{[(a-k\mu)+\alpha^{**}k\mu]\{(1+v)(a-k\mu)-\alpha^{**}k\mu[2+\lambda(3+v)]\}}{b(3+v)^2} \\
&= \frac{(a-k\mu)^2(1+\lambda)(2+v)\left\{(1+v)\left[v^2+5v+5+\lambda(3+v)(3+2v)\right]-[1-\lambda(3+v)(1+v)][2+\lambda(3+v)]\right\}}{b(3+v)[v^2+5v+5+\lambda(3+v)(3+2v)]^2}
\end{aligned} \tag{A.29}$$

Let r denote the inter-temporal discount factor. Firm i's incentive compatibility constraint for cooperation is then given by

$$\frac{W^*}{1-r} \geq W_i^{**} + r^2\frac{W^{***}}{1-r}. \tag{A.30}$$

We denote by $\hat{r}$ the discount rate at which the equality holds in (A.30). If the discount rate is higher than $\hat{r}$, there exists the collusive equilibrium with no insurance purchase, and, otherwise, firms will deviate from the collusive agreement and choose positive insurance coverage as in the equilibrium of the static game in our main model. We numerically show that, under reasonable parameter constellations, the trigger level for the discount rate, $\hat{r}$, which determines a firm's willingness to deviate from the collusive equilibrium, is decreasing in the intensity of product market competition, v. This suggests that, in a more competitive product market environment, firms are more willing to deviate from the collusive agreement with no insurance purchase and go back to the non-cooperative equilibrium that corresponds to the equilibrium outcome of the static game in our main model.

Appendix D. Premium loading factor and product market competition

In our main model, we assume a fixed premium loading that is invariant with both the level of insurance coverage purchased and the product market environment in which firms operate. This simplified assumption has been used often in the literature, for example, in Doherty and Schlesinger (1983). In this appendix, we extend our analysis by allowing the insurance premium loading factor λ to depend upon product market competition in which firms will engage after purchasing insurance. Specifically, we consider an insurance loading factor that is a function of the intensity of product market competition, v: $\lambda = \lambda(v) \in [0, 1]$. For the simplicity of exposition, we consider the case with symmetric risk-neutral firms in this extension.

The optimal output decisions of two risk-neutral firms in the second period are identical to those derived in the basic model. Consider the symmetric equilibrium under which the firms choose an output level of $q^*(\alpha, v) = \frac{a-(1-\alpha)k\mu}{b(3+v)}$ as shown in (8). In the first period, firm i selects insurance coverage α_i to maximize its expected payoff: $Max_{\alpha_i} W_i(\alpha_i, \alpha_j) = V_i(q_i^*, q_j^*, \alpha_i) - [1 + \lambda(v)]\alpha_i k\mu q_i^*$. Using the FOC (11) with $\lambda = \lambda(v)$, we obtain:

$$\alpha^* = \min\left(\max\left(\frac{(1+v)(3+v)[g(v)-\lambda(v)]}{v^2+5v+5+\lambda(v)(3+v)(3+2v)}\frac{a-k\mu}{k\mu}, 0\right), 1\right), \tag{A.31}$$

where $g(v) \equiv \frac{1}{(1+v)(3+v)}$. It is easy to verify that $g'(v) < 0$, for all $v \in (-1, 1]$. Denote

$$\psi(v) \equiv g(v) - \lambda(v). \tag{A.32}$$

Assume that $\psi(v) = 0$ has a unique solution, $\bar{v}$. Below, we distinguish and discuss two cases with regard to how the insurance loading factor (λ) reacts to the intensity of product market competition (v).

In the first case with $\lambda'(v) > 0$, that is, when a more competitive product market environment results in a lower insurance premium loading factor,[29] we have $\psi'(v) = g'(v) - \lambda'(v) < 0$. Therefore, in this case, when $v < \bar{v}$, $\psi(v) > 0(= \psi(\bar{v}))$, which implies that $\alpha^* > 0$; when $v \geq \bar{v}$, $\psi(v) \leq 0(= \psi(\bar{v}))$, which implies that $\alpha^* = 0$. In other words, when the insurance premium loading factor decreases with the competition intensity of the product market where firms operate, firms are more likely to purchase insurance when competing in a more competitive output market—a result that is in line with the findings from our main model with a fixed insurance loading factor.

In the second case with $\lambda'(v) < 0$, that is, when a more competitive product market environment leads to a higher insurance premium loading,[30] the sign of $\psi'(v) = g'(v) - \lambda'(v)$ depends on which term of $g(v)$ or $\lambda(v)$ is more responsive to the changes in v. If $g'(v) < \lambda'(v)$, that is, if an increase in the

---

[29] The reason for $\lambda'(v) > 0$ can be, for example, as follows: A more competitive product market typically accompanies more firms in the market, which naturally implies higher aggregate demand for insurance. Providing the same insurance service to more firms may allow the insurers to operate more efficiently due to economies of scale, thus to offer a lower expense loading factor, which translates to a lower insurance premium to the insured firms.

[30] The mechanism through which this effect works can be, for example, a higher aggregate demand for insurance that enables insurers to charge a higher profit loading. A higher aggregate product output level may also lead to a more volatile loss exposure, which translates into a higher contingency loading in the premium.

intensity of product market competition enhances the commitment value of insurance more than it increases the cost of insurance, we would have the same conclusion as in the first case, where $\bar{v}$ again serves as the threshold of market competition intensity for positive insurance demand. On the other hand, if $g'(v) \geq \lambda'(v)$, we would have the opposite conclusion to the first case. Particularly, now $v \leq \bar{v}$ implies that $\alpha^* = 0$, whereas $v > \bar{v}$ implies that $\alpha^* > 0$. In other words, following a marginal increase in the competition intensity of the firms' output market, if the insurance premium charged by insurers increases faster than the strategic benefit of insurance does, firms competing in a more competitive output market are less likely to purchase insurance coverage—a result that is opposite to the findings from our main model with a fixed insurance loading factor.

In summary, when the premium loading factor varies with firms' competitive environment, two outcomes possibly emerge. First, if the corporate insurance price drops with the degree of firms' output market competition, all our results derived from the main model with a fixed loading factor still hold true. Second, if the corporate insurance price increases with the degree of firms' output market competition, the positive impact of competition intensity on corporate demand of insurance may or may not continue to hold, depending on which of the two—the strategic commitment effect of insurance or the cost of insurance—increases faster with the product market rivalry.

Appendix E. Variable definitions

- Reinsurance ratio (REINS): Reinsurance premiums ceded divided by total business premiums (which is measured by the sum of direct premiums written and reinsurance premiums assumed)
- Net reinsurance ratio (NET_REINS): (Reinsurance premiums ceded minus reinsurance premiums assumed) divided by direct premiums written
- External reinsurance ratio (EXT_REINS): Reinsurance premiums ceded to non-affiliates divided by total business premiums
- Market competition (HHI): $\sum_i w_i HHI_i$, where i represents each specific market segmented by state and line of business, w_i is the portion of the insurer's direct premiums written in that specific market, and HHI_i is the Herfindahl index of the specific market
- Market competition (CR4): $\sum_i w_i CR4_i$, where $CR4_i$ is the four-firm concentration ratio of each specific market i; w_i is the portion of the insurer's direct premiums written in the market
- Market competition (CR8): $\sum_i w_i CR8_i$, where $CR8_i$ is the eight-firm concentration ratio of each specific market i; w_i is the portion of the insurer's direct premiums written in the market
- Market competition (AVG_PRICE): $\sum_i w_i AVG\_PRICE_i$, where AVG_PRICE_i is the average price among all firms operating in each specific market i; the price variable is measured by premiums earned divided by the sum of losses incurred and loss adjustment expenses; w_i is the portion of the insurer's direct premiums written in the market
- Log of market size (MKTSIZE): $\sum_i w_i MKTSIZE_i$, where $MKTSIZE_i$ is the log of the sum of direct premiums written by all insurers operating in market i; w_i is the portion of the insurer's direct premiums written in the market
- Market risk (MKTRISK): $\sum_i w_i MKTRISK_i$, where $MKTRISK_i$ is the average underwriting risk among all insurers operating in market i; the underwriting risk is measured by the past 3-year standard deviation of firm loss ratio (losses incurred plus loss adjustment expenses divided by premiums earned)
- Affiliated reins state (AFF_COMB): $\sum_j w_j COMB_j$, where j represents each firm assuming premiums from affiliates within the group to which the insurer belongs; w_j is the ratio of the insurer's premiums ceded to firm j to the insurer's total premiums ceded to its affiliates; and

$\mathrm{COMB_j}$ is the combined ratio of firm j (which is measured by the sum of losses incurred, loss adjustment expenses, and other underwriting expenses incurred divided by premiums earned

- US unaffiliated reins state (US_COMB): $\sum_k w_k \mathrm{COMB}_{k,}$ where k represents each US 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 US unaffiliated firms, and $\mathrm{COMB_k}$ is the combined ratio of firm k
- Non-US reins state (NONUS_COMB): Average combined ratio of non-US reinsurers that are the top 100–150 reinsurers around the world
- Reins contract with affiliate (AFF): Dummy variable equal to 1 if the insurer cedes premiums to any affiliates (i.e. receiving reinsurance service from any affiliates)
- Reins contract with US unaffiliate (US_UNAFF): Dummy variable equal to 1 if the insurer cedes premiums to any US unaffiliated firms
- Reins contract with non-US firm (NONUS): Dummy variable equal to 1 if the insurer cedes premiums to any non-US reinsurers
- Log of firm size (SIZE): Log of total assets
- Profitability (ROA): Return on assets (net income divided by total assets)
- Leverage (LEV): Total liabilities divided by total assets
- Cash flow volatility (CF_VOL): Overall volatility based on the volatility of losses, the volatility of assets, and the covariance of losses and assets
- Tax-exempt invest income (TAX-EXEMPT): Tax-exempt investment income (= bond interest exempt from federal taxes plus seventy percent of dividends received for common and preferred stock) divided by total investment income
- Catastrophe exposure (CAT): Percentage of direct premiums written by the insurer in Gulf Coast and Atlantic Coast states (Texas, Louisiana, Florida, Alabama, Mississippi, Georgia, Virginia, North Carolina, South Carolina) in several related property lines (fire, multiple peril crop, farm owners, homeowners, and commercial multiple peril, ocean marine, and auto physical damage) plus the percentage of direct premiums written in earthquake insurance
- Business mix concentration (BM_CONC): Herfindahl index of market concentration using direct premium
  written in market segmented by state and line of business by the insurer
- Line-of-business concentration (BL_CONC): Herfindahl index of line of business concentration using direct premiums written in line of business by the insurer
- Geographic concentration (G_CONC): Herfindahl index of geographic concentration using direct premium
  written in state by the insurer
- Log of age (AGE): Log of the insurer's age
- Publicly listed company (PUBLIC): Dummy variable equal to 1 if the insurer is a stock company
- Log of number of affiliates (NUM_AFF): Log of the number of companies in the insurer's group
- Company-to-affiliation size ratio (AFF_SIZE_RATIO): Ratio of the insurer's assets to the sum of the group's assets
- All line-of-business controls: Each represents the insurer's proportion of direct business written in each of 26 lines of business (Fire, Allied lines, Farmowners, Homeowners, Commercial, Mortgage guaranty, Ocean marine, Inland marine, Financial guaranty, Medical malpractice, Earthquake, Group Accident & Health (A&H), Credit A&H, Other A&H, Workers' compensation, Other liability, Product liability, Auto liability, Auto physical damage, Aircraft, Fidelity, Surety, Glass, Burglary and theft, Boiler and machinery, Credit)

Table 1 Summary statistics

This table report the summary statistics for the variables employed in our regression analysis. Panel A presents means, medians, standard deviations, and 25th and 75th percentiles of reinsurance ratios (dependent variables). Panel B provides summary statistics for firm-specific primary insurance market-related variables. Panel C presents summary statistics for firm-specific reinsurance supply-side variables. Finally, Panel D presents other firm-level control variables. The sample period is 1996–2008. All variables are defined in Appendix E.

Panel A: Reinsurance variables						
	N	Mean	SD	25th%	Median	75th%
Reinsurance ratio (REINS)	18,931	0.406	0.288	0.151	0.358	0.636
Net reinsurance ratio (NET_REINS)	14,835	0.390	0.295	0.137	0.317	0.624
External reinsurance ratio (EXT_REINS)	18,763	0.167	0.205	0.011	0.086	0.247
Panel B: Insurance market-related variables						
	N	Mean	SD	25th%	Median	75th%
Market competition (HHI)	18,931	0.065	0.052	0.038	0.052	0.071
Market competition (CR4)	18,931	0.369	0.127	0.280	0.351	0.422
Market competition (CR8)	18,931	0.495	0.137	0.402	0.479	0.552
Market competition (AVG_PRICE)	18,931	5.645	3.096	3.786	4.835	6.321
Log of market size (MKTSIZE)	18,931	20.900	1.122	20.339	21.105	21.662
Market risk (MKTRISK)	18,931	0.146	0.100	0.088	0.122	0.171
Panel C: Reinsurance supply-side variables						
	N	Mean	SD	25th%	Median	75th%
Affiliated reins state (AFF_COMB)	11,472	1.046	0.172	0.966	1.030	1.101
US unaffiliated reins state (US_COMB)	14,883	1.070	0.508	0.933	1.014	1.108
Non-US reins state (NONUS_COMB)	18,931	1.032	0.096	0.963	1.019	1.115
Reins contract with affiliate (AFF)	18,931	0.606	0.489	0	1	1
Reins contract with US unaffiliate (US_UNAFF)	18,931	0.786	0.410	1	1	1
Reins contract with non-US firm (NONUS)	18,931	0.560	0.496	0	1	1
Panel D: Other firm-level variables						
	N	Mean	SD	25th%	Median	75th%
Log of firm size (SIZE)	18,931	18.211	1.873	16.875	18.100	19.410
Profitability (ROA)	18,931	0.026	0.050	0.007	0.028	0.050
Leverage (LEV)	18,931	1.994	2.308	0.681	1.339	2.382
Cash flow volatility (CF_VOL)	18,931	0.421	0.149	0.303	0.399	0.523
Tax-exempt invest income (TAX-EXEMPT)	18,931	0.264	0.262	0.036	0.189	0.420
Catastrophe exposure (CAT)	18,931	0.098	0.211	0	0	0.091
Business mix concentration (BM_CONC)	18,931	0.319	0.297	0.074	0.226	0.481
Line-of-business concentration (BL_CONC)	18,931	0.527	0.287	0.284	0.460	0.751
Geographic concentration (G_CONC)	18,931	0.554	0.384	0.149	0.511	1
Log of age (AGE)	18,931	3.371	1.042	2.708	3.367	4.248
Publicly listed company (PUBLIC)	18,931	0.658	0.474	0	1	1
Log of number of affiliates (NUM_AFF)	18,931	1.160	1.168	0	0.693	1.946
Company-to-affiliation size ratio (AFF_SIZE_RATIO)	18,931	0.525	0.436	0.050	0.545	1

Table 2 Correlation between variables

This table shows the correlations between total reinsurance ratio (REINS), which is our main dependent variable, and independent variables of interest (firm-specific primary insurance market-related variables). All variables are defined in Appendix E.

	REINS	HHI	CR4	CR8	AVG_PRICE	MKTSIZE	MKTRISK
REINS	1						
HHI	-0.131	1					
CR4	-0.142	0.893	1				
CR8	-0.147	0.841	0.981	1			
AVG_PRICE	-0.053	0.126	0.103	0.141	1		
MKTSIZE	0.153	-0.392	-0.350	-0.362	-0.561	1	
MKTRISK	-0.006	0.342	0.305	0.310	0.301	-0.327	1

Table 3 Baseline results: Competition and reinsurance activity

The table shows the coefficient estimates for OLS regressions that examine the relation between the intensity of competition faced by primary insurers and their reinsurance utilization (Eq. (22)). The dependent variable is a primary insurer's total reinsurance ratio (REINS). The independent variables of interest are insurance market-related factors including the intensity of market competition faced by the primary insurer (HHI in columns (1) and (2), CR4 in column (3), CR8 in column (4), and AVG_PRICE in column (5); lower values of these variables indicate more competition), the market size, and the market underwriting risk. In all specifications, we include firm and year fixed effects, as well as all line-of-business controls (each of which represents the primary insurer's proportion of direct business written in that line of business). The sample period is 1996–2008, and all independent variables are lagged by one year. All variables are defined in Appendix E. We report standard errors adjusted for within-firm and within-year clustering in parentheses below the coefficient estimates. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Dep. Variable: REINS				
Variables	(1)	(2)	(3)	(4)	(5)
HHI	-0.159**	-0.152**			
	(0.077)	(0.076)			
CR4			-0.174***		
			(0.041)		
CR8				-0.192***	
				(0.040)	
AVG_PRICE					-0.002***
					(0.001)
MKTSIZE	0.025***	0.023***	0.025***	0.026***	0.024***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
MKTRISK	0.046***	0.044***	0.048***	0.048***	0.041***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
AFF*AFF_COMB	0.036***	0.035***	0.036***	0.036***	0.035***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
US_UNAFF*US_COMB	0.026***	0.025***	0.025***	0.025***	0.026***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
NONUS*NONUS_COMB	-0.007	-0.009	-0.008	-0.006	-0.008
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
SIZE	-0.070***	-0.071***	-0.069***	-0.069***	-0.070***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
ROA	0.177***	0.179***	0.178***	0.178***	0.184***
	(0.034)	(0.034)	(0.034)	(0.034)	(0.035)
LEV	0.028***	0.028***	0.028***	0.028***	0.028***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
CF_VOL	0.003	0.009	0.003	0.003	0.003
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
TAX-EXEMPT	-0.002	-0.002	-0.002	-0.002	-0.003
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
CAT	0.029	0.021	0.030	0.029	0.026
	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)
BM_CONC	-0.112***		-0.110***	-0.109***	-0.113***
	(0.016)		(0.016)	(0.016)	(0.016)
BH_CONC		-0.104***			
		(0.018)			
G_CONC		-0.083***			
		(0.014)			
AGE	-0.006	-0.006	-0.007	-0.008	-0.006
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
PUBLIC	-0.014**	-0.013**	-0.014**	-0.014**	-0.014**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)

AFF	-0.009	-0.008	-0.009	-0.009	-0.007
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
NUM_AFF	-0.002	-0.002	-0.002	-0.002	-0.002
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
AFF_SIZE_RATIO	-0.033**	-0.033**	-0.034**	-0.034**	-0.033**
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
US_UNAFF	-0.001	-0.001	-0.000	-0.000	-0.000
	(0.009)	(0.008)	(0.008)	(0.008)	(0.009)
NONUS	0.018	0.019	0.019	0.017	0.018
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Observations	18,931	18,931	18,931	18,931	18,931
Adjusted R^2	0.809	0.810	0.809	0.809	0.809

Table 4 Robustness tests: Alternate measures of reinsurance activity

This table shows the coefficient estimates of OLS regressions that examine the relation between the intensity of competition faced by primary insurers and their reinsurance utilization (Eq. (22)). In columns (1)–(4), the dependent variable is a primary insurer's net reinsurance activity (NET_REINS). In columns (5)–(8), the dependent variable is its external reinsurance (EXT_REINS). The independent variables of interest are insurance market-related factors including the intensity of market competition faced by primary insurers (HHI, CR4, CR8, and AVG_PRICE; lower values of these variables indicate more competition), the market size, and the market underwriting risk. In all specifications, we include firm and year fixed effects, as well as all line-of-business controls (each of which represents the primary insurer's proportion of direct business written in that line of business). The sample period is 1996–2008, and all the independent variables are lagged by one year. All variables are defined in Appendix E. We report standard errors adjusted for within-firm and within-year clustering in parentheses below the coefficient estimates. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Dep. Variable: NET_REINS				Dep. Variable: EXT_REINS			
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HHI	-0.147				-0.011			
	(0.103)				(0.061)			
CR4		-0.145***				-0.053*		
		(0.049)				(0.031)		
CR8			-0.163***				-0.077**	
			(0.050)				(0.030)	
AVG_PRICE				-0.003***				-0.002***
				(0.001)				(0.001)
MKTSIZE	0.026***	0.026***	0.027***	0.024***	0.020***	0.020***	0.020***	0.019***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.005)	(0.005)	(0.005)	(0.005)
MKTRISK	0.037**	0.038**	0.037**	0.032*	0.035***	0.036***	0.036***	0.032**
	(0.018)	(0.018)	(0.017)	(0.017)	(0.012)	(0.012)	(0.012)	(0.013)
AFF*AFF_COMB	0.027**	0.027**	0.027**	0.025*	0.017*	0.017*	0.017*	0.016*
	(0.014)	(0.014)	(0.014)	(0.014)	(0.009)	(0.009)	(0.009)	(0.009)
US_UNAFF*US_COMB	0.025***	0.024***	0.024***	0.024***	0.020***	0.020***	0.020***	0.020***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
NONUS*NONUS_COMB	-0.023	-0.023	-0.022	-0.022	0.004	0.004	0.005	0.004
	(0.025)	(0.025)	(0.025)	(0.025)	(0.016)	(0.016)	(0.016)	(0.016)
SIZE	-0.064***	-0.064***	-0.064***	-0.064***	-0.024***	-0.024***	-0.024***	-0.024***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
ROA	0.190***	0.191***	0.190***	0.197***	0.049	0.050	0.050	0.054*
	(0.039)	(0.039)	(0.039)	(0.039)	(0.033)	(0.033)	(0.033)	(0.033)
LEV	0.029***	0.029***	0.029***	0.029***	0.010***	0.010***	0.010***	0.010***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
CF_VOL	0.013	0.013	0.013	0.012	0.025***	0.025***	0.025***	0.025***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.009)	(0.009)	(0.009)	(0.009)
TAX-EXEMPT	0.005	0.005	0.006	0.005	-0.007	-0.007	-0.007	-0.007
	(0.009)	(0.009)	(0.009)	(0.009)	(0.007)	(0.006)	(0.006)	(0.006)
CAT	0.073	0.074	0.074	0.068	0.018	0.018	0.018	0.016
	(0.047)	(0.047)	(0.047)	(0.047)	(0.032)	(0.032)	(0.032)	(0.031)
BM_CONC	-0.053***	-0.051***	-0.050***	-0.055***	-0.036***	-0.035***	-0.035***	-0.036***
	(0.019)	(0.019)	(0.019)	(0.019)	(0.011)	(0.011)	(0.011)	(0.011)
AGE	-0.018**	-0.019**	-0.020**	-0.017**	-0.017***	-0.018***	-0.018***	-0.017***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.006)	(0.006)	(0.006)	(0.006)
PUBLIC	-0.015**	-0.015**	-0.016**	-0.015**	-0.006	-0.006	-0.006	-0.006
	(0.007)	(0.007)	(0.007)	(0.007)	(0.005)	(0.005)	(0.005)	(0.005)
AFF	-0.019	-0.019	-0.019	-0.017	-0.009	-0.009	-0.009	-0.008
	(0.016)	(0.016)	(0.016)	(0.016)	(0.011)	(0.011)	(0.011)	(0.011)
NUM_AFF	-0.010	-0.010	-0.010	-0.010	-0.006	-0.006	-0.006	-0.006
	(0.007)	(0.007)	(0.007)	(0.007)	(0.004)	(0.004)	(0.004)	(0.004)

AFF_SIZE_RATIO	-0.066***	-0.066***	-0.066***	-0.066***	0.062***	0.061***	0.061***	0.062***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.012)	(0.012)	(0.012)	(0.012)
US_UNAFF	0.025	0.025	0.024	0.024	-0.012	-0.011	-0.011	-0.011
	(0.027)	(0.027)	(0.027)	(0.027)	(0.008)	(0.008)	(0.008)	(0.008)
NONUS	-0.014	-0.013	-0.013	-0.014	0.005	0.005	0.004	0.005
	(0.010)	(0.010)	(0.010)	(0.010)	(0.017)	(0.017)	(0.017)	(0.017)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,835	14,835	14,835	14,835	18,763	18,763	18,763	18,763
Adjusted R^2	0.797	0.797	0.797	0.797	0.771	0.771	0.771	0.771

Table 5 Robustness tests: Single unaffiliated insurers and focused insurers

This table shows the coefficient estimates of OLS regressions that examine the relation between the intensity of competition faced by primary insurers and their reinsurance utilization (Eq. (22)). In columns (1)–(4), we run the regression by including unaffiliated single primary insurers only. In columns (5)–(8), we run the regression by including primary insurers for which the major market segment represents at least 25 percent of their business operation. As in the baseline regressions, the dependent variable is total reinsurance ratio (REINS) in all specifications. The independent variables of interest are insurance market-related factors including the intensity of market competition faced by primary insurers (HHI, CR4, CR8, and AVG_PRICE; lower values of these variables indicate more competition), the market size, and the market underwriting risk. In all specifications, we include firm and year fixed effects, as well as all line-of-business controls (each of which represents the primary insurer's proportion of direct business written in that line of business). The sample period is 1996–2008, and all the independent variables are lagged by one year. All variables are defined in Appendix E. We report standard errors adjusted for within-firm and within-year clustering in parentheses below the coefficient estimates. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Dep. Variable: REINS (Unaffiliated single insurers)				Dep. Variable: REINS (Focused insurers)			
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HHI	-0.051				-0.095			
	(0.083)				(0.064)			
CR4		-0.080*				-0.079***		
		(0.048)				(0.027)		
CR8			-0.096**				-0.083***	
			(0.049)				(0.026)	
AVG_PRICE				-0.002*				-0.002**
				(0.001)				(0.001)
MKTSIZE	0.017	0.018*	0.018*	0.015	0.008*	0.008*	0.008*	0.007
	(0.011)	(0.011)	(0.011)	(0.011)	(0.005)	(0.004)	(0.004)	(0.005)
MKTRISK	0.051***	0.052***	0.053***	0.049***	0.048***	0.050***	0.050***	0.047***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.012)	(0.012)	(0.012)	(0.012)
AFF*AFF_COMB					0.040**	0.040**	0.040**	0.040**
					(0.016)	(0.016)	(0.016)	(0.016)
US_UNAFF*US_COMB	0.032***	0.032***	0.032***	0.032***	0.028***	0.028***	0.028***	0.028***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.006)	(0.006)	(0.006)	(0.006)
NONUS*NONUS_COMB	-0.034	-0.034	-0.033	-0.033	-0.023	-0.024	-0.023	-0.024
	(0.030)	(0.030)	(0.030)	(0.030)	(0.027)	(0.027)	(0.027)	(0.027)
SIZE	-0.041***	-0.041***	-0.041***	-0.041***	-0.063***	-0.062***	-0.062***	-0.063***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.006)	(0.006)	(0.006)	(0.006)
ROA	0.145***	0.147***	0.146***	0.151***	0.206***	0.206***	0.205***	0.211***
	(0.053)	(0.053)	(0.053)	(0.053)	(0.040)	(0.040)	(0.040)	(0.040)
LEV	0.017***	0.017***	0.017***	0.017***	0.027***	0.027***	0.027***	0.027***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
CF_VOL	0.024	0.024	0.023	0.023	0.012	0.012	0.012	0.012
	(0.019)	(0.019)	(0.019)	(0.019)	(0.016)	(0.016)	(0.016)	(0.016)
TAX-EXEMPT	0.000	0.001	0.001	0.000	-0.009	-0.009	-0.009	-0.010
	(0.011)	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)
CAT	0.201***	0.203***	0.203***	0.200***	0.087*	0.087*	0.087*	0.084*
	(0.065)	(0.065)	(0.065)	(0.065)	(0.051)	(0.050)	(0.050)	(0.050)
BM_CONC	-0.108***	-0.108***	-0.107***	-0.109***	-0.112***	-0.111***	-0.112***	-0.111***
	(0.022)	(0.022)	(0.022)	(0.022)	(0.017)	(0.017)	(0.017)	(0.017)
AGE	-0.003	-0.004	-0.005	-0.003	-0.013	-0.014	-0.014	-0.013
	(0.010)	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)
PUBLIC	-0.002	-0.002	-0.003	-0.002	-0.020***	-0.020***	-0.020***	-0.020***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
AFF					0.004	0.004	0.004	0.004

					(0.019)	(0.019)	(0.019)	(0.019)
NUM_AFF					-0.013	-0.013	-0.013	-0.013
					(0.008)	(0.008)	(0.008)	(0.008)
AFF_SIZE_RATIO					-0.022	-0.023	-0.023	-0.023
					(0.019)	(0.019)	(0.019)	(0.019)
US_UNAFF	0.010	0.010	0.011	0.010	0.031	0.033	0.032	0.033
	(0.014)	(0.014)	(0.014)	(0.014)	(0.028)	(0.028)	(0.028)	(0.028)
NONUS	0.050	0.050	0.049	0.049	-0.001	-0.001	-0.001	-0.001
	(0.031)	(0.031)	(0.031)	(0.031)	(0.010)	(0.010)	(0.010)	(0.010)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,290	6,290	6,290	6,290	11,966	11,966	11,966	11,966
Adjusted R^2	0.826	0.826	0.826	0.826	0.797	0.797	0.797	0.797

Figure 1 Proxies of market competition

This figure shows the descriptive relation between the proxies of market competition faced by primary insurers (HHI, CR4 and CR8, and average price).