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Reinsurance Contracting with Adverse Selection and Moral Hazard: Theory and Evidence

Zhiqiang Yan

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REINSURANCE CONTRACTING WITH ADVERSE SELECTION AND MORAL HAZARD: THEORY AND EVIDENCE

BY

ZHIQIANG YAN

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree

Of

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ACCEPTANCE

This dissertation was prepared under the direction of *ZHIQIANG YAN*'s Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctor in Philosophy in Business Administration in the Robinson College of Business of Georgia State University.

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ABSTRACT

REINSURANCE CONTRACTING WITH ADVERSE SELECTION AND MORAL HAZARD: THEORY AND EVIDENCE

By

ZHIQIANG YAN

July 2009

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This dissertation includes two essays on adverse selection and moral hazard problems in reinsurance markets. The first essay builds a competitive principal-agent model that considers adverse selection and moral hazard jointly, and characterizes graphically various forms of separating Nash equilibria. In the second essay, we use panel data on U.S. property liability reinsurance for the period 1995-2000 to test for the existence of adverse selection and moral hazard. We find that (1) adverse selection is present in private passenger auto liability reinsurance market and homeowners reinsurance market, but not in product liability reinsurance market; (2) residual moral hazard does not exist in all the three largest lines of reinsurance, but is present in overall reinsurance markets; and (3) moral hazard is present in the product liability reinsurance market, but not in the other two lines of reinsurance.

Essay 1: Reinsurance Contracting with Adverse Selection and Moral Hazard

Zhiqiang Yan

Georgia State University

July 2009

Abstract

The adverse selection and moral hazard problems have been widely discussed in the context of insurance markets. However, previous studies on asymmetric information usually treat the adverse selection and moral hazard problems separately, though it is quite possible that they may coexist and interact with each other. This paper builds a principal-agent model to examine the optimal contracts in a competitive reinsurance market facing the adverse selection and moral hazard problems simultaneously. This paper finds that: (1) there are several forms of separating Nash equilibria, (2) separating Nash equilibria may not exist, (3) no agent is offered full coverage, and (4) the positive correlation property between insurance coverage and risk type found in the case of pure adverse selection still holds.

1 Introduction

The adverse selection and moral hazard problems have been widely discussed in the context of insurance markets. However, previous studies on asymmetric information usually treat the adverse selection and moral hazard problems separately, though it is quite possible that they may coexist and interact with each other. The aim of this paper is to examine the optimal contracts in a competitive reinsurance market facing the adverse selection and moral hazard problems simultaneously.

Similar to Chassagnon and Chiappori (1997), we develop a one-period principal-agent model with the simultaneous presence of moral hazard and adverse selection in a competitive environment. Then we characterize graphically various types of separating Nash equilibria, and analyze the characteristics of optimal contracts in equilibria. We find that: (1) there are several forms of separating Nash equilibria, (2) separating Nash equilibria may not exist, (3) no agent is offered full coverage, and (4) the positive correlation property between insurance coverage and risk type found in the case of pure adverse selection still holds.

In the present paper, although our model setup is similar to Chassagnon and Chiappori (1997), we contribute to the literature by applying more straightforward mathematical techniques, that is, change-of-variable method proposed by Laffont and Martimort (2002) and the familiar Kuhn-Tucker conditions, to the derivation and characterization of separating Nash equilibria, which resembles the results in Chassagnon and Chiappori (1997).

The remainder of this paper is organized as follows. Section 2 provides a brief review on the theoretical literature of adverse selection and moral hazard. Section 3 develops a simple principal-agent model with adverse selection and moral hazard problems simultaneously in the context of perfect competition, and graphically characterizes possible separating equilibria. Section 4 presents conclusions of this paper.

2 Literature Review

Inspired by the seminal works of Arrow (1963) and Akerlof (1970), numerous papers theoretically examined adverse selection problem (Akerlof, 1970; Rothschild and Stiglitz, 1976) and moral hazard problem (Pauly, 1974; Stiglitz, 1977; Shavell, 1979; Lambert, 1983; Smith and Stutzer, 1995).

One important work on adverse selection is Rothschild and Stiglitz (1976), which proposed to use price-quantity contracts to solve the adverse selection problem in a competitive environment. They proved that only a separating equilibrium (in a Nash sense) could exist, and that, in equilibrium, high-risk individuals self-selected into a contract with full insurance coverage at a higher unit price, while low-risk individuals self-selected into a contract with partial coverage at a lower unit price. Moreover, a separating equilibrium may not exist under certain conditions.

Stiglitz (1977) extended the Rothschild and Stiglitz (1976) model to the case of monopoly. In the monopolistic equilibrium, high-risk individuals purchased complete insurance while low-risk individuals purchased partial or no insurance. Cooper and Hayes (1987) investigated optimal multi-period insurance contracts with experience rating in both monopolistic and competitive environments. They demonstrated that the contract for high-risk individuals did not reflect loss experience while the contract for low-risk individuals did. Moreover, if individuals could not commit to multi-period contracts in a competitive setting, low-risk individuals would receive a contract providing lower expected utility in the first period but higher expected utility in the second period, comparing to a standard one-period optimal contract. Correspondingly, firm would make positive profit in the first period on low-risk individuals, but negative profit in the second period.

A limitation of previous studies on asymmetric information is that they usually treat the moral hazard problem and the adverse selection problem separately. However, in reality, it is quite possible that moral hazard and adverse selection may coexist in the same market, and interact with each other. The approach to deal with each problem separately, one at a time, can only provide us limited insight in this situation. Fortunately, people are taking a more realistic view in modeling asymmetric information problems in insurance markets. Whinston (1983) considered a single-period social insurance model with moral hazard and adverse selection and demonstrated that the optimal equilibrium was a pooling one.

Stewart (1994) built a competitive insurance market model with both moral hazard and adverse selection. In his model, agents only differed with respect to their marginal costs of loss prevention effort. A separating reactive equilibrium (versus Nash equilibrium as in Rothschild and Stiglitz, 1976) was characterized. It was shown that, in equilibrium, the adverse selection and moral hazard problems partially offset each other such that welfare losses were sub-additive.

Chassagnon and Chiappori (1997) set up a model of pure competition facing moral hazard and adverse selection simultaneously. In the model, there were two types of agents who could choose privately a discrete level of effort. By using mathematical techniques of correspondence and sequences, they demonstrated that there were three types of separating Nash equilibria (in the sense of Rothschild and Stiglitz 1976) and separating Nash equilibria may not exist under certain conditions. Furthermore, they extended the model to the case of continuous level of effort, and showed that pooling equilibria were possible in this context.

3 A Principal-Agent Model

3.1 The Model Framework

Following the literature, we assume that there are two groups of firms: a risk-neutral reinsurer group (or principals) and a risk-averse primary insurer group (or agents). A primary insurance company, even a publicly traded one, can behave in a risk-averse way which appears for various reasons, such as income tax convexity, agency conflicts, undiversifiable human capital of senior management, bankruptcy costs, regulatory surveillance, and so on. We assume that reinsurance markets are competitive and thus each reinsurer is constrained to earn zero expected profit. Primary insurers have an initial wealth w and possess von Neumann-Morgenstern utility function $u(w)$ with $u' > 0$ and $u'' < 0$ for all $w \in \mathbb{R}_+$.

In the simultaneous presence of moral hazard and adverse selection, defining an agent's risk type is a little tricky. In a standard adverse selection setting, the separation of high and low risk types is clear-cut: a high risk agent has a higher probability of accident, while a low risk type has a lower probability of accident. However, in the current setting, after introducing the moral hazard problem into the model of pure adverse selection, a high risk agent can now expend more effort to reduce his probability of accident, which may turn out to be actually lower than the probability of accident of a low risk type if she makes less or no effort. This possibility alone will complicate our traditional definitions of risk types.

A common approach taken in the literature (Stewart, 1994; Chassagnon and Chiappori, 1997) is to define an agent as a high risk type if the agent's probability of accident is higher, given the same level of effort expended, than another agent. In Stewart (1994), the probability function of avoiding a loss was continuous and identical across agents, but one type of agent had a higher marginal cost of effort, which made him a high risk type. Chassagnon and Chiappori (1997) defined accident probability function in a similar fashion except that they used a discrete probability function.

In this paper, to make things simpler, we follow Chassagnon and Chiappori (1997) to define a discrete probability function. Assume that there are two types of agents who differ *ex ante* in their risk types $\theta \in \Theta = \{\underline{\theta}, \overline{\theta}\}$. $\overline{\theta}$ represents a high risk type while $\underline{\theta}$ corresponds to a low risk type. The two risk types are independently distributed with probabilities ν and $1-\nu$ respectively, which are common knowledge to both agents and principals. Here, when we say that an agent (i.e., a primary insurer) is a high risk type, it means that the primary insurer may have inferior underwriting technology, a looser claim adjustment standard, or poorer risk management expertise, which results in a riskier book of business.

We assume that a type θ agent files a loss claim amounting to l with probability $1 - \pi(\theta, e)$, where $e \in \{0,1\}$ is the agent's loss prevention effort, and thus, the probability that the agent files no claim is $\pi(\theta, e)$. In addition, we assume that $\pi(\underline{\theta}, e) > \pi(\overline{\theta}, e)$ for every $e \in \{0,1\}$. Moreover, as in Chassagnon and Chiappori (1997), we rule out the non-generic case where $\pi(\overline{\theta}, 1) = \pi(\underline{\theta}, 0)$ to avoid peculiar equilibria. By exerting effort e, an agent suffers disutility $\psi(e)$, with $\psi(1) = \psi$ and $\psi(0) = 0$. To be more tractable, we assume that the utility function is separable in wealth and effort, which essentially assume away the non-convexity problem in the indifference curves and the zero expected profit curves.[1] In order to avoid the limited liability problem, we also assume that the endowment of an agent w is greater than the potential accident loss l, that is, $w > l$.

For each type of agent $\theta = \{\underline{\theta}, \overline{\theta}\}$, without reinsurance, its reservation utility is

$$U_0(\theta, e) = \pi(\theta, e)u(w) + (1 - \pi(\theta, e))u(w - l) - \psi(e).$$

A reinsurer offers primary insurers a menu of reinsurance contracts. Each contract specifies a premium P to be paid to the reinsurer if no loss claim is filed and an indemnity I to be paid to the primary insurer if a loss claim is filed. We use the notation $\overline{\delta} = \{\overline{P}, \overline{I}\}$ to denote the optimal contract offered to type $\overline{\theta}$ primary insurers, and $\underline{\delta} = \{\underline{P}, \underline{I}\}$ to type $\underline{\theta}$ primary insurers. The equilibrium in question will be a pure Nash equilibrium (i.e. a simultaneous game equilibrium) instead of a Stackelberg equilibrium (i.e. a sequential

[1] Refer to Arnott and Stiglitz (1983) for further details.

game equilibrium). As shown in Rothschild and Stiglitz (1976), a pooling equilibrium was not possible in a competitive adverse selection model, and it can not exist in the adverse selection and moral hazard model as well. Hence, in the following, we will only consider contracts supporting a separating equilibrium.

A separating Nash equilibrium should be characterized by the following conditions: (1) for each contract, the principal will earn zero expected profit, otherwise, rival competitors can undercut the principal and still make a profit until the expected profit goes to zero; (2) since we assume that premium is actuarially fair, according to standard results of insurance economics, we know that these risk-averse agents will always be better off by purchasing reinsurance.

Let us assume that the loss claim l is so large that it is always optimal for the reinsurer to induce agents to expend effort. In the competitive setting, each contract will maximize an agent's expected utility subject to the agent's participation constraint, adverse selection constraint, moral hazard constraint, and the principal's zero expected profit constraint.

When a high risk agent exerts effort and truthfully reports his type to the principal, the principal maximizes the high risk agent's expected utility:

$$\overline{V} = \max_{\{\overline{P},\overline{I}\}} \pi(\overline{\theta},1)u(w-\overline{P}) + (1-\pi(\overline{\theta},1))u(w-l+\overline{I}) - \psi$$

The high risk agent's participation constraint is:

$$\overline{V} \geq U_0(\overline{\theta},e) \equiv \max_{e\in\{0,1\}} \pi(\overline{\theta},e)u(w) + (1-\pi(\overline{\theta},e))u(w-l) - \psi(e).$$

To simplify the analysis, we also assume that

$$u(w) - u(w-l) \geq \frac{\psi}{\triangle\pi(\overline{\theta})}$$

where $\triangle\pi(\overline{\theta}) = \pi(\overline{\theta},1) - \pi(\overline{\theta},0)$. This assumption means that the type $\overline{\theta}$ agent will exert a positive effort if he is self-insured, which is consistent with the previous assumption that it is optimal for a principal to induce an agent to expend a positive effort due to the magnitude of claim l. With perfect competition and no transaction costs, risk-averse agents will always prefer insurance to self-insurance. Thus, the participation constraint is automatically satisfied.

Inducing the high risk agent to exert effort requires the following moral hazard incentive constraint to be satisfied:

$$\begin{aligned}&\pi(\overline{\theta},1)u(w-\overline{P})+(1-\pi(\overline{\theta},1))u(w-l+\overline{I})-\psi\\ &\geq \pi(\overline{\theta},0)u(w-\overline{P})+(1-\pi(\overline{\theta},0))u(w-l+\overline{I}),\end{aligned}$$

which can be reduced to

$$u(w-\overline{P})-u(w-l+\overline{I})\geq \frac{\psi}{\triangle\pi(\overline{\theta})},$$

To induce the high risk agent to truthfully report his risk type, the following adverse selection incentive constraint must be met:

$$\begin{aligned}&\pi(\overline{\theta},1)u(w-\overline{P})+(1-\pi(\overline{\theta},1))u(w-l+\overline{I})-\psi\\ &\geq \max_{e\in\{0,1\}}\pi(\overline{\theta},e)u(w-\underline{P})+(1-\pi(\overline{\theta},e))u(w-l+\underline{I})-\psi(e).\end{aligned}$$

Similarly, the low risk agent's adverse selection incentive constraint is:

$$\begin{aligned}&\pi(\underline{\theta},1)u(w-\underline{P})+(1-\pi(\underline{\theta},1))u(w-l+\underline{I})-\psi\\ &\geq \max_{e\in\{0,1\}}\pi(\underline{\theta},e)u(w-\overline{P})+(1-\pi(\underline{\theta},e))u(w-l+\overline{I})-\psi(e).\end{aligned}$$

To simplify the problem, we assume that, by exerting effort, the high risk agent can increase his probability of no loss more effectively, that is,

$$\pi(\underline{\theta},1)-\pi(\underline{\theta},0)<\pi(\overline{\theta},1)-\pi(\overline{\theta},0)$$

or

$$\triangle\pi(\underline{\theta}) < \triangle\pi(\overline{\theta}).$$

In order to induce the high risk agent to expend effort while selecting the low risk agent's contract, it requires that

$$\pi(\overline{\theta},1)u(w-\underline{P}) + (1-\pi(\overline{\theta},1))u(w-l+\underline{I}) - \psi$$
$$\geq \pi(\overline{\theta},0)u(w-\underline{P}) + (1-\pi(\overline{\theta},0))u(w-l+\underline{I}),$$

which can be reduced to

$$u(w-\underline{P}) - u(w-l+\underline{I}) \geq \frac{\psi}{\triangle\pi(\overline{\theta})}.$$

Since $u(w-\underline{P}) - u(w-l+\underline{I}) \geq \frac{\psi}{\triangle\pi(\underline{\theta})}$, which is the moral hazard constraint of low risk agent, and $\triangle\pi(\underline{\theta}) < \triangle\pi(\overline{\theta})$ by assumption, it is easy to see that $u(w-\underline{P}) - u(w-l+\underline{I}) > \frac{\psi}{\triangle\pi(\overline{\theta})}$, and thus the high risk agent will always exert effort if he selects contract $\underline{\delta} = \{\underline{P},\underline{I}\}$. Therefore, the adverse selection incentive constraint of the high risk agent becomes

$$\pi(\overline{\theta},1)u(w-\overline{P}) + (1-\pi(\overline{\theta},1))u(w-l+\overline{I}) - \psi$$
$$\geq \pi(\overline{\theta},1)u(w-\underline{P}) + (1-\pi(\overline{\theta},1))u(w-l+\underline{I}) - \psi.$$

Similarly, for low risk agent to exert effort while choosing contract $\overline{\delta} = \{\overline{P},\overline{I}\}$, we must have

$$\pi(\underline{\theta},1)u(w-\overline{P}) + (1-\pi(\underline{\theta},1))u(w-l+\overline{I}) - \psi$$
$$\geq \pi(\underline{\theta},1)u(w-\overline{P}) + (1-\pi(\underline{\theta},1))u(w-l+\overline{I}),$$

which can be reduced to

$$u(w-\overline{P}) - u(w-l+\overline{I}) \geq \frac{\psi}{\triangle\pi(\underline{\theta})},$$

and we can prove later that it will not hold.

Moreover, the assumption of competitive reinsurance markets implies that a principal earns zero expected profit on every contract offered in equilibrium. Thus, given contract $\overline{\delta} = \{\overline{P}, \overline{I}\}$ offered to type $\overline{\theta}$, we have:

$$\pi(\overline{\theta}, 1)\overline{P} - (1 - \pi(\overline{\theta}, 1))\overline{I} = 0$$

Therefore, every contract $\delta \in (\overline{\delta}, \underline{\delta})$ offered to an agent should maximize the agent's expected utility subject to a moral hazard constraint, two adverse selection incentive constraints and a zero-profit constraint.

However, when it comes to solving the optimization problem, a technical difficulty arises even in such a simple setting, that is, the maximization program may not be concave because the concave utility function appears on both sides of adverse selection constraints, which renders the Kuhn-Tucker method invalid. To resolve this non-concavity issue, we follow the change-of-variable method proposed by Laffont and Martimort (2002). Let us define $\overline{u}_a = u(w - l + \overline{I})$, $\overline{u}_n = u(w - \overline{P})$, $\underline{u}_a = u(w - l + \underline{I})$, and $\underline{u}_n = u(w - \underline{P})$. Meanwhile, we denote the inverse function of $u(\cdot)$ by $h = u^{-1}$. Since $u' > 0$ and $u'' < 0$ by assumption, we have $h' > 0$, $h'' > 0$, and $h(\cdot)$ is convex. Using these new variables, we can obtain that $\overline{I} = -w + l + h(\overline{u}_a)$, $\overline{P} = w - h(\overline{u}_n)$, $\underline{I} = -w + l + h(\underline{u}_a)$, and $\underline{P} = w - h(\underline{u}_n)$. Therefore, for type $\overline{\theta}$ agent, the utility maximization program can now be written as

$$\overline{V} = \max_{\{\overline{u}_n, \overline{u}_a\}} \pi(\overline{\theta}, 1)\overline{u}_n + (1 - \pi(\overline{\theta}, 1))\overline{u}_a - \psi$$

subject to the moral hazard constraint:

$$\overline{u}_n - \overline{u}_a \geq \frac{\psi}{\triangle\pi(\overline{\theta})},$$

the adverse selection constraint for type $\overline{\theta}$ agent:

$$\begin{aligned}&\pi(\overline{\theta},1)\overline{u}_n+(1-\pi(\overline{\theta},1))\overline{u}_a-\psi\\&\geq\pi(\overline{\theta},1)\underline{u}_n+(1-\pi(\overline{\theta},1))\underline{u}_a-\psi,\end{aligned}$$

the adverse selection constraint for type $\underline{\theta}$ agent:

$$\begin{aligned}&\pi(\underline{\theta},1)\underline{u}_n+(1-\pi(\underline{\theta},1))\underline{u}_a-\psi\\&\geq\max_{e\in\{0,1\}}\pi(\underline{\theta},e)\overline{u}_n+(1-\pi(\underline{\theta},e))\overline{u}_a-\psi(e),\end{aligned}$$

and the zero profit constraint:

$$\pi(\overline{\theta},1)(w-h(\overline{u}_n))-(1-\pi(\overline{\theta},1))(-w+l+h(\overline{u}_a))=0.$$

After the change of variables, we can now apply the familiar Kuhn-Tucker procedure to solve the optimization programming.

3.2 The Zero Profit Curve

Due to the assumption of perfect competition in reinsurance markets, reinsurers make zero expected profit on each contract offered in equilibrium. In the premium-indemnity (P,I) coordinates, the zero profit line of type $\theta\in\Theta=\{\underline{\theta},\overline{\theta}\}$ is given by

$$\pi(\theta,1)P-(1-\pi(\theta,1))I=0,$$

which is a ray from the origin with slope $\frac{1-\pi(\theta,1)}{\pi(\theta,1)}$. Here, the origin is the agent's uninsured state. Now, let us define $w_a=w-l+I$ and $w_n=w-P$, which represent the agent's incomes in the states of claim and no claim, respectively. Then $(w-l,w)$ represent the incomes in the uninsured state. After the change of variables, $u_a=u(w-l+I)$ and $u_n=u(w-P)$ represent the utilities in the states of claim and no claim, respectively. In the new coordinate system of (u_a, u_n), the point E with coordinates $(u(w-l), u(w))$ is the agent's utility levels in the uninsured state, which corresponds to the origin in the coordinate system of (P, I). Hence, every zero profit curve passes the point E in the new coordinate system. Moreover, for a type θ agent, the zero expect profit curve is now given by

$$\pi(\theta,1)(w-h(u_n))-(1-\pi(\theta,1))(-w+l+h(u_a))=0.$$

According to Implicit Function Theorem, we can obtain,

$$\frac{\partial u_n}{\partial u_a}=-\frac{1-\pi(\theta,1)}{\pi(\theta,1)}\frac{h'(u_a)}{h'(u_n)},$$

and

$$\frac{\partial^2 u_n}{\partial u_a^2}=-\frac{1-\pi(\theta,1)}{\pi(\theta,1)}\frac{h''(u_a)}{h'(u_n)}.$$

Since $u_a \leq u_n$, $h' > 0$ and $h'' > 0$, we have $\frac{h'(u_a)}{h'(u_n)} < 1$, $\partial u_n/\partial u_a < 0$ and $\partial^2 u_n/\partial u_a^2 < 0$. Therefore, each zero expected profit curve passes the point $E = (u(w-l), u(w))$ and decreases at an increasing rate. Meanwhile, the slope of the zero profit curve decreases in the probability of no claim $\pi(\cdot)$, that is, the zero expected profit curve gets flatter as the probability of no claim $\pi(\cdot)$ gets higher. Since the slope of the agent's indifference line is $-\frac{1-\pi(\theta,1)}{\pi(\theta,1)}$, we can obtain that $-\frac{1-\pi(\theta,1)}{\pi(\theta,1)}\frac{h'(u_a)}{h'(u_n)} < -\frac{1-\pi(\theta,1)}{\pi(\theta,1)}$ because of $\frac{h'(u_a)}{h'(u_n)} < 1$. It means that, for a type θ agent, the slope of zero expected profit curve is flatter than the indifference line, and thus these two cross only once. Hence, the single-crossing property is met.

Before we go into detail about our model of adverse selection and moral hazard, we first briefly present the standard models of pure adverse selection and pure moral hazard respectively, which serve as two benchmarks for the model of adverse selection and moral hazard.

3.3 The Case of Pure Adverse Selection (PAS)

The competitive pure adverse selection model was proposed and characterized in great detail in Rothschild and Stiglitz (1976). In the following, we simply present the main findings in our terminology to facilitate a comparison between the pure adverse selection model and the model of adverse selection and moral hazard.

In the case of pure adverse selection, risk type is an agent's private information, and principals only know that there are two types of agents. However, the principals are able to observe the actions of agents, or effort that agents exert to prevent losses. Because of perfect competition by assumption, contract offered to each agent should maximize the agent's expected utility subject to the adverse selection constraint of each risk type and the zero expected profit constraint.

Therefore, for a type $\overline{\theta}$ agent, the optimal contract in equilibrium should maximize the agent's expected utility

$$\max_{\{\overline{u}_n, \overline{u}_a\}} \pi(\overline{\theta}, 1)\overline{u}_n + (1 - \pi(\overline{\theta}, 1))\overline{u}_a - \psi$$

subject to the adverse selection constraint of the type $\overline{\theta}$ agent,

$$\pi(\overline{\theta}, 1)\overline{u}_n + (1 - \pi(\overline{\theta}, 1))\overline{u}_a - \psi \geq \pi(\overline{\theta}, 1)\underline{u}_n + (1 - \pi(\overline{\theta}, 1))\underline{u}_a - \psi, \tag{AH}$$

and subject to the adverse selection constraint of the type $\underline{\theta}$ agent,

$$\pi(\underline{\theta}, 1)\underline{u}_n + (1 - \pi(\underline{\theta}, 1))\underline{u}_a - \psi \geq \pi(\underline{\theta}, 1)\overline{u}_n + (1 - \pi(\underline{\theta}, 1))\overline{u}_a - \psi, \tag{AL}$$

and the zero expected profit constraint,

$$\pi(\overline{\theta}, 1)(w - h(\overline{u}_n)) - (1 - \pi(\overline{\theta}, 1))(-w + l + h(\overline{u}_a)) = 0$$

It is already a well known result that, in the presence of pure adverse selection, the principal offers a menu of contracts and the high risk agents self-select into a full insurance contract but pay a higher unit price for the insurance coverage while the low risk agents choose a partial insurance contract but pay a lower unit price, as illustrated in Figure 1. For the sake of completeness, the proof of this result is provided in the Appendices.

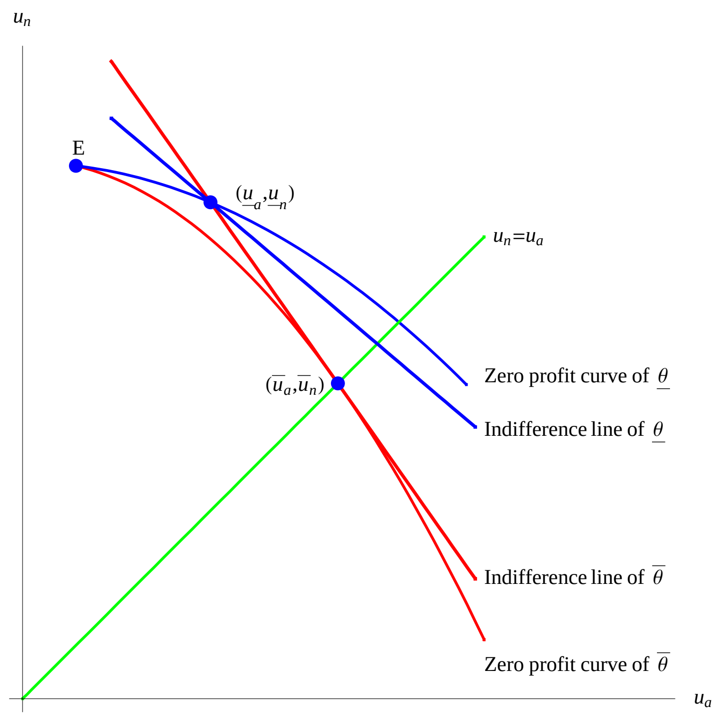

Figure 1: The Case of Pure Adverse Selection

Intuitively, if the adverse selection constraint AL is binding, the indifference line of the type $\underline{\theta}$ agent must cross the zero-profit curves of both types of agents. In addition, since $\pi(\overline{\theta},1) < \pi(\underline{\theta},1)$ by assumption, the indifference line of the type $\overline{\theta}$ agent is steeper than that of the type $\underline{\theta}$ agent, hence, the indifference line of the type $\overline{\theta}$ agent must cross the zero-profit curves of both types of agents as well. This implies that both agents' utilities are not maximized given the constraints, since new contracts can be offered to make both of them strictly better off. Therefore, the adverse selection constraint AL can never be binding, but the adverse selection constraint AH should be binding, and the utility of the type $\overline{\theta}$ agent is maximized when its indifference line is tangent to its zero-profit curve, which occurs at the point $\overline{u}_n = \overline{u}_a$. Meanwhile, the maximum utility that the type $\underline{\theta}$ agent can obtain under the constraints is given by the intersection of its zero-profit curve and type $\overline{\theta}$'s indifference line.

3.4 The Case of Pure Moral Hazard (PMH)

In the case of pure moral hazard, agents' risk types are publicly observable, but agents' actions, or effort that agents exert to reduce loss claims, are their private information. Since agents' types are assumed to be observable by principals, it is enough to formally analyze one type of agent's equilibrium contract only. Here we take a high risk type as an example. Because of perfect competition among reinsurers, the equilibrium contract offered to type $\overline{\theta}$ should maximize the agent's expected utility,

$$\max_{\{\overline{u}_n,\overline{u}_a\}} \pi(\overline{\theta},1)\overline{u}_n + (1-\pi(\overline{\theta},1))\overline{u}_a - \psi$$

subject to the moral hazard constraint,

$$\overline{u}_n - \overline{u}_a \geq \frac{\psi}{\triangle\pi(\overline{\theta})},$$

and the zero expected profit constraint for the reinsurance company,

$$\pi(\overline{\theta},1)(w-h(\overline{u}_n)) - (1-\pi(\overline{\theta},1))(-w+l+h(\overline{u}_a)) = 0.$$

The above constrained utility maximization program yields the same standard result as predicted in the moral hazard literature, that is, in the presence of pure moral hazard, a principal will offer a partial insurance contract to an agent, which will mitigate the moral hazard issue at hand, and this can be illustrated in Figure 2.

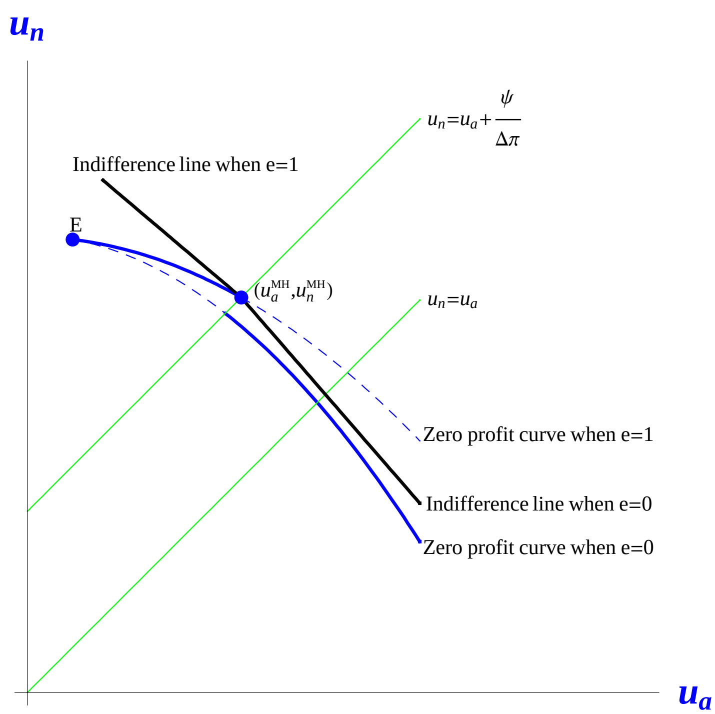

Figure 2: The Case of Pure Moral Hazard

3.5 The Case of Adverse Selection and Moral Hazard

When it comes to contract designing, the majority of studies in the literature treat moral hazard and adverse selection separately. A few technical issues such as non-convex programming and random coverage issues (Winter, 2000) may be responsible for it. In this paper, due to the application of change-of-variable technique and the simplifying assumption of separable utility function in wealth and effort, we can apply the familiar Kuhn-Tucker method to solve the maximization problem.

Let $\overline{\lambda}_M$ and $\underline{\lambda}_M$ be the respective multipliers on the moral hazard constraints of the high and low risk types, λ_{AH} and λ_{AL} be the respective multipliers on the adverse selection incentive constraints of the high and low risk types, while $\overline{\lambda}_Z$ and $\underline{\lambda}_Z$ be the respective multipliers on the zero profit constraints of the high and low risk types. Then the Lagrangian function of type $\overline{\theta}$ is:

$$\begin{aligned}
\mathscr{L} = \max_{\{\overline{u}_n,\overline{u}_a\}} & \pi(\overline{\theta},1)\overline{u}_n + (1-\pi(\overline{\theta},1))\overline{u}_a - \psi \\
& + \overline{\lambda}_M[\overline{u}_n - \overline{u}_a - \frac{\psi}{\triangle\pi(\overline{\theta})}] \\
& + \lambda_{AH}[\pi(\overline{\theta},1)\overline{u}_n + (1-\pi(\overline{\theta},1))\overline{u}_a - \psi - \pi(\overline{\theta},1)\underline{u}_n - (1-\pi(\overline{\theta},1))\underline{u}_a + \psi] \\
& + \lambda_{AL}[\pi(\underline{\theta},1)\underline{u}_n + (1-\pi(\underline{\theta},1))\underline{u}_a - \psi - \pi(\underline{\theta},\underline{e})\overline{u}_n - (1-\pi(\underline{\theta},\underline{e}))\overline{u}_a + \psi(\underline{e})] \\
& + \overline{\lambda}_Z[\pi(\overline{\theta},1)(w-h(\overline{u}_n)) - (1-\pi(\overline{\theta},1))(-w+l+h(\overline{u}_a))]
\end{aligned}$$

Differentiating the Lagrangian function with respect to $\overline{u}_n$ and $\overline{u}_a$ respectively leads, after some simplification, to the following first order conditions:

$$\frac{\partial\mathscr{L}}{\partial\overline{u}_n} = \pi(\overline{\theta},1)(1+\lambda_{AH}) + \overline{\lambda}_M - \lambda_{AL}\pi(\underline{\theta},\underline{e}) - \overline{\lambda}_Z h'(\overline{u}_n) = 0; \tag{1}$$

$$\begin{aligned}
\frac{\partial\mathscr{L}}{\partial\overline{u}_a} = & (1-\pi(\overline{\theta},1))(1+\lambda_{AH}) - \overline{\lambda}_M \\
& - \lambda_{AL}(1-\pi(\underline{\theta},\underline{e})) - \overline{\lambda}_Z h'(\overline{u}_a) = 0;
\end{aligned} \tag{2}$$

By $(1)\times(1-\pi(\overline{\theta},1)) - (2)\times\pi(\overline{\theta},1)$, we can obtain:

$$\overline{\lambda}_M + \lambda_{AL}[\pi(\overline{\theta},1) - \pi(\underline{\theta},\underline{e})] = \overline{\lambda}_Z\pi(\overline{\theta},1)(1-\pi(\overline{\theta},1))[h'(\overline{u}_n) - h'(\overline{u}_a)] \tag{3}$$

Similarly, we can derive the first order conditions for the low risk type. Based on these first order conditions, we can obtain the main results of our model, and the proofs of which are provided in the Appendices.

Lemma 1. *In equilibrium, if equilibrium exists, the marginal benefit of effort of each agent should be no less than its marginal cost of effort, but the marginal benefit of the high risk type should be no greater than the marginal cost of the low risk type, or mathematically speaking,* $\frac{\psi}{\triangle\pi(\overline{\theta})} \leq \overline{u}_n - \overline{u}_a < \frac{\psi}{\triangle\pi(\underline{\theta})} \leq \underline{u}_n - \underline{u}_a$. *In addition, the type* $\underline{\theta}$ *agent will not exert effort when she selects the type* $\overline{\theta}$ *agent's contract, that is,* $\underline{e} = 0$.

Intuitively, in order to induce an agent to expend effort, the agent's marginal benefit of effort should be no less than the marginal cost of effort. Since we assume that the high risk type agent is more efficient in expending effort, the marginal cost of the low risk agent must be no less than the marginal benefit of the high risk agent in case there is a separating equilibrium.

Lemma 2. *The adverse selection constraint and the moral hazard constraint of type $\underline{\theta}$ can not be binding at the same time. In other words, we can not have both $\underline{\lambda}_M > 0$ and $\lambda_{AL} > 0$.*

According to *Lemma 1*, $\underline{e} = 0$, thus equation (3) becomes:

$$\begin{aligned}&\overline{\lambda}_M + \lambda_{AL}[\pi(\overline{\theta},1) - \pi(\underline{\theta},0)] \\ &= \overline{\lambda}_Z \pi(\overline{\theta},1)(1-\pi(\overline{\theta},1))[h'(\overline{u}_n) - h'(\overline{u}_a)].\end{aligned} \tag{4}$$

Because $\overline{\lambda}_Z > 0$, $\overline{\lambda}_M \geq 0$ and $\lambda_{AL} \geq 0$, from equation (4), we know that $\overline{\lambda}_M$ and λ_{AL} can not equal zero simultaneously. Therefore, there are three pairs of $(\overline{\lambda}_M, \lambda_{AL})$, which are summarized below.

Case H1: $\overline{\lambda}_M = 0$, $\lambda_{AL} > 0$

In this case, the moral hazard constraint of the high risk type is not binding, while the adverse selection incentive constraint of the low risk type is binding.

Case H2: $\overline{\lambda}_M > 0$, $\lambda_{AL} = 0$

In this case, the moral hazard constraint of the high risk type is binding, but the adverse selection incentive constraint of the low risk type is not binding.

Case H3: $\overline{\lambda}_M > 0$, $\lambda_{AL} > 0$

In this case, both the moral hazard constraint of the high risk type and the adverse selection incentive constraint of the low risk type are binding.

Similar to the derivation of equation (4) for the high risk type, we can obtain the corresponding equation of the low risk type as follows,

$$\underline{\lambda}_M + \lambda_{AH}[\pi(\underline{\theta},1) - \pi(\overline{\theta},1)] = \overline{\lambda}_Z \pi(\underline{\theta},1)(1-\pi(\underline{\theta},1))[h'(\underline{u}_n) - h'(\underline{u}_a)]. \tag{5}$$

It is obvious that there are also three pairs of $(\underline{\lambda}_M, \lambda_{AL})$ that may satisfy equation (5), which are given as follows:

Case L1: $\underline{\lambda}_M = 0$, $\lambda_{AH} > 0$

In this case, the moral hazard constraint of the low risk type is not binding, while the adverse selection constraint of the high risk type is binding.

Case L2: $\underline{\lambda}_M > 0$, $\lambda_{AH} = 0$

In this case, the moral hazard constraint of the low risk type is binding, but the adverse selection constraint of the high risk type is not binding.

Case L3: $\underline{\lambda}_M > 0$, $\lambda_{AH} > 0$

In this case, both the moral hazard constraint of the low risk type and the adverse selection incentive constraint of the high risk type are binding.

Because the utility levels of the two types of agents, $(\overline{u}_n, \overline{u}_a)$ and $(\underline{u}_n, \underline{u}_a)$, are interdependent in equilibrium, we need to take the first order conditions of both agents into consideration in determining the optimal contracts. From equations (4) and (5), there are nine possible combinations of those Lagrangian multipliers, which can lead to various potential equilibria. The main findings of the investigation of all these cases are summarized in the following propositions, and the proofs are provided in the Appendices.

Proposition 1. *In a competitive reinsurance market with the simultaneous presence of adverse selection and moral hazard, the Nash equilibria in the sense of Rothschild-Stiglitz, when they exist, must be separating. In addition, there are several forms of equilibria:*

- Pure Adverse Selection*: both of the adverse selection constraints are binding, but none of the moral hazard constraints is binding.*
- Pure Moral Hazard*: both of the moral hazard constraints are binding, but none of the adverse selection constraint is binding.*
- Strong Adverse Selection*: both of the adverse selection constraints are binding, but only the moral hazard constraint of the high risk type is binding.*

- Strong Moral Hazard*: both of the moral hazard constraints are binding, but only the adverse selection constraint of the high risk type is binding.*

- Local Asymmetric Information*: the adverse selection constraint and the moral hazard constraint of the high risk type are binding, but none of the asymmetric information constraints of the low risk type is binding.*

Through the analysis of different equilibria, we can easily see how the simultaneous presence of adverse selection and moral hazard affects the optimal contracts offered in the case of either pure adverse selection or pure moral hazard. The following propositions summarize these findings.

Proposition 2. *In the simultaneous presence of adverse selection and moral hazard, the moral hazard problem dominates in the sense that optimal contracts provide a reinsurance coverage at most equal to the amount offered in the case of pure moral hazard, depending on model structures. Moreover, a larger reinsurance coverage is offered to type $\overline{\theta}$ at a higher unit price. More specifically,*

- $\pi(\overline{\theta},1) > \pi(\underline{\theta},0)$*: the optimal contract offered to type $\underline{\theta}$ provides a reinsurance coverage less than that in the case of pure moral hazard, while the optimal contract offered to type $\overline{\theta}$ provides a reinsurance coverage equal to or less than that in the case of pure moral hazard.*

- $\pi(\overline{\theta},1) < \pi(\underline{\theta},0)$*: the optimal contract offered to type $\underline{\theta}$ provides a reinsurance coverage equal to or less than that in the case of pure moral hazard, while the optimal contract offered to type $\overline{\theta}$ provides a reinsurance coverage equal to that in the case of pure moral hazard.*

Intuitively, when $\pi(\overline{\theta},1) > \pi(\underline{\theta},0)$, the type $\overline{\theta}$ agent is relatively riskier in the sense that the probability of loss of type $\overline{\theta}$ is higher if both types of agents expend the same level of effort. However, if the type $\overline{\theta}$ agent exerts effort while the type $\underline{\theta}$ agent does not, the latter then becomes the riskier one. This additional layer of adverse selection complicates the principal's job of contract designing even further and reduces the amount of coverage offered to the type $\underline{\theta}$ agent. When $\pi(\overline{\theta},1) < \pi(\underline{\theta},0)$, the type $\overline{\theta}$ agent is absolutely riskier no matter whether the type $\underline{\theta}$ agent expends effort or not. In this case, the highest possible amount of coverage, which occurs at the intersection of type $\overline{\theta}$'s zero profit curve and its moral hazard constraint line, is offered to the type $\overline{\theta}$ agent.

Proposition 2 implies that, in the simultaneous presence of adverse selection and moral hazard, no agent can obtain full insurance coverage. In addition, comparatively speaking, the high risk agent will be offered a larger amount of insurance coverage at a higher unit price, while the low risk agent will be offered a smaller amount of insurance coverage at a lower unit price. These findings demonstrate that the positive correlation property between insurance coverage and risk type of agents that is found in the pure adverse selection model holds, even in the simultaneous presence of moral hazard and adverse selection. Therefore, we can exploit this positive correlation property to test for the existence of moral hazard and adverse selection in reinsurance markets.

4 Conclusions

Since the early seventies, the theoretical studies on contract theory have been explosive. Various *optimal* contracts are designed to deal with different asymmetric information problems, such as adverse selection and moral hazard. However, the majority of the asymmetric information literature treats the adverse selection and moral hazard problems separately. In this paper, we consider a principal-agent model with the simultaneous presence of adverse selection and moral hazard in a competitive environment. To resolve the non-concavity issue in the optimization programming, we utilize the change-of-variable method proposed by Laffont and Martimort (2002), and then apply the familiar Kuhn-Tucker method to solving the optimization programming.

By analyzing the interaction between adverse selection and moral hazard, we find that there are several forms of separating Nash equilibria. In addition, we find that, in our framework, the moral hazard problem dominates in the sense that optimal contracts provide reinsurance coverage at most equal to the amount offered in the case of pure moral hazard. Furthermore, we find that the positive correlation property between insurance coverage and risk type found in the pure adverse selection model still holds no matter what form of separating Nash equilibrium it is.

References

[1] Akerlof, G.A., 1970, The Market for "Lemons": Quality Uncertainty and the Market Mechanism, *Quarterly Journal of Economics*, 84: 488-500.

[2] Arnott, R., and J. Stiglitz, 1988, The Basic Analytics of Moral Hazard, *The Scandinavian Journal of Economics*, 90: 383-413.

[3] Arrow, K.J., 1963, Uncertainty and the Welfare Economics of Medical Care, *American Economic Review*, 53(5): 941-973.

[4] Chassagnon, A., and Chiappori, P.A., 1997, Insurance under Moral Hazard and Adverse Selection: the Case of Pure Competition, *Working Paper*.

[5] Cooper, R., and B. Hayes, 1987, Multi-Period Insurance Contracts, *International Journal of Industrial Organization*, 5: 211-231.

[6] Dionne, G., N. Doherty, and N. Fombaron, 2000, Adverse Selection in Insurance Markets, in: G. Dionne, ed., *Handbook of Insurance*, (Boston: Kluwer Academic Publishers), pp. 185-243.

[7] Laffont, J.J., and D. Martimort, 2002, The Theory of Incentives, (Princeton, New Jersey: Princeton University Press).

[8] Lambert, R.A., 1983, Long-Term Contracts and Moral Hazard, *Bell Journal of Economics*, 14: 441-452.

[9] Pauly, M, 1974, Overinsurance and Public Provision of Insurance: The Roles of Moral Hazard and Adverse Selection, *Quarterly Journal of Economics*, 88: 44-62.

[10] Plantin, G., 2006, Does Reinsurance Need Reinsurers? *Journal of Risk and Insurance*, 73: 153-168.

[11] Rothschild, M., and J.E. Stiglitz, 1976, Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information, *Quarterly Journal of Economics*, 90: 629-649.

[12] Shavell, S., 1979, On Moral Hazard and Insurance, *Quarterly Journal of Economics*, 93: 541-562.

[13] Smith, B.D., and M. Stutzer, 1995, A Theory of Mutual Formation and Moral Hazard with Evidence from the History of the Insurance Industry, *Review of Financial Studies*, 8: 545-577.

[14] Stewart, J., 1994, The Welfare Implications of Moral Hazard and Adverse Selection in Competitive Insurance Markets, *Economic Inquiry*, 32: 193-208.

[15] Stiglitz, J.E., 1977, Monopoly, Nonlinear Pricing, and Imperfect Information: The Insurance Market, *Review of Economic Studies*, 44: 407-430.

[16] Whinston, M.D., 1983, Moral Hazard, Adverse Selection, and The Optimal Provision of Social Insurance, *Journal of Public Economics*, 22: 49-71.

[17] Winter, R.A., 2000, Optimal Insurance under Moral Hazard, in: G. Dionne, ed., *Handbook of Insurance*, (Boston: Kluwer Academic Publishers), pp. 155-183.

Appendix A: Proof in the Case of Pure Adverse Selection

Proof. Let λ_{AH} and λ_{AL} be the respective multipliers on the adverse selection incentive constraints AH and AL, $\overline{\lambda}_Z$ be the multiplier on the zero-profit constraint, then the first order conditions for this concave programming can be written as

$$\frac{\partial \mathscr{L}}{\partial \overline{u}_n} = \pi(\overline{\theta},1)(1+\lambda_{AH}) - \lambda_{AL}\pi(\underline{\theta},1) - \overline{\lambda}_Z\pi(\overline{\theta},1)h'(\overline{u}_n) = 0,$$

and

$$\frac{\partial \mathscr{L}}{\partial \overline{u}_a} = (1-\pi(\overline{\theta},1))(1+\lambda_{AH}) - \lambda_{AL}(1-\pi(\underline{\theta},1)) - \overline{\lambda}_Z(1-\pi(\overline{\theta},1))h'(\overline{u}_a) = 0.$$

By eliminating λ_{AH} from the first order conditions, we can obtain that

$$-(\pi(\underline{\theta},1)-\pi(\overline{\theta},1))\lambda_{AL} = \overline{\lambda}_Z\pi(\overline{\theta},1)(1-\pi(\overline{\theta},1))(h'(\overline{u}_n)-h'(\overline{u}_a))$$

Since $0 < \pi(\overline{\theta},1) < \pi(\underline{\theta},1) < 1$, $\overline{\lambda}_Z > 0$, $h' > 0$, $h'' > 0$, and $\overline{u}_n \geq \overline{u}_a$, we must have $\lambda_{AL} = 0$ and $\overline{u}_n = \overline{u}_a$. Therefore, agent $\overline{\theta}$ is offered full insurance and $h(\overline{u}_n) = h(\overline{u}_a) = w-(1-\pi(\overline{\theta},1))l$.

Similarly, we can easily form type $\underline{\theta}$'s maximization program and obtain its first order conditions. By eliminating λ_{AL} from the first order conditions, we can obtain that

$$(\pi(\underline{\theta},1)-\pi(\overline{\theta},1))\lambda_{AH} = \underline{\lambda}_Z\pi(\underline{\theta},1)(1-\pi(\underline{\theta},1))(h'(\underline{u}_n)-h'(\underline{u}_a))$$

Since $0 < \pi(\overline{\theta},1) < \pi(\underline{\theta},1) < 1$, $\underline{\lambda}_Z > 0$, $h' > 0$, $h'' > 0$, and $\underline{u}_n \geq \underline{u}_a$, we can have two possibilities: either $\lambda_{AH} = 0$ or $\lambda_{AH} > 0$. Notice that we have already derived that $\overline{u}_n = \overline{u}_a$ and that the AL constraint is not binding. Now suppose that $\lambda_{AH} = 0$, then $\underline{u}_n = \underline{u}_a$ and the AH constraint is not binding. Then we must have $\overline{u}_n = \overline{u}_a$ and $\underline{u}_n = \underline{u}_a$. However, the unbinding AH constraint implies that $\overline{u}_n > \underline{u}_n$, but the unbinding AL constraint implies that $\underline{u}_n > \overline{u}_n$, and then we have a contradiction. Hence, we must have $\lambda_{AH} > 0$. This means that the AH constraint is binding, and $\underline{u}_n > \underline{u}_a$. Therefore, agent $\underline{\theta}$ is offered partial insurance. □

Appendix B: Proof in the Case of Pure Moral Hazard

Proof. Denoting by $\overline{\lambda}_M$ and $\overline{\lambda}_Z$ the respective multipliers on those two constraints, the first-order conditions for this maximization problem can be written, respectively, as

$$\pi(\overline{\theta},1) + \overline{\lambda}_M - \overline{\lambda}_Z \pi(\overline{\theta},1) h'(\overline{u}_n) = 0$$

and

$$(1-\pi(\overline{\theta},1)) - \overline{\lambda}_M - \overline{\lambda}_Z (1-\pi(\overline{\theta},1)) h'(\overline{u}_a) = 0$$

Summing these two first order conditions yields

$$\overline{\lambda}_Z = \frac{1}{pi(\overline{\theta},1)h'(\overline{u}_n) + (1-\pi(\overline{\theta},1))h'(\overline{u}_a)} > 0$$

.

Hence, the zero profit constraint is binding at the equilibrium contract as we claim. Similarly, we can easily obtain that

$$\overline{\lambda}_M = \pi(\overline{\theta},1)(1-\pi(\overline{\theta},1)) \frac{h'(\overline{u}_n) - h'(\overline{u}_a)}{\pi(\overline{\theta},1)h'(\overline{u}_n) + (1-\pi(\overline{\theta},1))h'(\overline{u}_a)} > 0$$

because of $h' > 0$, $h'' > 0$, and $\overline{u}_n > \overline{u}_a$. Therefore, the moral hazard constraint is also binding at the equilibrium contract, which means that the marginal benefit of effort $\overline{u}_n - \overline{u}_a$ equals to the marginal cost of effort $\frac{\psi}{\triangle\pi(\overline{\theta})}$. Therefore, the equilibrium contract is determined by the two binding constraints. Since $\overline{u}_n - \overline{u}_a = \frac{\psi}{\triangle\pi(\overline{\theta})}$, only partial insurance is offered by reinsurance companies, which is implemented to mitigate the moral hazard problem. Moreover, the higher the cost of exerting effort $\frac{\psi}{\triangle\pi(\overline{\theta})}$ is, the greater the difference between utilities in two states of world is, and thus the smaller amount of insurance is offered. $\square$

Appendix C: Proofs in the Case of Moral Hazard and Adverse Selection

Proof of Lemma 1. Assume that $\underline{e}=1$, that is, type $\underline{\theta}$ exerts effort when she selects type $\overline{\theta}$'s contract $\overline{\delta}=\{\overline{P},\overline{I}\}$. In mathematical terms, it means that $\pi(\underline{\theta},1)\overline{u}_n+(1-\pi(\underline{\theta},1))\overline{u}_a-\psi\geq\pi(\underline{\theta},0)\overline{u}_n+(1-\pi(\underline{\theta},0))\overline{u}_a$, and this can be simplified as $\overline{u}_n-\overline{u}_a\geq\frac{\psi}{\triangle\pi(\underline{\theta})}$. Since $\triangle\pi(\underline{\theta})<\triangle\pi(\overline{\theta})$ by assumption, we thus obtain that $\overline{u}_n-\overline{u}_a\geq\frac{\psi}{\triangle\pi(\underline{\theta})}>\frac{\psi}{\triangle\pi(\overline{\theta})}$.

Since $h''(\cdot)>0$ and $\overline{u}_n>\overline{u}_a$, we have $h'(\overline{u}_n)-h'(\overline{u}_a)>0$. In addition, since $\pi(\overline{\theta},1)<\pi(\underline{\theta},1)$ by assumption, and $\lambda_{AL}\geq 0$ and $\overline{\lambda}_Z>0$ by definition, we can obtain from (3) that $\overline{\lambda}_M>0$. This implies that, if $\underline{e}=1$, the moral hazard constraint of type $\overline{\theta}$ is binding, and thus we must have $\overline{u}_n-\overline{u}_a=\frac{\psi}{\triangle\pi(\overline{\theta})}$, which contradicts the inequalities $\overline{u}_n-\overline{u}_a\geq\frac{\psi}{\triangle\pi(\underline{\theta})}>\frac{\psi}{\triangle\pi(\overline{\theta})}$! Therefore, the assumption that $\underline{e}=1$ is not true, and thus $\underline{e}=0$, and $\overline{u}_n-\overline{u}_a<\frac{\psi}{\triangle\pi(\underline{\theta})}$. Combining this with the two moral hazard constraints, we can easily obtain that $\frac{\psi}{\triangle\pi(\overline{\theta})}\leq\overline{u}_n-\overline{u}_a<\frac{\psi}{\triangle\pi(\underline{\theta})}\leq\underline{u}_n-\underline{u}_a$. $\square$

Proof of Lemma 2. Suppose that $\underline{\lambda}_M>0$ and $\lambda_{AL}>0$ hold simultaneously. It means that both the moral hazard constraint and the adverse selection constraint of type $\underline{\theta}$ are binding, thus

$$\begin{cases}\underline{u}_n-\underline{u}_a=\frac{\psi}{\triangle\pi(\underline{\theta})}\\ \pi(\underline{\theta},1)\underline{u}_n+(1-\pi(\underline{\theta},1))\underline{u}_a-\psi=\pi(\underline{\theta},0)\overline{u}_n+(1-\pi(\underline{\theta},0))\overline{u}_a\end{cases}$$

The binding moral hazard constraint of type $\underline{\theta}$ can also be written as

$$\pi(\underline{\theta},1)\underline{u}_n+(1-\pi(\underline{\theta},1))\underline{u}_a-\psi=\pi(\underline{\theta},0)\underline{u}_n+(1-\pi(\underline{\theta},0))\underline{u}_a.$$

By joining the moral hazard constraint with the adverse selection constraint, we can obtain,

$$
\begin{aligned}
&\pi(\underline{\theta},1)\underline{u}_n+(1-\pi(\underline{\theta},1))\underline{u}_a-\psi \\
=&\pi(\underline{\theta},0)\underline{u}_n+(1-\pi(\underline{\theta},0))\underline{u}_a \\
=&\pi(\underline{\theta},0)\overline{u}_n+(1-\pi(\underline{\theta},0))\overline{u}_a.
\end{aligned}
$$

These equations essentially imply that, in equilibrium if equilibrium exists, the optimal contract offered to type $\underline{\theta}$ is at the intersection of her moral hazard constraint and her indifference line, while the optimal contract offered to type $\overline{\theta}$ is at the intersection of his indifference line $\overline{V}(e=1)=\pi(\overline{\theta},1)u_n+(1-\pi(\overline{\theta},1))u_a-\psi$ and type $\underline{\theta}$'s indifference line $\underline{V}(e=0)=\pi(\underline{\theta},0)u_n+(1-\pi(\underline{\theta},0))u_a$. Moreover, the indifference line $\overline{V}(e=1)$ should cross the indifference line $\underline{V}(e=0)$ from above, otherwise type $\overline{\theta}$ surely will select type $\underline{\theta}$'s contract since it yields higher utility level to the type $\overline{\theta}$ agent (i.e., type $\underline{\theta}$'s contract lies above type $\overline{\theta}$'s indifference line).

A steeper indifference line $\overline{V}(e=1)$ implies that $\frac{1-\pi(\overline{\theta},1)}{\pi(\overline{\theta},1)}>\frac{1-\pi(\underline{\theta},0)}{\pi(\underline{\theta},0)}$, which can be simplified as $\pi(\overline{\theta},1)<\pi(\underline{\theta},0)$. $\pi(\overline{\theta},1)<\pi(\underline{\theta},0)$ means that type $\overline{\theta}$ is absolutely riskier than type $\underline{\theta}$, regardless of effort level. In addition, when $\pi(\overline{\theta},1)<\pi(\underline{\theta},0)$, the zero profit curve of type $\underline{\theta}$ at $e=0$ is flatter than the zero profit curve of type $\overline{\theta}$ at $e=1$. In equilibrium, the zero profit curve of type $\underline{\theta}$ at $e=0$ can not cross type $\underline{\theta}$ agent's indifference line $\underline{V}(e=0)$ (at most, to be tangent), otherwise a reinsurer can always offer another contract that shifts the type $\underline{\theta}$ agent's indifference line rightwards and make a profit himself as well. Therefore type $\overline{\theta}$'s zero profit curve does not cross the indifference line $\underline{V}(e=0)$, because the zero profit curve of type $\underline{\theta}$ at $e=0$ is flatter than the zero profit curve of type $\overline{\theta}$ at $e=1$ and the former is at most tangent to the indifference line $\underline{V}(e=0)$. Hence, there is no point on the indifference line $\underline{V}(e=0)$ that can be an optimal contract offered to the type $\overline{\theta}$ agent. This completes the proof that $\underline{\lambda}_M>0$ and $\lambda_{AL}>0$ can not hold simultaneously in equilibrium. □

Proof of Proposition 1. In the proof, we investigate every case in turn. When there is a

Rothschild-Stiglitz Nash equilibrium, we will illustrate the equilibrium in a figure.

Case 1: (Case H1)+ (Case L1), that is, $\overline{\lambda}_M = 0$, $\lambda_{AL} > 0$, $\underline{\lambda}_M = 0$, and $\lambda_{AH} > 0$

In this case, the two moral hazard constraints are not binding, but the two adverse selection incentive constraints are binding instead. Coupled with the two binding zero-profit constraints, we now have four equations to solve for the four unknowns $\overline{u}_n$, $\overline{u}_a$, $\underline{u}_n$, and $\underline{u}_a$:

$$\begin{cases} \pi(\underline{\theta},1)\underline{u}_n + (1-\pi(\underline{\theta},1))\underline{u}_a - \psi = \pi(\underline{\theta},0)\overline{u}_n + (1-\pi(\underline{\theta},0))\overline{u}_a \\ \pi(\overline{\theta},1)(w-h(\overline{u}_n)) - (1-\pi(\overline{\theta},1))(-w+l+h(\overline{u}_a)) = 0 \\ \pi(\overline{\theta},1)\overline{u}_n + (1-\pi(\overline{\theta},1))\overline{u}_a - \psi = \pi(\overline{\theta},1)\underline{u}_n + (1-\pi(\overline{\theta},1))\underline{u}_a - \psi \\ \pi(\underline{\theta},1)(w-h(\underline{u}_n)) - (1-\pi(\underline{\theta},1))(-w+l+h(\underline{u}_a)) = 0 \end{cases}$$

Unfortunately, it is difficult to analytically solve this system of equations without given the specific functional forms of the zero profit constraints. But we can graphically demonstrate some features of the contracts in equilibrium as illustrated in Figure 3, if there are equilibrium contracts in this case. Since both of the adverse selection constraints are binding, ($\overline{u}_n$, $\overline{u}_a$) should be at the intersection of type $\overline{\theta}$'s indifference line $\overline{V}(e=1) = \pi(\overline{\theta},1)u_n + (1-\pi(\overline{\theta},1))u_a - \psi$ and type $\underline{\theta}$'s indifference line $\underline{V}(e=0) = \pi(\underline{\theta},0)u_n + (1-\pi(\underline{\theta},0))u_a$, while ($\underline{u}_n$, $\underline{u}_a$) should be at the intersection of type $\overline{\theta}$'s indifference line $\overline{V}(e=1) = \pi(\overline{\theta},1)u_n + (1-\pi(\overline{\theta},1))u_a - \psi$ and type $\underline{\theta}$'s indifference line $\underline{V}(e=1) = \pi(\underline{\theta},1)u_n + (1-\pi(\underline{\theta},1))u_a - \psi$.

Furthermore, type $\overline{\theta}$'s zero profit curve $\pi(\overline{\theta},1)(w-h(u_n)) - (1-\pi(\overline{\theta},1))(-w+l+h(u_a)) = 0$ should cross the intersection ($\overline{u}_n$, $\overline{u}_a$), while type $\underline{\theta}$'s zero profit curve $\pi(\underline{\theta},1)(w-h(u_n)) - (1-\pi(\underline{\theta},1))(-w+l+h(u_a)) = 0$ should cross the intersection ($\underline{u}_n$, $\underline{u}_a$). From Figure 3, we can see that type $\underline{\theta}$'s indifference line $\underline{V}(e=0) = \pi(\underline{\theta},0)u_n + (1-\pi(\underline{\theta},0))u_a$ crosses type $\overline{\theta}$'s indifference line from above, we must have $\pi(\underline{\theta},0) < \pi(\overline{\theta},1) < \pi(\underline{\theta},1)$. Otherwise, there is no intersection ($\overline{u}_n$, $\overline{u}_a$), which implies that there is no separating equi-

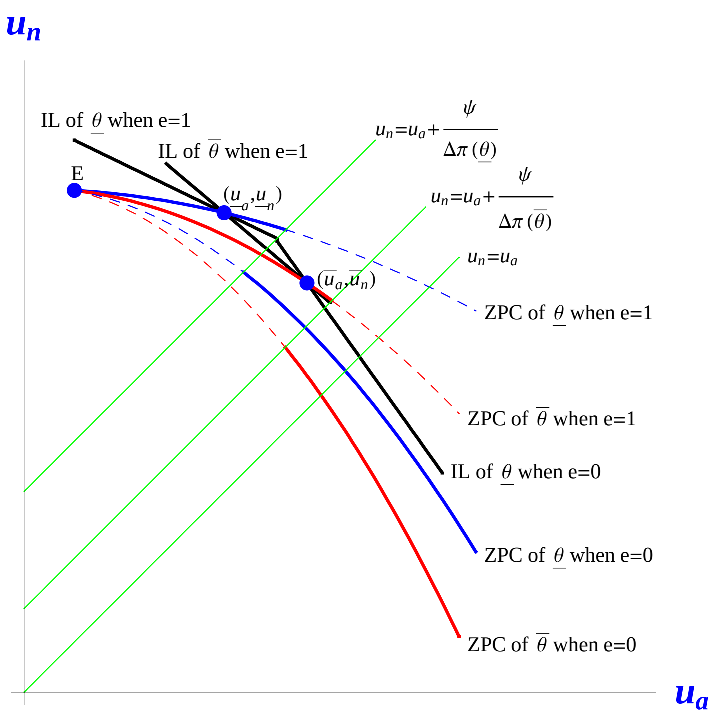

Figure 3: Case 1 of Adverse Selection and Moral Hazard

librium. Moreover, since both of the intersections, $(\overline{u}_n, \overline{u}_a)$ and $(\underline{u}_n, \underline{u}_a)$, are above its respective moral hazard incentive constraint line, the amount of insurance offered to each type is even less than that offered in the case of pure moral hazard.

Case 2: (Case H1)+ (Case L2), that is, $\overline{\lambda}_M = 0$, $\lambda_{AL} > 0$, $\underline{\lambda}_M > 0$, and $\lambda_{AH} = 0$

In this case, the moral hazard constraint and the adverse selection of type $\overline{\theta}$ are not binding, but those of type $\underline{\theta}$ are binding. According to *Lemma 2*, there is no equilibrium in this case.

Case 3: (Case H1)+ (Case L3), that is, $\overline{\lambda}_M = 0$, $\lambda_{AL} > 0$, $\underline{\lambda}_M > 0$, and $\lambda_{AH} > 0$

In this case, the moral hazard constraint and the adverse selection constraint of type $\underline{\theta}$ are binding. Again, according to *Lemma 2*, there is no equilibrium.

Case 4: (Case H2)+ (Case L1), that is, $\overline{\lambda}_M > 0$, $\lambda_{AL} = 0$, $\underline{\lambda}_M = 0$, and $\lambda_{AH} > 0$

In this case, the moral hazard constraint and adverse selection constraint of type $\overline{\theta}$ are binding, while none of the constraints of type $\underline{\theta}$ is binding. Combined with the two binding zero profit constraints, we have four equations with four unknowns:

$$\begin{cases} \overline{u}_n - \overline{u}_a = \frac{\psi}{\triangle\pi(\overline{\theta})} \\ \pi(\overline{\theta},1)\overline{u}_n + (1-\pi(\overline{\theta},1))\overline{u}_a - \psi = \pi(\overline{\theta},1)\underline{u}_n + (1-\pi(\overline{\theta},1))\underline{u}_a - \psi \\ \pi(\overline{\theta},1)(w-h(\overline{u}_n)) - (1-\pi(\overline{\theta},1))(-w+l+h(\overline{u}_a)) = 0 \\ \pi(\underline{\theta},1)(w-h(\underline{u}_n)) - (1-\pi(\underline{\theta},1))(-w+l+h(\underline{u}_a)) = 0 \end{cases}$$

Since type $\underline{\theta}$'s moral hazard constraint is not binding but the adverse selection constraint of type $\overline{\theta}$ is binding, ($\underline{u}_a$, $\underline{u}_n$) should locate above its moral hazard constraint line and be the intersection of indifference lines of the two types. As for ($\overline{u}_a$, $\overline{u}_n$), since the moral hazard constraint of type $\overline{\theta}$ is binding, it is the intersection of its indifference line and moral hazard constraint line. Meanwhile, ($\overline{u}_a$, $\overline{u}_n$) should be to the left of type $\underline{\theta}$'s indifference line, since the adverse selection constraint of the low risk type is not binding. Figure 4 illustrates the set of constraints in equilibrium in this case. It is obviously that type $\overline{\theta}$ is offered the same contract as in the case of pure moral hazard, while type $\underline{\theta}$ is offered even smaller amount of insurance than that in the pure moral hazard case.

Case 5: (Case H2)+ (Case L2), that is, $\overline{\lambda}_M > 0$, $\lambda_{AL} = 0$, $\underline{\lambda}_M > 0$, and $\lambda_{AH} = 0$

In this case, both of the moral hazard constraints are binding, while none of the adverse selection constraints is binding. The two binding moral hazard constraints and the binding zero profit constraints give us a system of four equations with four unknowns:

$$\begin{cases} \overline{u}_n - \overline{u}_a = \frac{\psi}{\triangle\pi(\overline{\theta})} \\ \underline{u}_n - \underline{u}_a = \frac{\psi}{\triangle\pi(\underline{\theta})} \\ \pi(\overline{\theta},1)(w-h(\overline{u}_n)) - (1-\pi(\overline{\theta},1))(-w+l+h(\overline{u}_a)) = 0 \\ \pi(\underline{\theta},1)(w-h(\underline{u}_n)) - (1-\pi(\underline{\theta},1))(-w+l+h(\underline{u}_a)) = 0 \end{cases}$$

Since both of the moral hazard constraints are binding, ($\underline{u}_a$, $\underline{u}_n$)and ($\overline{u}_a$, $\overline{u}_n$) should be on

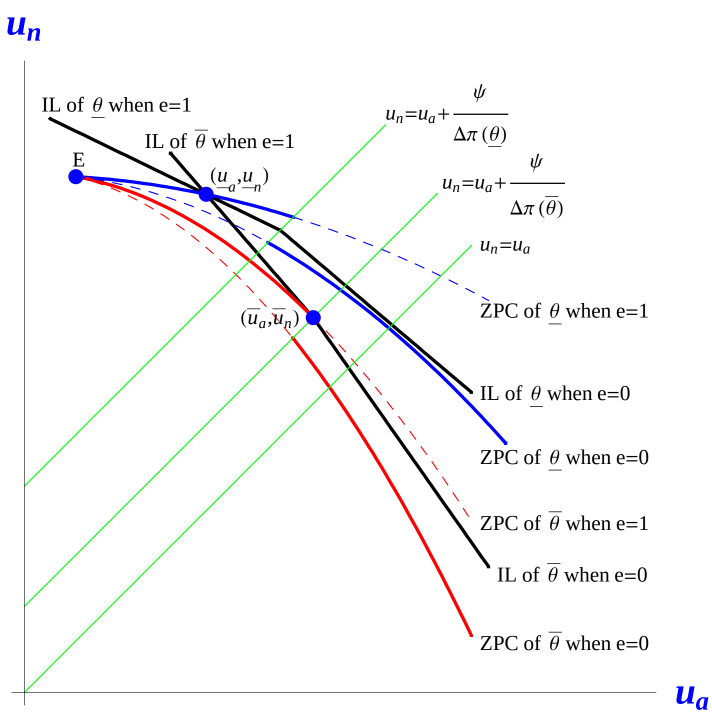

Figure 4: Case 4 of Adverse Selection and Moral Hazard

its respective moral hazard constraint line, thus each agent is offered the same contract as in the case of pure moral hazard. Moreover, since both of the adverse selection constraints are not binding, the indifference line of high risk type must cross the indifference line of low risk type from above, as illustrated in Figure 5. This implies that type $\overline{\theta}$ is absolutely riskier than type $\underline{\theta}$ no matter whether the latter expends effort or not.

Case 6: (Case H2)+ (Case L3), that is, $\overline{\lambda}_M > 0$, $\lambda_{AL} = 0$, $\underline{\lambda}_M > 0$, and $\lambda_{AH} > 0$

In this case, both of the moral hazard constraints and type $\overline{\theta}$'s adverse selection constraint are binding, while type $\underline{\theta}$'s adverse selection constraint is not binding. Therefore, similar to the previous case, each agent is offered the same contract as in the case of pure moral hazard; the only difference between this case and the previous one is that type $\overline{\theta}$ is now indifferent between the two contracts offered, while he strictly prefers his own contract in the previous case. The equilibrium is illustrated in Figure 6.

Case 7: (Case H3)+ (Case L1), that is, $\overline{\lambda}_M > 0$, $\lambda_{AL} > 0$, $\underline{\lambda}_M = 0$, and $\lambda_{AH} > 0$

In this case, both of the adverse selection constraints and type $\overline{\theta}$'s moral hazard con-

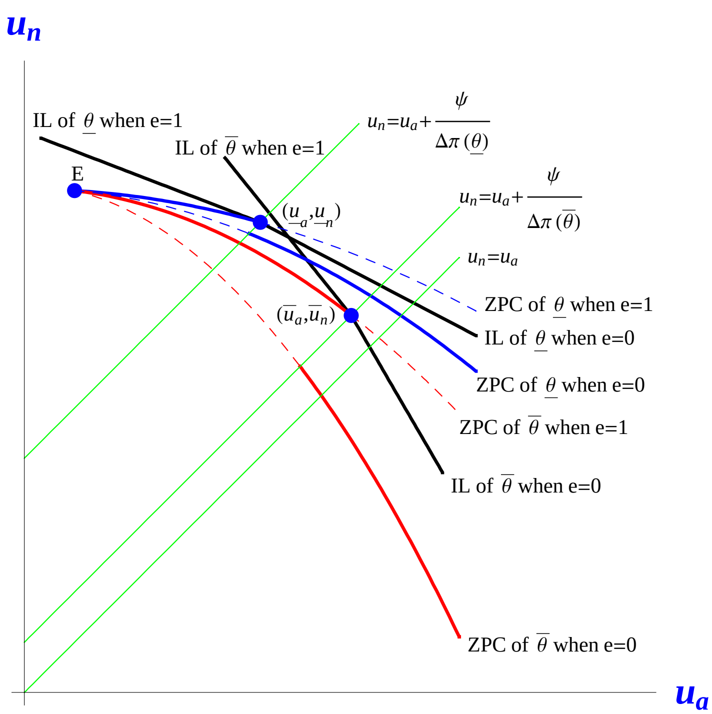

Figure 5: Case 5 of Adverse Selection and Moral Hazard

straint are binding, but type $\underline{\theta}$'s moral hazard constraint is not binding. Similar to Case 4, type $\overline{\theta}$ is offered the same contract as in the case of pure moral hazard, while type $\underline{\theta}$ is offered even smaller amount of insurance than that in the pure moral hazard case. One major difference between this one and Case 4 is that type $\underline{\theta}$ is now indifferent between the two contracts offered, while she strictly prefers her own contract in the Case 4. Figure 7 demonstrates the equilibrium in this case.

Case 8: (Case H3)+ (Case L2), that is, $\overline{\lambda}_M > 0$, $\lambda_{AL} > 0$, $\underline{\lambda}_M > 0$, and $\lambda_{AH} = 0$

In this case, both of the moral hazard constraints and type $\underline{\theta}$'s adverse selection constraint are binding, but type $\overline{\theta}$'s adverse selection constraint is not binding. According to *Lemma 2*, there is no equilibrium.

Case 9: (Case H3)+ (Case L3), that is, $\overline{\lambda}_M > 0$, $\lambda_{AL} > 0$, $\underline{\lambda}_M > 0$, and $\lambda_{AH} > 0$

In this case, all constraints are binding. According to *Lemma 2*, there is no equilibrium.

This completes the proof of Proposition 1. □

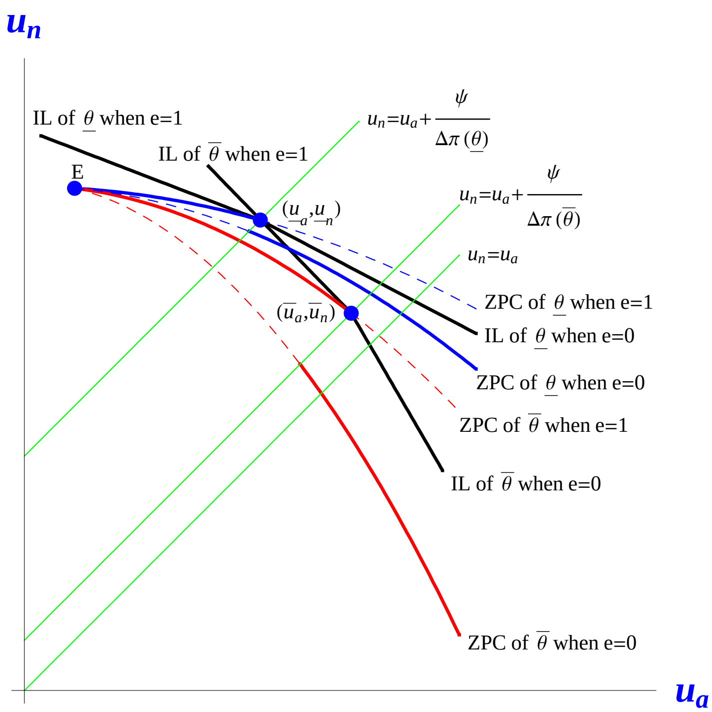

Figure 6: Case 6 of Adverse Selection and Moral Hazard

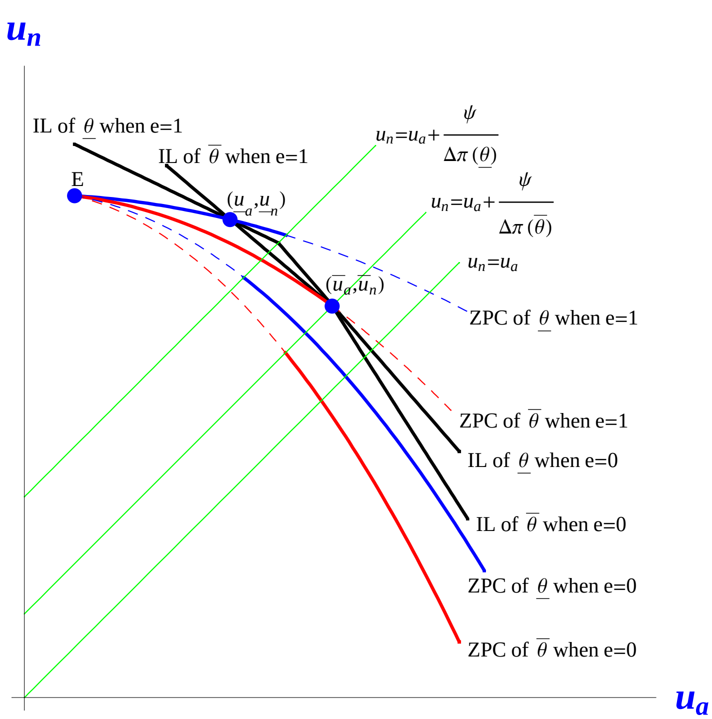

Figure 7: Case 7 of Adverse Selection and Moral Hazard

Essay 2: Testing for Adverse Selection and Moral Hazard in Reinsurance Markets

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Abstract

Over the past decade, due to unexpected huge insured losses in the wake of a series of catastrophic events, reinsurance markets are playing a more significant role in insurance industry as evidenced by the dramatic increase in reinsurance premiums. However, few studies have empirically investigated asymmetric information problems in these markets. To bridge the gap, this paper tests for the existence of adverse selection and moral hazard in reinsurance markets for the period 1995-2000, and finds that (1) adverse selection is present in private passenger auto liability and homeowners reinsurance market; (2) residual moral hazard is not present in the three largest lines of reinsurance but present in reinsurance markets as a whole; and (3) moral hazard is present in product liability reinsurance market, but not in the other two major lines of reinsurance.

1 Introduction

After the seminal work of Akerlof (1970) and Rothschild and Stiglitz (1976), the theory of contract grows dramatically over the past 30 years. In contrast, empirical studies on contract theory, although they are catching up in the past decade, are left far behind. Due to the nature of insurance industry, many insurance markets such as auto insurance, health insurance, and life insurance, are the favorite subjects of these empirical studies. However, reinsurance markets are largely ignored in the empirical asymmetric information literature, even though reinsurance plays a significant role in insurance industry.

According to National Association of Insurance Commissioners (NAIC), in year 2006, U.S. property-liability insurers have ceded insurance premiums worth 492 billion dollars, which amounts to about 52 percent of their direct business written. The high cession rate reflects a peculiar organizational structure in the reinsurance market. Insurance companies are often affiliated with an insurance group, and many reinsurance transactions take place within affiliates of insurance groups. In 2006, there are 3,091 property-liability insurers reporting to the NAIC, among which 2,136 insurers are affiliated with 428 insurance groups, and 76 percent of reinsurance activities (by ceded premiums volume) go to affiliated member insurers of an insurance group (later called internal reinsurance), while the rest take place among unaffiliated insurance companies (later called external reinsurance).

Although the bulk of reinsurance activities occur within insurance groups, many previous studies on reinsurance markets either totally disregard internal reinsurance or treat internal reinsurance solely as a corporate capital structure phenomenon (Powell and Sommer, 2007), and few studies place it in the framework of optimal risk sharing and analyze the related incentive problems.[1] Doherty and Smetters (2005) argue that, price incentives are more effective in resolving agency conflicts between separate contracting parties where asymmetric information problem is more severe, while monitoring is more efficient in controlling agency conflicts within organization. However, monitoring within organizations

[1] Exceptions include Doherty and Smetters (2005), and Garven and Grace (2007).

can still be expensive and is very unlikely to be perfect. Therefore, agency conflicts cannot be completely internalized and eliminated within organizations, although the level of information asymmetry may be reduced to some extent.

This study investigates the adverse selection and moral hazard problems in reinsurance market by examining internal and external reinsurance jointly. The different levels of information asymmetry for internal versus external reinsurance are exploited to test for the existence of asymmetric information problems in this market.

In this empirical study, We first test for the existence of adverse selection by using random effects Tobit model. We then test for the existence of both moral hazard and residual moral hazard in a single GLS fixed effects model. To test for the presence of residual moral hazard, we exploit a peculiar institutional feature in reinsurance markets, that is, the simultaneous presence of external and internal reinsurance markets. To our knowledge, this is the first empirical test for the existence of residual moral hazard in reinsurance market.

As a preview of our empirical results, we find evidence of adverse selection in private passenger auto liability reinsurance market, homeowners reinsurance market, and overall reinsurance markets, but not in product liability reinsurance market. In addition, we find indecisive evidence of residual moral hazard in homeowners reinsurance market and reinsurance markets as a whole, but no evidence in private passenger auto liability reinsurance market and product liability reinsurance market. Furthermore, we find some evidence of moral hazard only in product liability reinsurance market, which is properly controlled by reinsurers using retention limit.

The remainder of this paper is organized as follows. Section 2 discusses the related empirical literature regarding asymmetric information problems. Section 3 presents data description and variable development. Section 4 proposes strategies to test for adverse selection and moral hazard in reinsurance markets and presents empirical results. Section 5 includes discussion of empirical tests and proposes robust checks. Section 6 presents conclusions and implications of the paper.

2 Literature Review

A standard prediction of contract theory is the positive correlation property: everything being equal, people who face contracts with more comprehensive coverage should exhibit higher accident probability. The majority of empirical studies in contract theory boil down to test this positive correlation property. Therefore, if a sample data set demonstrates a positive correlation between insurance coverage and accident occurrence, it is evidence of the existence of asymmetric information. However, the positive correlation alone does not give us too much insight into the nature of the underlying asymmetric information problem. It is well argued in the literature that the positive correlation can be the result of adverse selection, moral hazard, or even unobserved heterogeneous preference.

Under adverse selection, people are characterized by different levels of risk. High risk people, knowing they are more likely to have an accident in the future, tend to purchase contracts with more comprehensive coverage. However, in a context of moral hazard, people first choose different contracts due to exogenous reasons, and then they are faced with different incentive schemes; those who end up facing a contract with more comprehensive coverage will have less incentive to adopt a more cautious behavior, which may result in higher accident probability. In practice, although the distinction between adverse selection and moral hazard may be crucial, it is very difficult, if not impossible, to separate them, especially on cross-sectional data.

Until now, the empirical findings on the presence of adverse selection are far from reaching a consensus. Dahlby (1983) tests for the presence of adverse selection in the Canadian automobile insurance market, and he find evidence of adverse selection. By comparing actual amount of health insurance purchased in the individual market with an predicted amount purchased in the group market by low-risk families, Browne (1992) finds evidence of adverse selection in the health insurance market.

Puelz and Snow (1994) use observations of claim-filing at the end of the contractual period to measure individual risks. They find that high risk individuals choose the lowest deductible, and thus they claim the presence of adverse selection in the automobile collision insurance market. However, Dionne, Gouriéroux and Vanasse (2001) argue that the finding of adverse selection in Puelz and Snow (1994) is spurious and due to potential nonlinear effects of observable risk classification variables. By including the expected number of accidents in the regression model, they do not find evidence of adverse selection any longer.

Cardon and Hendel (2001) estimate a structural model of health insurance and health care choices. They test for the unobservables linking health insurance status and health care consumption, and find no evidence of adverse selection. By using data on U.K. annuity markets, Finkelstein and Poterba (2004) test relationships between ex post mortality and annuity characteristics, such as the degree of back-loading and the possibility of payments to the annuitant's estate, and find evidence consistent with the existence of adverse selection in U.K. annuity markets. Garven and Grace (2007) empirically test some implications of the adverse selection model on reinsurance developed in Jean-Baptiste and Santomero (2000). More specifically, they test how long-term reinsurance contracting relationships affect amount of reinsurance coverage, primary insurer's profitability, and primary insurer's probability of bankruptcy. Their empirical findings are largely consistent with predictions of the adverse selection model.

The lack of consensus among empirical studies on the adverse selection problem is not unique at all, and it is a recurring theme in empirical studies on the moral hazard problem as well. One major difficulty in testing for moral hazard is that effort is not directly observable to outsiders such as reinsurance companies, courts, or researchers. To provide convincing evidence in the empirical tests, various ingenious strategies are employed in the literature. One common approach to testing for the presence of moral hazard is to use experiments, natural experiments (Chiappori and Salanie, 2003) or other strategies to establish a reference group, and the reference group is used as a benchmark for comparison in testing for the existence of "residual" moral hazard among the rest of population.

By dividing the variation of total consumption of worker's compensation insurance benefits with respect to changes in insurance coverage into two parts (the variation due to a given level of asymmetric information, and the variation due to a greater level of asymmetric information), Dionne and St-Michel (1991) find evidence of moral hazard in Canadian workers' compensation insurance market. Cummins and Tennyson (1996) use survey data on consumer attitudes toward various types of dishonest behaviors related to insurance claims as an indicator of moral hazard, and find strong evidence of moral hazard in U.S. automobile insurance markets.

Chiappori, Durand and Geoffard (1998) use a subgroup of individuals facing no change in co-payment rate in the French medical insurance markets as a control group, and investigate how an introduction of a co-payment rate affects the demand for physician services. They find evidence of moral hazard in the French medical insurance markets. In the French auto insurance markets for young drivers, Chiappori and Salanie (2000) find no evidence of moral hazard , and they argue that the auto insurance markets for young drivers should be absent from contamination of the adverse selection problem, which makes possible the separation of moral hazard from adverse selection. Although both used data on French auto insurance, Abbring, Pinquet and Chiappori (2003) find no evidence of moral hazard, while Dionne, Michaud and Dahchour (2004) demonstrate the presence of moral hazard to the contrary by jointly estimating a bivariate probit model with correlated errors.

Doherty and Smetters (2005) develop a two-period principal-agent model to study the moral hazard problem in reinsurance markets. Then they test the empirical implications of their model using panel data on homeowners reinsurance and product liability reinsurance. They not only find evidence for the existence of moral hazard in these reinsurance markets, but also identify the methods that reinsurers use to address the moral hazard problem across different types of business relationship. A more recent study (Barros, Machado and Galdeano, 2007) estimated how extra health insurance coverage affected the demand for health care services. By using matching estimators technique, they found presence of moral hazard in certain types of health care but not in the others.

In this paper, we contribute to the empirical literature on asymmetric information by investigating the existence of adverse selection and moral hazard in the three largest property/liability reinsurance markets in U.S., which are largely ignored in the previous empirical studies. Ideally, we should test for the presence of adverse selection and moral hazard simultaneously, however, as it is well known in the literature, it is very difficult, if not impossible, to achieve that. Therefore, based on U.S. reinsurance market structure and the characteristics of our data, we employ different empirical strategies to test for the presence of adverse selection and moral hazard separately in the reinsurance markets.

3 Data Description and Variable Development

3.1 Data Description

We mainly use two data sources: one is NAIC property and casualty annual statement data sets, and the other is A.M. Best's Key Rating Guide - Property/Casualty. NAIC data sets contain detailed information on most American insurance companies, such as total assets, premium written, organization form, group affiliation, reinsurance premium ceded, reinsurance premium assumed, etc. A.M. Best's Key Rating Guide - Property/Casualty complements NAIC data set with data such as insurers' financial strength ratings and lead company. Data from year 1995 to 2000 are used, since the reinsurance markets are widely viewed as soft markets during this period of time, and thus the markets are more close to competitive markets. In addition, data from year 2001 to 2006 are collected as well to construct a few key variables. The following three of the largest property/casualty lines of reinsurance are used for our empirical tests: private passenger auto liability reinsurance, homeowners reinsurance, and product liability reinsurance.

For the years 1995 to 2000, a total of 17,996 observations of insurance companies were reported to the NAIC, among which 7,875 observations were reported to write positive ceded reinsurance premiums in private passenger auto liability insurance, 7,636 observations in homeowners insurance, while 4,225 observations in product liability insurance. To obtain appropriate sample for this study, we apply the following sample selection criteria:

1. The firm must report to be *active* and file its annual statement individually;

2. The firm must report positive numbers for direct written premiums, both for the entire firm and for the line of business under study;

3. The firm's policyholder surplus and total admitted assets must be greater than $250,000;

4. The firm must have been classified as a stock, mutual or reciprocal company;

5. For individual line of business, the firm must not be classified as a reinsurer. According to the classification scheme used by A.M. Best, reinsurers are defined as "firms whose reinsurance assumed from nonaffiliates is more than 75 percent of the direct business written plus reinsurance assumed from affiliates" (Cole and McCullough, 2007). [2]

The final sample on private passenger auto liability reinsurance includes 2121 affiliated insurer observations and 393 unaffiliated insurer observations for the period from 1995 through 2000. The final sample on homeowners reinsurance includes 1865 affiliated insurer observations and 602 unaffiliated insurer observations for the period from 1995 through 2000. The final sample on product liability reinsurance includes 789 affiliated insurer observations and 39 unaffiliated insurer observations for the period from 1995 through 2000. To reduce the impact of outliers and data errors, some variables are winsorized at the 1^{st} and 99^{th} percentiles.[3]

3.2 Variable Development

Based on prior studies on reinsurance and related topics, the following variables, which we believe to be relevant for the purpose of the current study, are constructed for hypotheses testing. Table 1 provides a summary of the definitions of all of the variables.

Net Amount of Reinsurance. The net amount of reinsurance is usually defined as the ratio of reinsurance premiums ceded to the sum of direct premiums written and reinsurance premiums assumed.[4] However, this definition may be not appropriate when we consider internal and external reinsurance simultaneously, because internal reinsurance can be used for other purposes except for the traditional risk transfer function. For instance, a leading affiliated insurer of an insurance group may, due to its stronger financial status, assume

[2]It is also used by Powell and Sommer (2007).

[3]Refer to Cox (1998) for detailed discussion and Stata command on winsorizing. Garven and Grace (2007) also apply winsorizing in their study on reinsurance.

[4]This definition is used by Berger, Cummins and Tennyson (1990), Mayer and Smith (1990), Garven (1990), and Cole and McCullough (2006).

reinsurance from other affiliates for the purpose of purchasing reinsurance from outside reinsurers as a single entity, which may be more cost efficient or result in a stronger bargaining power with outside reinsurers. However, after the purchase of external reinsurance, the leading affiliate may allocate reinsurance back to the other affiliates. In this situation, the net reinsurance purchased by a non-leading affiliate is the difference between the reinsurance ceded to and assumed from the leading affiliate. To mitigate the problems associated with the utilization of internal reinsurance, we treat an affiliated insurer either as a net buyer or a net seller of internal reinsurance. Therefore, we define *net amount of reinsurance* as the ratio of the sum of external reinsurance premiums ceded and net internal reinsurance ceded to the sum of direct premiums written and reinsurance premiums assumed, or

$$\begin{array}{c}\text{net amount}\\ \text{of reinsurance}\end{array} = \frac{\text{external ceded reinsurance + net internal ceded reinsurance}}{\begin{array}{c}\text{direct premiums written + external assumed}\\ \text{reinsurance + net internal assumed reinsurance}\end{array}}$$

where net internal ceded reinsurance = internal ceded reinsurance - internal assumed reinsurance.[5]

Loss Ratio Volatility / Future Loss Ratio Volatility. We estimate the standard deviation of loss ratio for primary insurance companies using data from year t to year t+6. For instance, the value for *loss ratio volatility* in year 1995 for a given insurance company is computed using loss ratios of the years 1995-2001. Loss ratio volatility is commonly used in the literature to measure the riskiness of an insurer (Hoerger, Sloan and Hassan, 1990; Cummins, et al., 2008), and it is usually computed using historical data. However, loss ratio volatility constructed in this way essentially contains only public information, and thus is not appropriate for the purpose of current study. Hence, we believe that loss ratio volatility should be computed using future data instead of historical data to capture any potential asymmetric information between a primary insurer and a reinsurer.

Loss Reserve Error / Loss Forecast Revision. An alternative measure of riskiness of a

[5] Note here that, in the definition, either *net internal ceded reinsurance* or *net internal assumed reinsurance* or both are equal to zero.

primary insurer is loss reserve error.[6] Loss reserve error in year t is the difference between the actually developed incurred losses as of year t+5 and the originally reported incurred losses in year t. A five-year development period is used since a high percentage of losses is settled during this period. If an insurer has a positive loss reserve error, it implies that the losses and loss adjustment expenses actually developed in the future is higher than originally estimated by the insurer, and it is evidence of under-reserving. Comparing to *loss ratio volatility*, *loss reserve error* should be a better measure of risk since it mainly reflects the asymmetric information between a primary insurer and a reinsurer at the time of contracting, while *loss ratio volatility*, by its nature, should be a noisier measure of risk. To remove the effect of firm size, we use percentage error. The percentage error is computed as the ratio of loss reserve error to the originally reported incurred losses.

Loss Ratio Difference. Alternatively, we gauge the riskiness of a primary insurer by *loss ratio difference*, which is measured by the difference between an insurer's loss ratio in year t and the average of yearly industry loss ratio over the previous three years. Therefore, this measure reflects an insurer's relative riskiness comparing to the industry.

Loss Ratio Ceded. For each line of reinsurance business, loss ratio ceded is defined as the ratio of total loss ceded[7] to total premiums ceded. In order to estimate total loss ceded more accurately, we use a five-year development period.

External Reinsurance Ratio. For each line of reinsurance business, external reinsurance ratio is defined as the ratio of external ceded reinsurance to total ceded reinsurance.

Year Dummies. Year dummies are included to eliminate any industry-wide effect on the risk measures of individual insurance companies.

Best's Ratings. A.M. Best's financial strength ratings are used to measure financial strength of insurers. Four rating dummies are used. The rating dummy "*Rating1*" takes a value of 1 if an insurer is assigned a rating of either A++ or A+, and zero elsewhere. The rating dummy "*Rating2*" takes a value of 1 if an insurer is assigned a rating of either A or

[6]Harrington and Danzon (1994) called it *loss forecast revision*.

[7]Since insurers do not report loss ceded to affiliated and nonaffiliated insurers separately, the total loss ceded is the total ceded loss of internal and external reinsurance.

A-, and zero elsewhere. The rating dummy "*Rating3*" takes a value of 1 if an insurer is assigned a rating of either B++ or B+, and zero elsewhere. The rating dummy "*Rating4*" takes a value of 1 if an insurer is assigned a rating of either B or B-, and zero elsewhere. The omitted group includes insurers with a rating of C++ or lower. In general, we hypothesize that the higher the Best's rating is, the smaller the amount of ceded reinsurance is, because a financially strong primary insurer may have the luxury of retaining a larger proportion of underwriting risks and thus purchase a smaller amount of reinsurance. However, since insurers with a rating of either B+ or B are on the verge of being regarded as either secure or vulnerable, they may be more prudent and thus purchase more reinsurance in the hope of improving their ratings.

Organizational Form. An organizational form dummy called "*Mutual*" takes a value of 1 if an insurer is either a mutual or a reciprocal insurer, and 0 otherwise (that is, a stock insurer).

Distribution System. Two distribution system dummies are included. The dummy "*Direct*" takes a value of 1 if an insurer is a direct writer, and 0 otherwise. The dummy "*Agency*" takes a value of 1 if an insurer uses an independent agency distribution system, and 0 otherwise.

Firm Size. Warner (1977) finds evidence that bankruptcy costs were less than proportional to firm size, or in other words, bankruptcy costs were relatively higher for small firms. Mayers and Smith (1990) argue that firm size could affect insurance demand through a few channels, such as expected bankruptcy costs and real-service efficiencies, both of which imply that large firms should purchase proportionally smaller amount of reinsurance. In addition, several studies use firm size as a measure of bankruptcy costs (Mayers and Smith, 1990; Garven and Lamm-Tennant, 2003; Weiss and Chung, 2004), and find that firm size negatively affects the purchase of reinsurance. Here, firm size is defined as the natural logarithm of total admitted assets.

Leverage. Leverage is calculated as total net premiums written to policyholders' surplus, and it measures the probability of bankruptcy of an insurer.

Line-of-Business Concentration. It is computed as the ratio of premiums written in a specific line to total premiums written. If a certain line of business, say homeowners, accounts for a large proportion of an insurer's underwriting risks, it is likely that the insurer tends to purchase more reinsurance in this line.

Premium Growth Rate. The growth rate of a firm's business is measured as the percentage growth in direct premiums written. Rapid growth usually causes a drain on the primary insurer's surplus, and thus the rapidly growing insurer needs more reinsurance to provide surplus relief. In addition, rapid growth may be the direct result of the primary insurer's aggressive underwriting strategies, which can generate more volatile loss ratio. In order to stabilize its profitability, the rapidly growing insurer may purchase more reinsurance.

Tax Rate. The cedent's effective tax rate is computed as $1 - \frac{NI_t}{BTNI_t}$, where NI_t is the after-tax net income in year t, and BTNI_t is the before-tax net income in year t (Garven and Grace, 2007).

Contract Sustainability. Lambert (1983) shows theoretically that long-term contracts can be used to "diversify away some of the uncertainty surrounding the agent's actions", and thus control the moral hazard problem. Jean-Baptiste and Santomero (2000) demonstrate that long-term implicit contracts can mitigate the adverse selection problem and thus lead to more complete reinsurance coverage. Unfortunately, we do not have detailed information on individual reinsurance contracts, thus we have to indirectly measure contract sustainability. Following Garven and Grace (2007), we include two variables to measure contract sustainability. The first proxy is called "SUSTAIN", and is defined as the percentage of premiums ceded over a three-year period to external reinsurers which are present in all three years. The second proxy is called "RHERF", which is defined as the average of yearly Herfindahl index of reinsurance premiums ceded over year t-2 to year t. It "measures the degree to which the cedent tends to have 'focus' versus diffuse contractual relationships with external reinsurers" (Garven and Grace, 2007).

Herfindahl Indexes. Product Herfindahl measures the degree of product diversification of an insurer. It equals 1 if an insurer underwrites insurance only in a single line, and converges to zero as the lines of insurance business underwritten increases. *Geographic Herfindahl* measures the degree of geographic diversification of an insurer's business. It equals 1 if an insurer underwrites insurance only in one state, and approaches zero as the number of states an insurer operates in increases.

Long Tail. Long Tail measures the proportion of an insurer's premiums written in long tail lines. Following Phillips, Cummins and Allen (1998), long tail lines include Farmowners Multiple Peril, Homeowners Multiple Peril, Commercial Multiple Peril, Ocean Marine, Medical Malpractice, International, Reinsurance, Workers' Compensation, Other Liability, Products Liability, Aircraft, Boiler and Machinery, and Automobile Liability.

Profitability. Two financial ratios are used to measure profitability of an insurance company: *return on assets (ROA)* and *return on equity (ROE)*. The *ROA* is the ratio of net income to total admitted assets and *ROE* is the ratio of net income to surplus.

Age. Age is measured by natural log of the number of years that an insurer has commenced insurance business at the time of data observation. The older an insurer is, the better the insurer may be known by people inside insurance industry, and thus the less severe the asymmetric information problem might be between the insurer and a reinsurer. Therefore, age is used to capture this asymmetric information effect (Powell and Sommer, 2007).

Retention Limit. Retention limit is measured by the ratio of retained losses (that is, the difference between total losses and ceded losses) to total losses. If the reinsurance contract is an excess-of-loss contract, then this ratio measures the retention limit of the reinsurance contract. If the reinsurance contract is a proportional contract, then this ratio gauges a primary insurer's share of loss. According to Global Reinsurance Market Report 2006,[8] proportional reinsurance contracts account for almost twice as much premium as non-proportional reinsurance contracts in lines of non-life reinsurance. Therefore, *retention*

[8]By International Association of Insurance Supervisors.

limit defined above, to a great extent, measures a primary insurer's share of loss. However, loss experience of insurance companies can be very volatile over time, which causes this measure of *retention limit* a noisy variable. Therefore, as an alternative, *retention limit* is also estimated by the ratio of net premiums written (that is, the direct premiums written plus reinsurance premiums assumed minus reinsurance premiums ceded) to total premium written (that is, the sum of direct premiums written and reinsurance premiums assumed). Lagged retention limit is used to avoid a spurious correlation or endogeneity problem.

Experience Rating. Similar to Doherty and Smetters (2005), experience rating is measured by the ratio of lagged total premiums earned (assumed and direct business) to lagged total losses incurred. Loss experience can provide useful information about the risk type of a primary insurer, thus reinsurers can use experience rating technique to reduce the adverse selection problem. Moreover, in a multi-period setting, experience rating can also mitigate the moral hazard problem as long as past loss experience of a primary insurer is public information and available to all reinsurers.

Lead Company. Lead company is a binary variable which takes a value of 1 if an insurer is the lead company of an insurance group, and 0 otherwise. Among an insurance group, a lead insurer tends to be larger and financially stronger comparing to non-lead affiliates.

Coastal States. Due to exposures to hurricane risks, the homeowners insurance markets in the hurricane-prone states behave quite differently. The dummy variable *Coastal States* takes a value of 1 if an insurer is domiciled in one of the following states, which are called hurricane-prone states according to the Landscape of Natural Disasters of USATODAY.com: Alabama, Arkansas, Connecticut, Delaware, Florida, Georgia, Louisiana, Maine, Maryland, Massachusetts, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina, Texas, Vermont, and Virginia, and 0 otherwise.

4 Empirical Tests

4.1 Testing for Adverse Selection

The methodology to test for adverse selection is pretty standard in the literature. Essentially, we run a regression of reinsurance coverage on a measure of primary insurers' risk level and other control variables. Although individual reinsurance contract information is ideal for this type of empirical test, we only have aggregate reinsurance data at firm level, and thus we use the amount of reinsurance purchased by a primary insurer to measure the amount of reinsurance coverage. The measure of the risk level of individual primary insurers is critical here. The measure of individual firm risk should *"represent some asymmetric information between the insurer and the insured in the sense that, at the date of contract choice, the insured has more information than the insurer about his individual (residual) risk during the contractual period"* (Dionne, Gouriéroux and Vanasse, 1998).

Previous empirical studies use forward-looking data in the sense that it is not available at the time of contracting to measure risk of individuals. For instance, Dionne, Gouriéroux and Vanasse (1998), and Dionne, Gouriéroux and Vanasse (2001) use the expected number of accidents or the *ex post* actual number of accidents to measure agents' risk level in automobile insurance markets, while Edelberg (2004) utilizes predicted probability of late payments to gauge agents' risk level in mortgage and automobile loan markets. In this paper, in a similar fashion, we use forward-looking data to construct our risk measure, which is called *loss reserve error* (Weiss, 1985), or *loss forecast revision* Harrington and Danzon (1994). Loss reserve error is the difference between the actually developed losses and loss adjustment expenses outstanding at a given valuation date and the losses and loss adjustment expenses originally estimated and reported. If an insurer has a positive loss reserve error, it implies that the losses and loss adjustment expenses actually developed in the future are higher than originally estimated by the insurer, and it is evidence of under-reserving.

There are several hypotheses about under-reserving, such as intentional managerial bias, unintentional over-optimism, unpredictable bad experience (Petroni, 1992), and income smoothing (Weiss, 1985). By assuming that the total claim losses paid as an unbiased estimate of the expectation of outstanding loss claim, Petroni (1992) finds evidence consistent with the hypothesis that managers of financially weak insurers bias downward their estimates of claim loss reserves relative to other insurers after controlling for exogenous economic factors. In addition, she also rules out the explanations of unintentional over-optimism of management and unpredictable bad experience. Hence, *loss reserve error* is a good measure of risk in the context of testing for adverse selection, since this measure of risk, according to the findings of Petroni (1992), does contain some asymmetric information between a primary insurer and a reinsurer.

4.1.1 Empirical Framework

The regression model used to test for the existence of adverse selection can be expressed as follows:

$$\text{REINS}_{it} = \alpha + \beta\ \text{Risk}_{it} + \sum \gamma X_{it} + \varepsilon_{it},$$

where,

$$\text{REINS} = \frac{\text{external ceded reinsurance + net internal ceded reinsurance}}{\begin{array}{c}\text{(direct premiums written + external assumed}\\ \text{reinsurance + net internal assumed reinsurance)}\end{array}};$$

$$\text{Risk} = \begin{array}{l}\text{the measure of risk of a primary insurer, either the loss ratio}\\ \text{volatility or the loss reserve error;}\end{array}$$

and X_{it} X_{it} includes the following exogenous variables: two proxies for long-term reinsurance contracting relationship (i.e., *SUSTAIN* and *RHERF*), firm size, line-of-business concentration, line-specific premium growth rate, firm premium growth rate, financial leverage, net income tax rate, product Herfindahl, geographic Herfindahl, the proportion of premiums written in long tail lines, return on assets, lead company, coastal states, and year dummies.

In the above regression model, the dependent variable, *net amount of reinsurance*, takes on the value zero with positive probability but is roughly continuous and bounded on [0,1]. For instance, of 2419 observations in the sample of private passenger auto liability reinsurance, 262 observations take a value of 0; of 2211 observations in the sample of homeowners reinsurance, 144 observations take on the value zero. Figures 8, 9, and 10 provide the histograms of *net amount of reinsurance* for private passenger auto liability reinsurance, homeowners reinsurance, and product liability reinsurance, respectively. Therefore, the dependent variable, *net amount of reinsurance*, is a typical *corner solution outcome*, which renders the coefficient estimates of generalized linear regression model inconsistent (Wooldridge, 2001). Hence, a *corner solution model*, or Tobit model, should be employed to deal with this kind of "censored" data. Moreover, in order to take advantage of our panel data feature, we estimate a random-effects Tobit regression of the amount of reinsurance purchased by primary insurers on a measure of individual firm risk and other exogenous economic factors.[9] If the coefficient on the measure of risk, *loss reserve error*, is positive and significant, we find evidence for the existence of adverse selection.

Before we discuss the empirical results of Tobit model, we need to keep in mind that, for the purpose of our empirical test for adverse selection, we only care about the sign and significance level of the coefficient estimates, thus we will not report the partial effects of every independent variable on the conditional expectations of the dependent variable.

4.1.2 Results on Adverse Selection

Table 3A, 3B and 3C contain the summary statistics for the variables used in the empirical regression models for each line of business. As previously discussed, variables winsorized at the 1^{st} and 99^{th} percentiles are line-specific net amount of reinsurance, loss ratio volatility, loss reserve error, experience rating, retention limit, line-specific premiums growth rate,

[9]STATA command *xttobit* is used here to exploit the panel data feature of our data samples. Since unconditional fixed-effects Tobit estimates are biased, we employ random-effects Tobit model here. Please refer to STATA manual for further discussion (http://www.stata.com/help.cgi?xttobit).

firm premiums growth rate, leverage, tax rate, product Herfindahl, geographic Herfindahl, proportion of premiums written in long tail lines, and return on assets.

Table 4A, 4B and 4C report the random-effects Tobit regression results for the following three lines of reinsurance, respectively: private passenger auto liability reinsurance, homeowners reinsurance, and product liability reinsurance. Since there is a number of observations containing missing values of SUSTAIN and RHERF, we run our regressions with and without these two variables.[10]

Table 4A reports the regression results for the private passenger auto liability reinsurance. The coefficient on our risk measure, *loss reserve error*, is positive and statistically significant at the 1 percent level when *SUSTAIN* and *RHERF* are included, and statistically significant at the 10 percent level when *SUSTAIN* and *RHERF* are excluded. The positive correlation between our risk measure and the amount of reinsurance purchased conforms to our hypothesis that high risk insurers tend to purchase a larger amount of reinsurance. Therefore, we conclude that adverse selection is present in the private passenger auto liability reinsurance market.

The coefficient on *experience rating* is positive as hypothesized, but insignificant at conventional significance levels. The coefficient on *retention limit* is always negative and significant at the 1 percent level, suggesting that an insurer retaining a higher proportion of direct business premiums purchases a smaller amount of reinsurance. This may imply that reinsurers use retention limit to mitigate the adverse selection problem. *firm premiums growth rate* is positive and significant at the 1 percent level in every econometric specification, suggesting that rapidly growing primary insurers utilize reinsurance to resolve their growth-related problems, such as surplus drain and volatile profitability. However, *auto premiums growth rate* is never significant, suggesting that reinsurance purchase decision is made at the firm level. The coefficient on *auto concentration* is positive but only statistically significant at the 10 percent level when *SUSTAIN* and *RHERF* are included, in-

[10]Because *SUSTAIN* is defined as the percentage of premiums ceded over a three-year period to external reinsurers which are present in all three years, the construction of this variable will reduce our sample size by about 25 percent.

dicating that an insurer tends to purchase more private passenger auto liability reinsurance if the insurer's business is highly concentrated in this line of business.

The coefficient on *leverage* is negative and significant at the 1 percent level in both econometric specifications. Since *leverage* proxies for the probability of bankruptcy, a negative and statistically significant coefficient on it implies that the higher the probability of bankruptcy, the smaller amount of reinsurance purchased. This may be because reinsurers are reluctant to provide reinsurance coverage to those financially weak insurers or because higher reinsurance price charged by reinsurers to those financially weak insurers dampens these insurers' desire to purchase reinsurance coverage. The coefficient on *firm size* is always negative and statistically significant at the 1 percent level, suggesting that larger primary insurers tend to purchase less private passenger auto liability reinsurance. The two proxies for long-term contracting relationship, *SUSTAIN* and *RHERF*, are never significant.

The coefficient on *geographic Herfindahl* is always negative, and statistically significant at the 1 percent level when *SUSTAIN* and *RHERF* are included, suggesting that a more geographically diversified primary insurer tends to purchase a larger amount of reinsurance. This finding is consistent with the real service hypothesis[11] of Mayers and Smith (1990). The coefficient on *lead company* is always negative, and statistically significant at the 1 percent level when *SUSTAIN* and *RHERF* are included, indicating that those financially strong lead companies within an insurance group tend to purchase less private passenger auto liability reinsurance. Other variables such as *tax rate*, *long tail lines*, *product Herfindahl*, *ROA*, and *year dummies* are not statistically significant at conventional significance levels.

Table 4B contains the regression results for homeowners reinsurance. The coefficient on *loss reserve error* is positive and statistically significant at the 5 percent level when *SUSTAIN* and *RHERF* are included, and statistically significant at the 10 percent level

[11]This hypothesis states that those small insurance companies that geographically diversified or that offer insurance across many lines put a greater value on the set of services provided by reinsurance companies and thus tend to purchase more reinsurance.

when *SUSTAIN* and *RHERF* are excluded. Again, this positive correlation between our risk measure and the net amount of reinsurance purchased suggests that adverse selection exists in homeowners reinsurance markets.

The coefficient on *experience rating* is always positive and significant at the 5 percent level, suggesting that a favorable loss experience in previous year helps a primary insurer to secure better homeowners reinsurance coverage.[12] As in the line of private passenger auto liability reinsurance, the coefficient on *retention limit* is always negative and significant at the 1 percent level, suggesting that an insurer retaining a higher proportion of direct business premiums purchases a smaller amount of reinsurance. The two proxies for long-term contracting relationship, *SUSTAIN* and *RHERF*, are not statistically significant. Therefore, we conclude that adverse selection is present in the homeowners reinsurance market, and reinsurers use *experience rating* and *retention limit* to mitigate the adverse selection problem.

Table 4C reports the regression results for product liability reinsurance. In both econometric specifications, the risk measure, *loss reserve error*, is not statistically significant at conventional significance levels, indicating that the adverse selection problem does not exist in product liability reinsurance market. *retention limit* is again negative and significant at the 1 percent level in both econometric specifications. However, the coefficients on *experience rating* are not significant, though positive as hypothesized. Also, both *SUSTAIN* and *RHERF* are not statistically significant at the conventional 5 percent level. Therefore, we claim that we find no evidence for the existence of adverse selection in the product liability reinsurance market.

In sum, we find evidence for the existence of adverse selection in private passenger auto liability and homeowners reinsurance markets, but not in product liability reinsurance market. In addition, *retention limit* is widely used in every reinsurance market to mitigate the adverse selection problem, while *experience rating* is found to be important in con-

[12] *Experience rating* is defined as the ratio of lagged total premiums earned to lagged total losses incurred. Thus, a larger number of *Experience rating* implies a better loss experience in the previous year.

trolling the adverse selection problem only in homeowners reinsurance market. However, long-term contracting relationship seems not important in mitigating adverse selection in reinsurance markets.

4.2 Testing for Moral Hazard

As discussed previously, one major difficulty in testing for moral hazard is that an agent's action or effort is either unobservable to an outsider or too costly to observe. Therefore, without a good measure of effort level, a direct test for moral hazard is infeasible. One common approach to overcome this difficulty is to test for "residual" moral hazard. More specifically, a population in question is divided into two or more groups based on some *exogenous* criteria. If one group is believed to be more likely subject to the moral hazard problem than another, the latter group is then used as a reference group and econometric tests can be designed to test for this additional layer of moral hazard in the former group. This approach has been used in a few previous empirical studies on moral hazard, such as Dionne and St-Michel (1991), Chiappori, Durand and Geoffard (1998), Chiappori and Salanie (2000), and Barros, Machado and Galdeano (2007).

To test for the existence of the residual moral hazard problem in reinsurance markets, we use the approach described above by exploiting a peculiar feature in reinsurance markets. In insurance industry, many insurance companies are affiliated with various insurance groups. Primary insurers affiliated with an insurance group can purchase reinsurance from both affiliated member insurers and non-affiliated insurers, while non-affiliated insurers can only purchase reinsurance from other independent insurance companies. To simplify terminology, a reinsurance transaction between insurance companies affiliated with the same insurance group is called *internal reinsurance*, while a reinsurance transaction between non-affiliated insurance companies is called *external reinsurance*. As argued by Doherty and Smetters (2005), price incentives should be more effective in mitigating agency conflicts between separate organizations, while monitoring should be more efficient to resolve agency conflicts within organizations where it is easier to have access to information. This implies that it is more difficult for a non-affiliated reinsurer to monitor a ceding company than an affiliated reinsurer does. Therefore, if the moral hazard problem exists in reinsurance markets, it should be more severe in external reinsurance markets than in internal reinsurance markets. Consequently, everything else equal, the loss experience of ceded reinsurance should be worse for primary insurers using a higher proportion of external reinsurance than for primary insurers using only internal reinsurance or a smaller proportion of external reinsurance.

In addition, we construct two variables, *experience rating* and *retention limit*, to capture any dynamics of the moral hazard problem. By exploiting the panel data feature of our reinsurance data set, if we find that the loss experience of reinsurance in year t is positively correlated with *experience rating* and/or *retention limit* in year t-1, then we find evidence of moral hazard in that line of reinsurance.

In the following, we propose two empirical strategies to test the above hypothesis, the first one is the matching estimators method, and the second one is the fixed effects model for panel data.

4.2.1 Empirical Framework

A. Matching Estimators Method

Matching estimators technique is one of the recently developed semi-parametric approaches used to estimate average treatment effects. Comparing to traditional regression analysis, matching estimators technique does not make the linear functional form assumption, thus can overcome the potential spurious correlation problem due to the omitted nonlinear effects (Dionne, Gouriéroux and Vanasse, 2001). In our context, we apply matching estimators in order to estimate the impact of having internal reinsurance coverage on the loss experience of ceded reinsurance. As discussed previously, an affiliated member of an insurance group can purchase reinsurance from other members of the insurance group (called *internal reinsurance*) as well as independent reinsurers (call *external reinsurance*), while an unaffiliated insurer can only purchase reinsurance from independent reinsurers. If the moral hazard problem is less severe within an insurance group due to easier access to information, the loss experience of internal reinsurance should be more favorable than that of external reinsurance, everything else equal.

More specifically, by taking group affiliation as the treatment variable, we can treat non-affiliated insurance companies as the control group while affiliated insurance companies as the treatment group. Furthermore, by taking *Loss Ratio Ceded* as the dependent variable, we can apply the matching estimators technique to estimate the average differential of loss experience of ceded reinsurance between these two groups. Denote by $Y_i(0)$ the outcome (i.e., *loss ratio ceded* in our context) obtained by individual insurer i, $i = 1, \ldots, N$, if under the control group (i.e., unaffiliated insurers), and $Y_i(1)$ the outcome individual insurer i would obtain if under the treatment group (i.e., affiliated insurers). If both $Y_i(0)$ and $Y_i(1)$ were observable, the treatment effect on individual i would be simply computed as $Y_i(1) - Y_i(0)$. In the same fashion, we could compute the treatment effect across the full sample and then calculate the sample average treatment effect (SATE) as follows,

$$SATE = \frac{1}{N} \sum_{i=1}^{N} \{Y_i(1) - Y_i(0)\}$$

If the estimated sample average treatment effect is negative and statistically significant at conventional levels, it suggests that, on average, ceded reinsurance loss ratio of a primary insurer in the treatment group (i.e., affiliated companies) is better than that of a similar insurer in the control group (i.e., non-affiliated companies). Hence, we claim that *residual moral hazard* exists in the reinsurance market.

However, only one of the two outcomes $Y_i(0)$ and $Y_i(1)$ is observed for individual i. Therefore, to estimate the average treatment effect, we have to estimate the unobserved potential outcome for each individual in the sample. If assignment to treatment is independent of the potential outcomes for individuals with similar values of covariates X_i, we could use the average outcomes of some similar individuals of the opposite treatment group to estimate the unobserved potential outcomes.[13] This is the main idea behind the matching estimators method. The independence assumption is reasonable in our context because an insurer's group affiliation, we believe, is exogenous to its loss experience of ceded reinsurance. This belief is also supported by Cummins et al. (2008) as they argued that

[13] See Abadie and Imbens (2002) and Abadie et al. (2004) for detailed discussions.

"ownership structure, group membership, distribution system and head office state are most of the time once and for all decisions unaffected by the current situation of the firm... It is therefore very unlikely that unobserved variables affecting reinsurance, risk management and financial intermediation would also affect these variables."[14]

B. Fixed Effects Model on Panel Data

The regression model used to test for the existence of moral hazard can be expressed as follows:

$$\text{Loss Ratio Ceded}_{it} = \alpha + \beta \text{ External Reinsurance Ratio}_{it} + \sum \gamma X_{it} + \varepsilon_{it},$$

where,

$$\text{Loss Ratio Ceded} = \text{Total Loss Ceded}/\text{Total Ceded Premiums Earned},$$

$$\text{External Reinsurance Ratio} = \text{External Ceded Reinsurance}/\text{Total Ceded Reinsurance}.$$

The vector of control variables X includes lag of loss ratio ceded, lag of retention limit, lag of experience rating, firm size, geographical concentration, line of business concentration, line of business growth rate, firm growth rate, leverage, tax rate, SUSTAIN, RHERF, product Herfindahl, geographic Herfindahl, proportion of premiums written in long tail lines, return on assets, lead company, coastal states, and year dummies.

To take advantage of the panel data feature of our sample data, fixed effects model on panel data[15] is used to estimate the above regression model. Since the two proxies for long-term contracting relationship, *SUSTAIN* and *RHERF*, reduce the number of observations significantly, we run the above regression model on the sample data without and with these two variables.

If monitoring is more effective in mitigating asymmetric information problems within an insurance group due to easier access to information, the loss experience of internal reinsurance should

[14] On pages 8-9 of Cummins et al. (2008).

[15] STATA command *xtreg* is used here to exploit the panel data features of our data samples. A Hausman specification test is used to determine whether to employ a fixed effects model or a random effects model. The specification test always indicates that the random effects model is not appropriate, and thus we employ the fixed effects model. In addition, since we have only 3-4 years observations on average for each insurer, clustering effect should not be of major concern according to Wooldridge (2001). Hence, we use White robust standard error to control heterogeneity.

be more favorable than that of external reinsurance, everything else equal. Therefore, we hypothesize that if the moral hazard problem is more severe in external reinsurance markets, or called as the *residual* moral hazard in external reinsurance markets, the coefficient on *External Reinsurance Ratio* should be positive and significant.

4.2.2 Results on Moral Hazard

Table 5A, 5B and 5C contain the summary statistics for private passenger auto liability reinsurance, homeowners reinsurance, and product liability reinsurance, respectively. To mitigate the impact of outliers and data errors, the following variables are winsorized at the 1^{st} and 99^{th} percentiles: loss ratio ceded, amount of reinsurance for each line of business, experience rating, retention limit, line-specific premiums growth rate, firm premiums growth rate, leverage, tax rate, product Herfindahl, geographic Herfindahl, proportion of premiums written in long tail lines, and return on assets.

A. Matching Estimators Method

As discussed previously, the dependent variable for the matching estimators method is *loss ratio ceded*. The treatment variable is group affiliation, and affiliated insurers belong to the treatment group while unaffiliated insurers belong to the control group. Independent matching variables include external reinsurance ratio, firm size, line-of-business concentration, line-of-business growth rate, firm growth rate, leverage, tax rate, SUSTAIN, RHERF, lag of loss ratio ceded, retention limit, experience rating, product Herfindahl, geographic Herfindahl, proportion of premiums written in long tail lines, return on assets, and lead company. The STATA command *nnmatch*[16] is used to estimate the sample average treatment effect. By using simulations, Abadie and Imbens (2002) find that four matches perform well in terms of mean-squared error, thus we choose four matches to estimate the unobserved potential outcome for each individual in the sample. In addition, the matching estimators are adjusted for bias caused by continuous matching variables and robust standard errors are estimated to allow for heteroskedasticity.

Table 6A and 6B report the empirical results of the matching estimators method in the line of

[16] See Abadie et al. (2004) for detailed description of *nnmatch* procedure.

private passenger auto liability reinsurance without and with *SUSTAIN* and *RHERF*, respectively. The sample average treatment effects on both sample data sets are positive and significant at the 1 percent level, indicating that group affiliation increases the loss ratio of ceded reinsurance. This implies that monitoring within an insurance group is not perfect and external reinsurers may use other methods to effectively mitigate the moral hazard problem.

Table 7A and 7B contain the empirical results of the matching estimators method in the line of homeowners reinsurance without and with *SUSTAIN* and *RHERF*, respectively. The sample average treatment effect on the full sample is negative as hypothesized and statistically significant at the 1 percent level, while the sample average treatment effect on the sample with *SUSTAIN* and *RHERF* is negative but not statistically significant, indicating that, on average, affiliated insurers have lower ceded reinsurance loss ratio than non-affiliated insurers. This empirical finding suggests that residual moral hazard may exist in the homeowners reinsurance market, while long term contracting relationship is effective in controlling the residual moral hazard problem.

In sum, the results from the matching estimators method suggest that the moral hazard problem is no more severe in external reinsurance markets than in internal reinsurance markets in private passenger auto liability reinsurance market, but may be so in homeowners reinsurance market.[17] Hence, we find some evidence for the existence of *residual moral hazard* in homeowners reinsurance market, but not in private passenger auto liability reinsurance market.

B. Fixed Effects Model on Panel Data

Table 8A reports the empirical results of the fixed effects model on panel data for private passenger auto liability reinsurance. The coefficient on *external reinsurance ratio* is negative and insignificant no matter whether we include *SUSTAIN* and *RHERF* or not. This implies that monitoring is not effective in reducing the moral hazard problem within an insurance group. This result is consistent with our finding from the above matching estimators method. IN addition, the coefficients on the lag of *loss ratio ceded*, *retention limit*, *experience rating*, *SUSTAIN*, and *RHERF* are not statistically significant.

[17] We do not apply the matching estimators method on the sample of product liability reinsurance because the data set includes only 39 unaffiliated insurers, which makes the matching estimators method highly unreliable.

The coefficient on firm size is negative and significant at the 10 percent level, suggesting that the loss experience of ceded reinsurance is more favorable for larger insurers. The coefficient on *auto liability insurance concentration* is negative and significant at the 1 percent level in both econometric specifications, indicating that the more concentrated in auto liability insurance a primary insurer is, the better the loss experience of auto liability reinsurance is. The coefficients on *year dummies* are all negative and significant, suggesting that the loss experience of auto liability reinsurance are more favorable comparing to that in year 2000. Moreover, the coefficients on *year dummies* decrease over the years in terms of absolute value, implying that the loss experience of auto liability reinsurance deteriorates during this period.

However, one concern about the above regression model is that *external reinsurance ratio* may be endogenous since it is constructed by using current year reinsurance premiums data. To resolve this technical issue, we perform an exogeneity test proposed by Laffont and Matoussi (1995) on *external reinsurance ratio*, and the strategy of the exogeneity test is laid out as follows: First, we run a regression of *loss ratio ceded* on *external reinsurance ratio* and a vector of control variables X_1, which include lag of loss ratio ceded, lag of experience rating, lag of retention limit, SUSTAIN, RHERF, firm size, auto liability insurance concentration, auto liability insurance premium growth rate, firm premium growth rate, leverage, tax rate, product Herfindahl, geographic Herfindahl, proportion of premiums written in long tail lines, return on assets, lead company, and year dummies.

Second, we run a regression of *external reinsurance ratio* on a vector of instruments Z and some other control variables, where the instruments Z mainly include exogenous firm characteristics such as mutual, direct, agency, age, and rating dummies. We save the residuals from the regression for the next step.

Third, we rerun the regression model in the first step by including the residuals from the second step as an additional independent variable. If the coefficient on the residuals is not statistically different from zero, we can accept the exogeneity of *external reinsurance ratio*.

Table 8B, and 8C report the empirical results of the second and third steps of the exogeneity test, respectively. Since the coefficient on *residuals* is never significant in Table 8C, we conclude that *external reinsurance ratio* is exogenous in our regression model.

In conclusion, we find no evidence for the existence of *residual moral hazard* in the private passenger auto liability reinsurance market, which is consistent with our empirical findings by using matching estimators method. In addition, we find that monitoring, experience rating, retention limit, and long term contracting relationship are not influential on the loss experience of private passenger auto liability reinsurance.

The empirical results of the fixed effects model on panel data for homeowners reinsurance appears in Table 9A. The coefficient on *external reinsurance ratio* is positive as expected but insignificant in both econometric specifications, indicating that monitoring does not effectively mitigate the moral hazard problem within an insurance group. The lag of *loss ratio ceded* is negative and significant at the 1 percent level without or with *SUSTAIN* and *RHERF*, indicating the presence of negative serial dependence in loss experience of ceded reinsurance in homeowners reinsurance market. In addition, the coefficients on the lag of *retention limit*, and the long-term contracting proxies, *SUSTAIN* and *RHERF*, are not statistically significant.

Recall that *experience rating* is defined as the ratio of total premiums earned to total losses incurred for direct and assumed business, which essentially is the inverse of loss ratio for direct and assumed business. An increase in the lag of *experience rating* implies that an insurer's loss experience is more favorable in the previous year. If this favorable loss experience in the previous year justifies reinsurers to reduce current year's reinsurance price based on experience rating practice, the lower reinsurance price in current year will dull the primary insurer's incentive to exert loss prevention effort, which in turn causes the current year's loss ratio of ceded reinsurance to rise. Therefore, a positive and significant coefficient on the lag of *experience rating* should suggest the presence of the moral hazard problem. However, we find that the coefficient on the lag of *experience rating* is now negative and significant at the 10 percent level, which contradicts the hypothesis of moral hazard.

Table 9B, and 9C contain the empirical results of the exogeneity test on *external reinsurance ratio* in homeowners reinsurance. Since the coefficient on *residuals* in Table 9C is not statistically significant, we conclude that *external reinsurance ratio* is exogenous in our regression model.

In conclusion, we find no evidence of residual moral hazard in homeowners reinsurance market by using fixed effects model. Therefore, comparing to the empirical findings in matching estimators method, we obtain contradicting results concerning the *residual moral hazard* problem in homeowners reinsurance market. Moreover, we find that loss experience of homeowners reinsurance are negatively serially correlated.

Table 10A reports the empirical results of fixed effects model on panel data for product liability reinsurance. The coefficient on *external reinsurance ratio* is positive as hypothesized but not statistically significant at the conventional 5 percent level, indicating that the residual moral hazard problem does not exist in product liability reinsurance market. The lag of *loss ratio ceded* is positive and significant at the 5 percent level for the data sample without *SUSTAIN* and *RHERF*, but statistically insignificant once we include *SUSTAIN* and *RHERF*. The coefficient on *experience rating* is positive as hypothesized but statistically insignificant. The coefficients on *SUSTAIN* and *RHERF* are not statistically significant as well.

The coefficient on the lag of *retention limit* is positive and significant at the 10 percent level in both econometric specifications. Recall that *retention limit* measures a primary insurer's share of total loss incurred. A higher value of the lag of *retention limit* implies a larger proportion of total loss retained by a primary insurer. An increase in the lag of a primary insurer's share of total loss may incentivize the insurer to expend more effort to prevent loss, and thus improve the insurer's loss experience in that year. The favorable loss experience in previous year may justify reinsurers to reduce reinsurance price in current year, based on experience rating practice. The lower reinsurance price in current year can reduce the primary insurer's loss prevention effort, and eventually cause an increase in loss ratio of ceded reinsurance in current year. Therefore, the positive and significant coefficient on the lag of *retention limit* indicates the existence of the moral hazard problem.

Table 10B, and 10C report the empirical results of the exogeneity test on *external reinsurance ratio* in the line of product liability reinsurance. Since the coefficient on the *residuals* in Table 10C is not statistically significant, we conclude that *external reinsurance ratio* is exogenous in our regression model.

In sum, we find no evidence of residual moral hazard in the three largest lines of reinsurance. However, we find some weak evidence for the existence of moral hazard in product liability reinsurance market, which is properly controlled by the method of retention limit. In addition, we find that loss experience are serially correlated in homeowners reinsurance and product liability reinsurance markets.

5 Discussion and Robust Tests

5.1 Robust Test of Adverse Selection

As we discuss earlier that the key is the construction of risk measure in the test of adverse selection. Although we believe that *loss reserve error* is a good risk measure in our test of adverse selection, we still construct two additional risk measures, *future loss ratio volatility* and *loss ratio difference*, to test the hypothesis of adverse selection in reinsurance markets.

5.1.1 Future Loss Ratio Volatility as Risk Measure

The first alternative risk measure is *volatility of loss ratio*. This statistic has been used by Hoerger, Sloan and Hassan (1990) and Cummins et al. (2008), but it is constructed using historical data. However, it is unlikely that historical data contains any asymmetric information between a primary insurer and an outsider such as a reinsurance company. In order to capture any asymmetric information in this risk measure, we use data from year t to year t+6 to compute *volatility of loss ratio* at year t, instead of using historical data. We then use *volatility of loss ratio* as our risk measure in random-effects Tobit model to test for the existence of adverse selection in reinsurance markets.

Table 11A reports the Tobit coefficient estimates in the line of private passenger auto liability reinsurance without and with the two proxies for long term contracting relationship, *SUSTAIN* and *RHERF*, respectively. The coefficient on *loss ratio volatility* is always positive as hypothesized, but not statistically significant at conventional significance levels. This may be because loss ratio volatility so constructed is not a good risk measure that captures asymmetric information, or because adverse selection does not exist in private passenger auto liability reinsurance market.

The coefficient on *experience rating* is not statistically significant at conventional significance levels in every econometric specification, but positive as predicted. *Retention limit* is always negative and statistically significant at the 1 percent level, suggesting that an insurer retaining a higher proportion of direct business premiums tends to purchase a smaller amount of reinsurance. The coefficients on *SUSTAIN* and *RHERF* are not statistically significant.

Table 11B contains the empirical results of Tobit model in the line of homeowners reinsurance without and with *SUSTAIN* and *RHERF*. The coefficient on *loss ratio volatility* is always positive as expected, but only statistically significant at the 10 percent level in the econometric specification with *SUSTAIN* and *RHERF*. Therefore, we conclude that we find weak evidence of adverse selection in the homeowners reinsurance market.

The coefficient on *experience rating* is always positive as expected and statistically significant at the 5 percent level when we exclude *SUSTAIN* and *RHERF*, and is significant at the 1 percent level when we include *SUSTAIN* and *RHERF*, suggesting that reinsurers employ the practice of experience rating to mitigate the adverse selection problem. *Retention limit* is always negative as predicted and statistically significant at the 1 percent level, indicating that retention limit is used to reduce the adverse selection problem as well. In addition, the coefficients on *SUSTAIN* and *RHERF* are never statistically significant.

Table 11C provides the Tobit coefficient estimates in the line of product liability reinsurance. The coefficient on *loss ratio volatility* is not statistically significant in both econometric specifications. The coefficient on *experience rating* is positive but statistically insignificant in the econometric specification without *SUSTAIN* and *RHERF*. However, once we include *SUSTAIN* and *RHERF*, *experience rating* becomes negative and statistically significant at the 1 percent level. The coefficient on *retention limit* is always negative as expected and statistically significant at the 1 percent level in every econometric specification.

In sum, when we employ *loss ratio volatility* as the risk measure, we hardly find any evidence for the existence of adverse selection in all the three largest lines of reinsurance. In addition, we find that *retention limit* is widely used by reinsurers to mitigate any potential adverse selection problem while the practice of experience rating is used in homeowners insurance market.

5.1.2 Loss Ratio Difference as Risk Measure

The second alternative risk measure is *loss ratio difference*. As we discuss earlier, *loss ratio difference* is measured by the difference between an insurer's loss ratio in year t and the average of yearly industry loss ratio over the previous three years. Therefore, this measure captures an insurer's relative riskiness comparing to the industry.

Table 12A reports the Tobit coefficient estimates using data on private passenger auto liability reinsurance without and with *SUSTAIN* and *RHERF*, respectively. The coefficient on *loss ratio* *difference* is always positive but not statistically significant. *Experience rating* is always positive but not statistically significant at conventional significance levels in every econometric specification. In addition, the coefficient on *retention limit* is always negative and statistically significant at the 1 percent level.

Table 12B contains the empirical results of Tobit model in the line of homeowners reinsurance without and with *SUSTAIN* and *RHERF*. When we do not include *SUSTAIN* and *RHERF*, the coefficient on *loss ratio difference* is positive as expected and statistically significant at the 10 percent level; however, with *SUSTAIN* and *RHERF*, *loss ratio difference* becomes significant at the 5 percent level. Therefore, we conclude that we find some evidence of adverse selection in homeowners reinsurance market. In addition, *experience rating* is always positive as expected and statistically significant at the 5 percent level, and *retention limit* is always negative as predicted and statistically significant at the 1 percent level.

Table 12C provides the Tobit coefficient estimates in the line of product liability reinsurance. The coefficient on *loss ratio difference* is positive as predicted but not statistically significant in both econometric specifications. The coefficient on *experience rating* is positive but statistically insignificant in every econometric specification. The coefficient on *retention limit* is always negative as expected and statistically significant at the 1 percent level.

In conclusion, when we use *loss ratio difference* as the risk measure, we find some evidence for the existence of adverse selection in homeowners reinsurance market, but not in private passenger auto liability and product liability reinsurance markets. Moreover, we find that reinsurers tend to use *retention limit* to mitigate any potential adverse selection problem.

5.2 Empirical Tests on Firm-Level Reinsurance

Following Doherty and Smetters (2005), we use data on individual lines of reinsurance to test the existence of asymmetric information. However, from the perspective of an insurer, reinsurance purchase decision is made at the corporate level instead of at the level of individual line, since the loss experience of many lines of insurance are correlated to some extent. For example, if an insurer's portfolio of insurance business consists of life insurance and annuity of similar proportion, the insurer may not have much incentive to purchase reinsurance for each individual line, since the business of life insurance and annuity forms a "natural hedge" against each other. Therefore, as a robust check, we also test for the existence of adverse selection and moral hazard using firm level data.

Table 13A contains the summary statistics for the variables used in the test for adverse selection for all lines of reinsurance. As previously discussed, variables winsorized at the 1^{st} and 99^{th} percentiles are net amount of reinsurance, loss ratio volatility, loss reserve error, experience rating, retention limit, firm premiums growth rate, leverage, tax rate, product Herfindahl, geographic Herfindahl, proportion of premiums written in long tail lines, and return on assets.

Table 13B reports the empirical results for all lines of reinsurance using *loss reserve error* as the risk measure of individual insurers. The coefficient on *loss reserve error* is always positive as hypothesized and statistically significant at the 1 percent level, indicating the existence of adverse selection in overall reinsurance markets. The coefficient on *experience rating* is positive as hypothesized and significant at the 1 percent level, suggesting that primary insurers purchase more reinsurance if the loss experience in previous year is favorable. The coefficient on *retention limit* is always negative as hypothesized and significant at the 1 percent level, suggesting that an insurer retaining a higher proportion of direct business premiums purchases a smaller amount of reinsurance. This may imply that reinsurers use retention limit to mitigate the adverse selection problem. However, the coefficients on *RHERF* and *SUSTAIN* are not significant.

Table 13C provides the Tobit coefficient estimates using *loss ratio volatility* as the risk measure. The coefficient on *loss ratio volatility* is positive and significant at the 5 percent level, suggesting the existence of adverse selection in overall reinsurance markets. In addition, the coefficient on *experience rating* is positive and significant at the 1 percent level, while the coefficient on *retention limit* is always negative and significant at the 1 percent level.

Table 13D contains the Tobit coefficient estimates using *loss ratio difference* as the risk measure. The coefficient on *loss ratio difference* is positive as hypothesized and significant at the 1 percent level, indicating the existence of adverse selection in overall reinsurance markets. In addition, as predicted, the coefficient on *experience rating* is positive while the coefficient on *retention limit* is always negative, and both of them are statistically significant at the 1 percent level in every econometric specification, suggesting that reinsurers use the practices of experience rating and retention limit to control the adverse selection problem in reinsurance markets.

In summary, we find strong evidence of adverse selection in overall reinsurance markets, no matter which risk measure we employ in our empirical test. Moreover, consistent with our findings in the three largest individual lines of reinsurance, *experience rating* and *retention limit* are used in mitigating any potential adverse selection problem in overall reinsurance markets.

Table 14A provides the summary statistics for all lines of reinsurance. Again, the following variables are winsorized at the 1^{st} and 99^{th} percentiles: loss ratio ceded, amount of reinsurance for each line of business, experience rating, retention limit, line-specific premiums growth rate, firm premiums growth rate, leverage, tax rate, product Herfindahl, geographic Herfindahl, proportion of premiums written in long tail lines, and return on assets.

Table 14B reports the sample average treatment effect estimated by the matching estimators method for firm-level reinsurance without and with *SUSTAIN* and *RHERF*, respectively. The sample average treatment effect on both sample data sets are positive but not statistically significant at the conventional 5 percent level, indicating that group affiliation tends to increase the loss ratio of ceded reinsurance. This suggests that monitoring within an insurance group is not effective in mitigating asymmetric information problems.

Table 14C, 14D and 14E provide the empirical results of the three-step regressions of the exogeneity test, respectively. The coefficient on *residuals* in Table 14E is statistically significant at the 5 percent level for the data sample with *SUSTAIN* and *RHERF*, indicating that *external reinsurance ratio* is not exogenous in the fixed effects GLS regression. Therefore, we run two stage least squares (2SLS) on panel data with bootstrap standard errors. [18] The endogenous variable *external reinsurance ratio* is instrumented by exogenous firm characteristics such as mutual, direct, agency, age, and rating dummies.

Table 14F contains the empirical results of the 2SLS regressions. The coefficient on *external reinsurance ratio* is positive and significant at the 5 percent level for the data sample with *SUSTAIN* and *RHERF*. Recall that *external reinsurance ratio* is defined as the ratio of external ceded reinsurance to total ceded reinsurance. A positive and statistically significant coefficient on *external reinsurance ratio* indicates that the loss experience of ceded reinsurance is worse for primary insur-

[18] STATA command *xtivreg* is used here to exploit the panel data feature of our data samples.

ers using a higher proportion of external reinsurance than for those using only internal reinsurance or a smaller proportion of external reinsurance, which is evidence of residual moral hazard. The coefficient on *SUSTAIN* is negative and statistically significant at the 5 percent level, suggesting that long term contracting relationship and loss experience of reinsurance are negatively correlated. Moreover, the coefficients on the lag of *loss ratio ceded*, *experience rating*, *retention limit*, and *RHERF* are not statistically significant.

Therefore, we find some evidence of residual moral hazard in overall reinsurance markets, but we do not find any evidence indicating that *experience rating* and *retention limit* are effective in mitigating the moral hazard problem in overall reinsurance markets.

6 Conclusions

In this study, we use NAIC data and A.M.Best's Key Rating Guide for the years 1995 to 2000 to empirically investigate the existence of adverse selection and moral hazard in three lines of reinsurance: private passenger auto liability reinsurance, homeowners reinsurance, and product liability reinsurance. Due to the empirical difficulty in testing for the existence of adverse selection and moral hazard simultaneously, we test for the presence of adverse selection and moral hazard separately in the reinsurance markets.

In order to test the existence of adverse selection, we construct three measures of risk for individual insurers. The first risk measure is *loss reserve error*, which is our favored measure of risk in the test of adverse selection; the second measure of risk is *loss ratio volatility*; and the third measure of risk is called *loss ratio difference*. By employing random-effects Tobit model on panel data, we empirically investigate the validity of the positive correlation property between amount of reinsurance coverage and the constructed risk measures by using two data samples. We find evidence of adverse selection in private passenger auto liability reinsurance market, homeowners reinsurance market, and overall reinsurance markets, but no evidence of adverse selection in product liability reinsurance market. In addition, we find that experience rating and retention limit are widely used by reinsurers to mitigate the adverse selection problem.

To investigate the existence of the residual moral hazard problem in the reinsurance markets, we design two empirical tests. The first one is the matching estimators method. The basic idea behind this test is that the loss ratio of ceded reinsurance should be lower on average for affiliated insurers than for unaffiliated ones if the moral hazard problem is less severe within an insurance group due to easier access to information. Our empirical findings from the matching estimators method suggest that the residual moral hazard problem exists in homeowners reinsurance market, but not in private passenger auto liability reinsurance market and overall reinsurance markets. The second empirical test for residual moral hazard is the fixed effects model on panel data. Using this empirical test, we find no evidence of residual moral hazard in the three largest lines of reinsurance. However, we do find evidence of residual moral hazard problem in overall reinsurance markets by employing two stage least squares method. The contradicting findings from the two empirical tests prevent us from drawing a decisive conclusion on the existence of residual moral hazard in homeowners reinsurance market, but we are quite confident to claim that the residual moral hazard problem does not exist in private passenger auto liability and product liability reinsurance markets. However, we find some evidence for the existence of residual moral hazard in overall reinsurance markets. In addition, we find some evidence that reinsurers use *retention limit* to mitigate any potential moral hazard problem in product liability reinsurance market.

References

[1] Abadie, A., D. Drukker, J. Herr, and G.Imbens, 2004, Implementing Matching Estimators for Average Treatment Effects in Stata, *Stata Journal*, 4(3): 290-311.

[2] Abadie, A., and G. Imbens, 2002, Simple and Bias-Corrected Matching Estimators, *Technical Report*, Department of Economics, University of California, Berkeley.

[3] Abbring, Jaap H., P.A. Chiappori, and J. Pinquet, 2003, Moral Hazard and Dynamic Insurance Data, *Journal of the European Economic Association*, 1(4): 767-820.

[4] Ackerberg, D., and M. Botticini, 2002, Endogenous Matching and the Empirical Determinants of Contract Form, *Journal of Political Economy*, 110(3): 564-591.

[5] Berger, L.A., J.D. Cummins, and S. Tennyson, 1992, Reinsurance and the Liability Insurance Crisis, *Journal of Risk and Uncertainty*, 5: 253-272

[6] Barros, P.P., M.P. Machado, and A.S. Galdeano, 2007, Moral Hazard and the Demand for Health Services: A Matching Estimator Approach, *Working Paper*.

[7] Browne, M., 1992, Evidence of Adverse Selection in the Individual Health Insurance Market, *Journal of Risk and Insurance*, 59: 13-33.

[8] Cardon, J., and I. Hendel, 2001, Asymmetric Information in Health Insurance: Evidence from the National Health Expenditure Survey, *Rand Journal of Economics*, 32: 408-427.

[9] Chiappori, P.A., F. Durand, and P.Y. Geoffard, 1998, Moral Hazard and the Demand for Physician Services: First Lessons from a French Natural Experiment, *European Economic Review*, 42: 499-511.

[10] Chiappori, P.A., and B. Salanie, 2000, Testing for Asymmetric Information in Insurance Markets, *Journal of Political Economy*, 108: 56-78.

[11] Chiappori, P.A., and B. Salanie, 2003, Testing Contract Theory: A Survey of Some Recent Work, in: M. Dewatripont, L.P. Hansen, and S.J. Turnovsky, eds., *Advances in Economics and Econometrics: Theory and Applications*, Eighth World Congress, Volume I (Cambridge, UK: Cambridge University Press), pp. 115-149.

[12] Cole, C.R., and K.A. McCullough, 2006, A Reexamination of the Corporate Demand for Reinsurance, *Journal of Risk and Insurance*, 73: 169-192.

[13] Cox, N., 1998, WINSOR: Stata module to Winsorize a variable, *Statistical Software Components S361402*, Boston College Department of Economics.

[14] Cummins, J.D., G. Dionne, R. Gagne, and A. Nouira, 2008, The Costs and Benefits of Reinsurance, *Working Paper*.

[15] Cummins, J.D., and S. Tennyson, 1996, Moral Hazard in Insurance Claiming: Evidence from Automobile Insurance, *Journal of Risk and Uncertainty*, 12: 29-50.

[16] Dahlby, B., 1983, Adverse Selection and Statistical Discrimination: An Analysis of Canadian Automobile Insurance, *Journal of Public Economics*, 20: 121-130.

[17] Dionne, G., C. Gouriéroux, and C. Vanasse, 1998, Evidence of Adverse Selection in the Automobile Insurance Markets, *Working Paper*.

[18] Dionne, G., C. Gouriéroux, and C. Vanasse, 2001, Testing for Adverse Selection in Automobile Insurance Markets: A Comment, *Journal of Political Economy*, 109: 444-453.

[19] Dionne, G., P.C. Michaud, and M. Dahchour, 2004, Separating Moral Hazard from Adverse Selection in Automobile Insurance: Longitudinal Evidence from France, *Working Paper*.

[20] Dionne, G, and P. St-Michel, 1991, Workers' Compensation and Moral Hazard, Review of Economics and Statistics, 73: 236-244.

[21] Doherty, N., and K. Smetters, 2005, Moral Hazard in Reinsurance Markets, *Journal of Risk and Insurance*, 72: 375-391.

[22] Edelberg, W., 2004, Testing for Adverse Selection and Moral Hazard in Consumer Loan Markets, *Working Paper*.

[23] Finkelstein, A. and J. Poterba, 2004, Adverse Selection in Insurance Markets: Policyholder Evidence from the U.K. Annuity Market, *Journal of Political Economy*, 112: 183-208.

[24] Finkelstein, A. and K. McGarry, 2003, Private Information and Its Effect on Market Equilibrium: New Evidence from Long-Term Care Insurance, *Working Paper*, NBER.

[25] Garven, J.R. and M. Grace, 2007, Adverse Selection in Reinsurance Markets, *Working Paper*.

[26] Garven, J.R. and J. Lamm-Tennant, 2003, Economic and Financial Perspectives on the Demand for Reinsurance, in: N. Golden, ed., *Rational Reinsurance Buying*, (London: Risk Publications), pp. 163-186.

[27] Harrington, S.E., and P.M. Danzon, 1994, Price Cutting in Liability Insurance Markets, *Journal of Business*, 67: 511-538.

[28] Harrison, C.M., 2004, Reinsurance Principles and Practices, (Insurance Institute of America).

[29] Hoerger, T. J., F.A. Sloan, and M. Hassan, 1990, Loss Volatility, Bankruptcy, and the Demand for Reinsurance, *Journal of Risk and Uncertainty*, 3: 221-245.

[30] Jean-Baptiste, E.L., and A.M. Santomero, 2000, The Design of Private Reinsurance Contracts, *Journal of Financial Intermediation*, 9: 274-297.

[31] Laffont, J.J., and M.S. Matoussi, 1995, Moral Hazard, Financial Constraints and Sharecropping in El Oulja, *Review of Economic Studies*, 62: 381-399.

[32] Mayers, D., and C.W. Smith, 1990, On the Corporate Demand for Insurance: Evidence from the Reinsurance Market, *Journal of Business*, 63: 19-40.

[33] Mayers, D., and C.W. Smith, 2002, Ownership Structure and Control: Property-Casualty Insurer Conversion to Stock Charter, *Journal of Financial Services Research*, 21: 117-144.

[34] Petroni, K.R., 1992, Optimistic Reporting in the Property-Casualty Insurance Industry, *Journal of Accounting and Economics*, 15: 485-508.

[35] Petroni, K.R., S.G. Ryan, and J.M. Wahlen, 2000, Discretionary and Non-Discretionary Revisions of Loss Reserves by Property-Casualty Insurers: Differential Implications for Future Profitability, Risk and Market Value, *Review of Accounting Studies*, 5: 95-125.

[36] Phillips, R.D., J.D. Cummins, and F. Allen, 1998, Financial Pricing of Insurance in the Multiple-Line Insurance Company, *Journal of Risk and Insurance*, 65: 597-636.

[37] Powell, L.S., and D.W. Sommer, 2007, Internal Versus External Capital Markets in the Insurance Industry: the Role of Reinsurance, *Journal of Financial Services Research*, 31; 173-188.

[38] Puelz, R., and A. Snow, 1994, Evidence on Adverse Selection: Equilibrium Signaling and Cross-Subsidization in the Insurance Market, *Journal of Political Economy*, 102: 236-257.

[39] Smith, B.D., and M. Stutzer, 1995, A Theory of Mutual Formation and Moral Hazard with Evidence from the History of the Insurance Industry, *Review of Financial Studies*, 8: 545-577.

[40] Weiss, M.A., 1985, A Multivariate Analysis of Loss Reserving Estimates in Property-Liability Insurers, *Journal of Risk and Insurance*, 52: 199-221.

[41] Weiss, M.A., and J. Chung, 2004, U.S. Reinsurance Prices, Financial Quality, and Global Capacity, *Journal of Risk and Insurance*, 71: 437-467.

[42] Warner, J, 1977, Bankruptcy Costs: Some Evidence, *Journal of Finance*, 32: 337-348.

[43] Winter, R.A., 2000, Optimal Insurance under Moral Hazard, in: G. Dionne, ed., *Handbook of Insurance*, (Boston: Kluwer Academic Publishers), pp. 155-183.

[44] Wooldridge, J.M., 2001, Econometric Analysis of Cross Section and Panel Data, (the MIT Press).

Table 1: Variable definitions

Variable	Prediction in Adverse Selection	Prediction in Moral Hazard	Definition
External Reinsurance	N/A	N/A	premiums ceded to non-affiliates, line-specific
Internal Reinsurance	N/A	N/A	premiums ceded to affiliates, line-specific
Net Amount of Reinsurance	N/A	N/A	(external reinsurance + net internal reinsurance) / total premiums written; alternatively, (external reinsurance + internal reinsurance) / total premiums written; line-specific
External Reinsurance Ratio	N/A	+	external reinsurance / (external reinsurance + net internal reinsurance); alternatively, external reinsurance / (external reinsurance + internal reinsurance); line-specific
Loss Ratio Ceded	N/A	N/A	total loss ceded / total premiums ceded, line-specific
Loss Reserve Error	+	N/A	(losses as actually developed as of year t+5 - originally reported incurred losses in year t) / originally reported incurred losses in year t, line-specific
Loss Ratio Volatility	+	N/A	loss ratio using data from year t to t+6, line-specific
Loss Ratio Difference	+	N/A	difference between an insurer's loss ratio in year t and the average of yearly industry loss ratio over previous three years
Experience Rating	+	+	total premiums earned / total losses incurred, line-specific
Retention Limit	–	+	retained losses / total losses incurred; alternatively, net premiums written / total premiums written; line-specific
Sustain	+	±	precentage of premiums ceded over a 3-year period to external reinsurers which are present in all three years, firm-specific
Rherf	±	±	average of yearly Herfindahl indeces of reinsurance premiums ceded over year t-2 to year t, firm-specific
Firm Size			natural logarithm of total admitted assets, firm-specific
Line-of-Business Concentration			premiums written in a certain line / total premiums written of the insurer
Premium Growth Rate			(premiums written in year t-1 / premiums written in year t) - 1

Table 1: Variable definitions (continued)

Variable	Prediction in Adverse Selection	Prediction in Moral Hazard	Definition
Leverage			total net premiums written / policyholder's surplus, firm-specific
Tax Rate			1 - (after-tax net income / before-tax net income)
Long Tail Lines			proportion of an insurer's premiums written in long tail lines
Product Herfindahl			a Herfindahl index of premiums written in different lines
Geographic Herfindahl			a Herfindahl index of premiums written in different states
Return on Assets (ROA)			net income in year t / total admitted assets in year t
Lead Company			dummy variable equal to one if the insurer is a lead company of an insurance group
Coastal States			dummy variable equal to one if the insurer is domiciled in a hurricane-prone state
Mutual			dummy variable equal to one if the insurer is a mutual company
Direct			dummy variable equal to one if the insurer is a direct writer
Agency			dummy variable equal to one if the insurer uses independent agency distribution system
Age			natural logarithm of the insurer's age as of year t
Rating1			dummy variable equal to one if the A.M Best's financial strength rating of the insurer is either A++ or A+
Rating2			dummy variable equal to one if the A.M Best's financial strength rating of the insurer is either A or A-
Rating3			dummy variable equal to one if the A.M Best's financial strength rating of the insurer is either B++ or B+
Rating4			dummy variable equal to one if the A.M Best's financial strength rating of the insurer is either B or B-

Table 2: Summary of Empirical Findings in Tests of Adverse Selection and Moral Hazard

Line of Business	Existence of Adverse Selection[a] ?	Existence of Residual Moral Hazard[b] ?	Existence of Moral Hazard[c] ?
Private Passenger Auto Liability Reinsurance	Yes	No	No
Homeowners Reinsurance	Yes	Inconclusive [d]	No
Product Liability Reinsurance	No	No	Yes
All-Line Reinsurance	Yes	No	No

[a] If the coefficients on the risk measures (*loss reserve error*, *loss ratio volatility* and *loss ratio difference)* are positive and significant in the regression of net amount of reinsurance, we find evidence of adverse selection.

[b] If the coefficient on *external reinsurance ratio* is positive and significant in the regression of *loss ratio ceded*, or the *sample average treatment effect (SATE)* is negative and significant in the matching estimators mothod, we find evidence of residual moral hazard.

[c] If the coefficients on *experience rating* and *retention limit* are positive and significant in the regression of *loss ratio ceded*, we find evidence of moral hazard.

[d] The matching estimators method finds evidence of residual moral hazard in homeowners reinsurance market, but the fixed effects model does not.

Table 3A: Descriptive Statistics

Sample of Private Passenger Auto Liability Reinsurance for Adverse Selection Test

Variables	Obs	Mean	Std. Dev.	Min	Max
Auto Liability Reinsurance	2420	0.230	0.291	0	0.956
Loss reserve error	2420	-0.001	0.290	-0.810	1.444
Loss ratio volatility	2420	0.097	0.109	0.020	0.837
Loss ratio difference	2420	0.030	0.149	-0.296	0.667
Sustain	1958	0.726	0.331	0	1
Rherf	1958	0.443	0.310	0.026	1
Experience Rating$_{t-1}$	2420	1.239	0.209	0.687	1.944
Retention Limit$_{t-1}$	2420	0.670	0.299	0.043	1
Firm size	2420	19.048	1.758	15.128	25.107
Auto Liab. Concentration	2420	0.317	0.206	0	0.987
Auto premium growth rate	2420	0.024	0.319	-0.798	1.710
Firm premium growth rate	2420	0.066	0.197	-0.394	1.078
Leverage	2420	1.501	0.768	0.205	4.267
Tax rate	2420	0.245	0.754	-4.779	3.041
Long Tail Lines	2420	0.707	0.130	0.190	0.973
Product Herfindahl	2420	0.332	0.150	0.120	0.762
Geographic Herfindahl	2420	0.502	0.366	0.043	1
ROA	2420	0.027	0.034	-0.100	0.120
Lead Company	2420	0.450	0.498	0	1
Year	2420	1997.574	1.702	1995	2000

[a]The following variables are winsorized at the 1st and 99th percentiles: auto liability reinsurance, loss reserve error, loss ratio volatility, experience rating$_{t-1}$, retention limit$_{t-1}$, auto liability premiums growth rate, firm premiums growth rate, leverage, product Herfindahl, geographic Herfindahl, long tail lines, and tax rate.

Table 3B: Descriptive Statistics

Sample of Homeowners Reinsurance for Adverse Selection Test

Variables	Obs	Mean	Std. Dev.	Min	Max
Homeowners Reinsurance	2211	0.291	0.283	0	0.967
Loss reserve error	2205	0.037	0.357	-0.723	2.301
Loss ratio volatility	2211	0.191	0.219	0.037	1.619
Loss ratio difference	2211	-0.015	0.249	-0.712	0.995
Sustain	1812	0.761	0.305	0	1
Rherf	1812	0.425	0.312	0.018	1
Experience Rating$_{t-1}$	2211	1.384	0.475	0.573	3.759
Retention Limit$_{t-1}$	2211	0.627	0.283	0.029	0.999
Firm size	2211	18.840	1.933	13.623	24.358
Homeowners Concentration	2211	0.206	0.183	0	0.966
Ho. premium growth rate	2211	0.082	0.210	-0.396	1.301
Firm premium growth rate	2211	0.057	0.158	-0.331	0.927
Leverage	2211	1.303	0.661	0.073	2.945
Tax rate	2211	0.272	0.644	-3.114	3.480
Long Tail Lines	2211	0.739	0.148	0.137	0.979
Product Herfindahl	2211	0.302	0.135	0.119	0.798
Geographic Herfindahl	2211	0.529	0.374	0.044	1
ROA	2211	0.026	0.032	-0.084	0.108
Lead Company	2211	0.542	0.498	0	1
Coastal States	2211	0.478	0.500	0	1
Year	2211	1997.620	1.690	1995	2000

[a]The following variables are winsorized at the 1st and 99th percentiles: homeowners reinsurance, loss reserve error, loss ratio volatility, experience rating$_{t-1}$, retention limit$_{t-1}$, homeowners premiums growth rate, firm premiums growth rate, leverage, product Herfindahl, geographic Herfindahl, long tail lines, and tax rate.

Table 3C: Descriptive Statistics

Sample of Product Liability Reinsurance for Adverse Selection Test

Variables	Obs	Mean	Std. Dev.	Min	Max
Product Liability Reinsurance	638	0.249	0.293	0.000	0.979
Loss reserve error	638	0.793	2.987	-0.981	23.261
Loss ratio volatility	638	0.230	0.198	0.031	1.289
Loss ratio difference	638	-0.090	0.487	-0.864	2.017
Sustain	492	0.810	0.252	0	1.000
Rherf	492	0.273	0.225	0.026	1.000
Experience Rating$_{t-1}$	638	1.931	1.941	0.246	13.278
Retention Limit$_{t-1}$	638	0.614	0.279	0.031	1.000
Firm size	638	19.984	1.478	16.411	24.379
Prod. Liab. Concentration	638	0.025	0.051	0.000	1.000
Prod. premium growth rate	638	0.174	0.832	-0.697	5.771
Firm premium growth rate	638	0.074	0.191	-0.256	1.151
Leverage	638	1.170	0.556	0.128	2.647
Tax rate	638	0.200	0.941	-5.972	2.981
Long Tail Lines	638	0.770	0.130	0.335	1
Product Herfindahl	638	0.247	0.125	0.108	0.849
Geographic Herfindahl	638	0.244	0.240	0.035	1
ROA	638	0.027	0.028	-0.059	0.123
Lead Company	638	0.398	0.490	0	1
Year	638	1997.577	1.731	1995	2000

[a]The following variables are winsorized at the 1st and 99th percentiles: product liability reinsurance, loss reserve error, loss ratio volatility, experience rating$_{t-1}$, retention limit$_{t-1}$, product liability premiums growth rate, firm premiums growth rate, leverage, product Herfindahl, geographic Herfindahl, long tail lines, and tax rate.

Figure 8: Histogram of Private Passenger Auto Liability Reinsurance

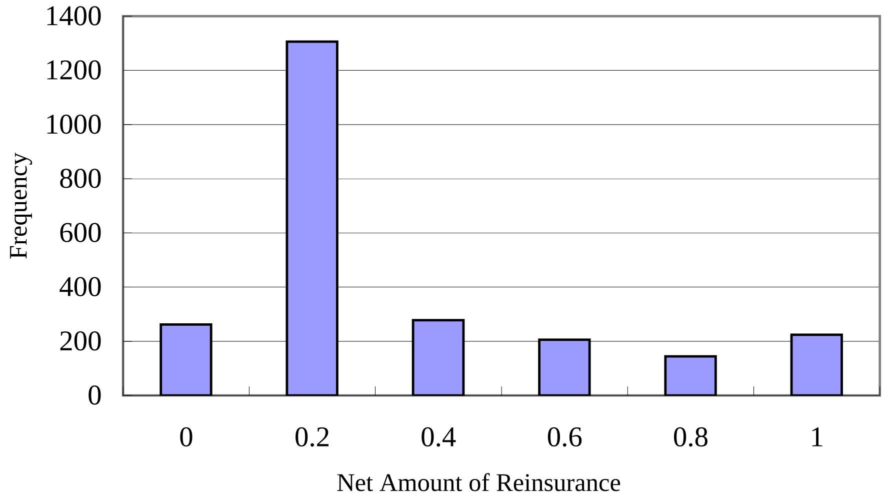

Figure 9: Histogram of Homeowners Reinsurance

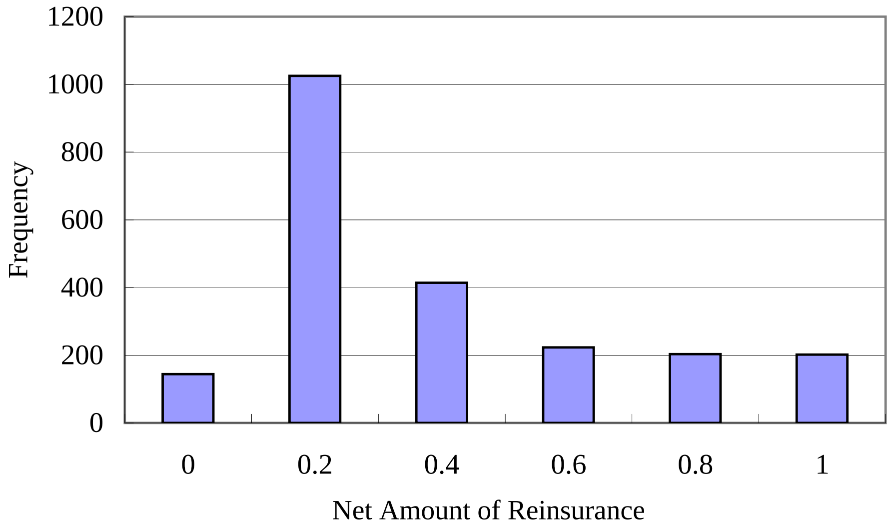

Figure 10: Histogram of Product Liability Reinsurance

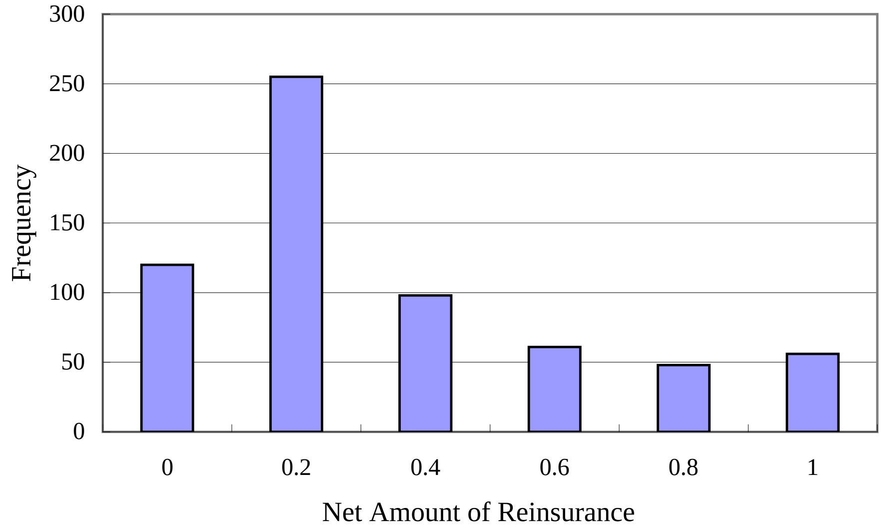

Figure 11: Histogram of All-Line Reinsurance

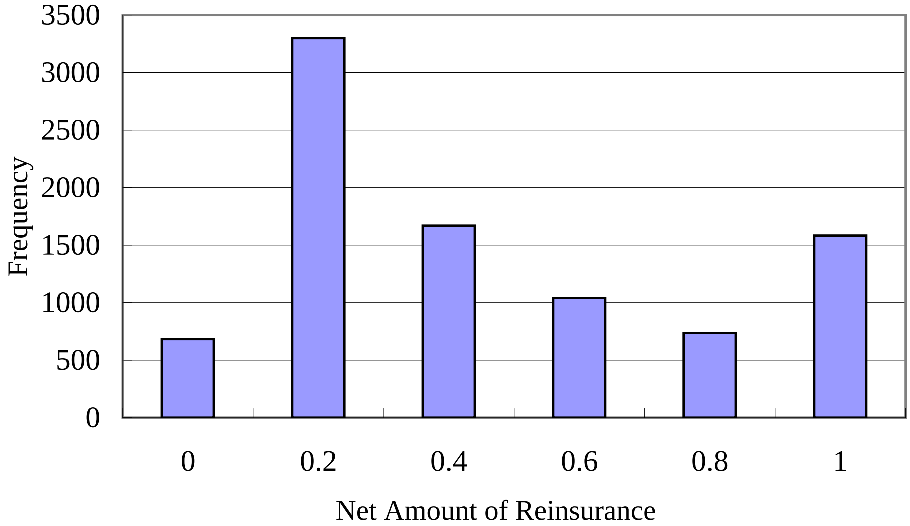

Table 4A: Test for Adverse Selection - Private Passenger Auto Liability Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of private passenger auto liability reinsurance

Risk of primary insurer is measured by *loss reserve error*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.677	7.42***	1.258	6.26***
Loss reserve error	0.064	2.62***	0.040	1.84*
Sustain			-0.007	-0.53
Rherf			0.000	0.01
Experience Rating$_{t-1}$	0.013	0.45	0.029	1.09
Retention Limit$_{t-1}$	-0.326	-7.14***	-0.358	-7.14***
Firm size	-0.053	-6.94***	-0.038	-5.57***
Auto Concentration	0.287	1.95*	0.087	1.20
Auto premium growth rate	0.006	0.22	-0.012	-0.49
Firm premium growth rate	0.114	3.39***	0.125	2.61***
Leverage	-0.074	-5.95***	-0.067	-5.98***
Tax rate	0.003	0.67	0.002	0.31
Long Tail Lines	-0.037	-0.28	0.030	0.23
Product Herfindahl	-0.165	-1.05	0.005	0.04
Geographic Herfindahl	-0.147	-3.45***	-0.044	-1.32
ROA	0.271	1.77*	0.103	0.68
Lead Company	-0.068	-2.62***	-0.039	-1.33
year1995	0.011	0.75	0.022	1.58
year1996	-0.005	-0.34	0.010	0.83
year1997	-0.018	-1.14	-0.008	-0.72
year1998	-0.013	-0.91	-0.012	-1.24
year1999	-0.018	-1.83*	-0.015	-1.97**
N	2419 (262 observations left-censored at 0, and 2157 uncensored)		1957 (110 observations left-censored at 0, and 1857 uncensored)	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 4B: Test for Adverse Selection - Homeowners Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of homeowners reinsurance

Risk of primary insurer is measured by *loss reserve error*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.343	8.40***	1.001	5.86***
Loss reserve error	0.053	2.36**	0.031	1.78*
Sustain			-0.007	-0.48
Rherf			0.026	0.84
Experience Rating$_{t-1}$	0.017	2.25**	0.022	2.42**
Retention Limit$_{t-1}$	-0.193	-6.23***	-0.213	-6.22***
Firm size	-0.038	-5.68***	-0.023	-3.29***
Homeowners Concentration	-0.017	-0.23	-0.044	-0.63
Ho. premium growth rate	0.001	0.05	-0.026	-0.70
Firm premium growth rate	0.086	2.84***	0.152	3.12***
Leverage	-0.068	-4.72***	-0.062	-4.23***
Tax rate	-0.002	-0.33	0.001	0.33
Long Tail Lines	0.007	0.10	-0.049	-0.53
Product Herfindahl	-0.186	-2.05**	-0.118	-1.27
Geographic Herfindahl	-0.067	-2.09**	-0.008	-0.20
ROA	0.258	2.40**	0.177	1.59
Lead Company	-0.111	-4.75***	-0.076	-2.87***
Coastal States	0.015	0.78	0.035	2.23**
year1995	0.014	1.18	0.023	2.22**
year1996	0.010	1.02	0.013	1.42
year1997	0.005	0.51	0.017	2.05**
year1998	-0.006	-0.61	0.000	0.02
year1999	-0.009	-1.08	-0.006	-0.80
N	2202 (144 observations left-censored at 0, and 2058 uncensored)		1803 (46 observations left-censored at 0, and 1757 uncensored)	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 4C: Test for Adverse Selection - Product Liability Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of produt liability reinsurance

Risk of primary insurer is measured by *loss reserve error*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.418	3.02***	1.669	3.48***
Loss reserve error	0.006	1.15	-0.001	-0.23
Sustain			-0.041	-1.12
Rherf			-0.100	-1.92*
Experience Rating$_{t-1}$	0.002	0.38	0.001	0.22
Retention Limit$_{t-1}$	-0.346	-3.53***	-0.347	-3.82***
Firm size	-0.040	-1.86*	-0.046	-2.30**
Prod. Liab. Concentration	0.473	0.84	0.396	0.40
Prod. premium growth rate	0.003	0.26	-0.005	-0.59
Firm premium growth rate	0.068	1.08	0.018	0.55
Leverage	-0.170	-4.59***	-0.129	-4.01***
Tax rate	0.003	0.35	0.004	0.60
Long Tail Lines	0.289	1.38	0.133	0.61
Product Herfindahl	-0.503	-3.58***	-0.341	-1.96**
Geographic Herfindahl	-0.173	-2.38**	-0.156	-2.10**
ROA	0.106	0.37	0.314	1.10
Lead Company	-0.036	-0.82	-0.064	-1.59
year1995	0.094	2.75***	0.050	2.27**
year1996	0.054	1.90*	0.023	1.05
year1997	0.040	1.67*	0.009	0.48
year1998	-0.006	-0.34	-0.016	-1.25
year1999	-0.039	-2.19**	-0.027	-2.36**
N	638 (120 observations left-censored at 0, and 518 uncensored)		492 (39 observations left-censored at 0, and 453 uncensored)	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 5A: Descriptive Statistics

Sample of Private Passenger Auto Liability Reinsurance for Moral Hazard Test

Variables	Obs	Mean	Std. Dev.	Min	Max
Loss Ratio Ceded	2514	1.689	4.200	0	28.250
Loss Ratio Ceded$_{t-1}$	2514	0.837	1.062	0	8.241
Auto Liability Reinsurance	2514	0.250	0.300	0	0.980
External Auto Reinsurance Ratio	2514	0.674	0.561	-12.983	1
Sustain	2052	0.726	0.329	0	1
Rherf	2052	0.445	0.311	0.026	1
Experience Rating$_{t-1}$	2514	1.239	0.210	0.692	1.999
Retention Limit$_{t-1}$	2514	0.653	0.302	0.024	0.999
Firm size	2514	18.971	1.767	15.108	25.107
Auto Liab. Concentration	2514	0.310	0.206	0	0.987
Auto premium growth rate	2514	0.033	0.376	-0.828	2.197
Firm premium growth rate	2514	0.066	0.207	-0.443	1.110
Leverage	2514	1.510	0.792	0.149	4.479
Tax rate	2514	0.238	0.774	-4.779	3.041
Mutual	2514	0.300	0.458	0	1
Direct	2514	0.206	0.404	0	1
Agency	2514	0.729	0.445	0	1
Rating1	2514	0.321	0.467	0	1
Rating2	2514	0.469	0.499	0	1
Rating3	2514	0.111	0.315	0	1
Rating4	2514	0.059	0.236	0	1
Long Tail Lines	2514	0.709	0.132	0.199	0.973
Product Herfindahl	2514	0.329	0.147	0.120	0.729
Geographic Herfindahl	2514	0.492	0.364	0.044	1
ROA	2514	0.025	0.035	-0.104	0.122
Age	2514	3.649	0.885	0	5.328
Lead Company	2512	0.438	0.496	0	1
Year	2514	1997.536	1.702	1995	2000

[a]The following variables are winsorized at the 1st and 99th percentiles: loss ratio ceded, loss ratio ceded$_{t-1}$, auto liability reinsurance, experience rating$_{t-1}$, retention limit$_{t-1}$, auto liability premiums growth rate, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, and ROA.

Table 5B: Descriptive Statistics

Sample of Homeowners Reinsurance for Moral Hazard Test

Variables	Obs	Mean	Std. Dev.	Min	Max
Loss Ratio Ceded	2467	0.843	1.332	0	8.625
Loss Ratio Ceded$_{t-1}$	2467	0.622	0.793	0	4.769
Homeowners Reinsurance	2467	0.299	0.286	0	0.971
External Ho. Reinsurance Ratio	2467	0.724	0.446	-1.805	6.807
Sustain	2001	0.761	0.303	0	1
Rherf	2001	0.419	0.309	0.018	1
Experience Rating$_{t-1}$	2467	1.404	0.507	0.623	4.016
Retention Limit$_{t-1}$	2467	0.617	0.284	0.028	0.991
Firm size	2467	18.814	1.939	13.318	24.358
Homeowners Concentration	2467	0.203	0.182	0.000	0.967
Ho. premium growth rate	2467	0.076	0.226	-0.520	1.371
Firm premium growth rate	2467	0.057	0.166	-0.359	0.980
Leverage	2467	1.309	0.664	0.084	3.075
Tax rate	2467	0.260	0.688	-3.531	3.593
Mutual	2467	0.429	0.495	0	1
Direct	2467	0.179	0.383	0	1
Agency	2467	0.776	0.417	0	1
Rating1	2467	0.298	0.457	0	1
Rating2	2467	0.502	0.500	0	1
Rating3	2467	0.126	0.332	0	1
Rating4	2467	0.034	0.180	0	1
Long Tail Lines	2467	0.735	0.152	0.118	0.979
Product Herfindahl	2467	0.301	0.133	0.117	0.797
Geographic Herfindahl	2467	0.523	0.374	0.043	1
ROA	2467	0.025	0.034	-0.097	0.115
Age	2467	3.920	0.850	0	5.328
Lead Company	2465	0.516	0.500	0	1
Coastal States	2467	0.470	0.499	0	1
Year	2467	1997.584	1.678	1995	2000

[a]The following variables are winsorized at the 1st and 99th percentiles: loss ratio ceded, loss ratio ceded$_{t-1}$, homeowners reinsurance, experience rating$_{t-1}$, retention limit$_{t-1}$, homeowners premiums growth rate, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, and ROA.

Table 5C: Descriptive Statistics

Sample of Product Liability Reinsurance for Moral Hazard Test

Variables	Obs	Mean	Std. Dev.	Min	Max
Loss Ratio Ceded	828	1.912	3.567	0	21.737
Loss Ratio Ceded$_{t-1}$	828	1.009	2.070	0	14.391
Product Liability Reinsurance	828	0.280	0.310	0.000	0.973
External prod. Reinsurance Ratio	828	0.671	0.475	-0.957	5.284
Sustain	601	0.788	0.272	0	1
Rherf	601	0.272	0.227	0.018	1
Experience Rating$_{t-1}$	828	1.988	2.187	0.338	15.742
Retention Limit$_{t-1}$	828	0.591	0.290	0.026	0.999
Firm size	828	19.974	1.495	16.411	23.877
Prod. Liab. Concentration	828	0.024	0.054	0.000	1
Prod. premium growth rate	828	0.096	0.696	-0.740	5.413
Firm premium growth rate	828	0.058	0.169	-0.315	0.924
Leverage	828	1.124	0.548	0.095	2.631
Tax rate	828	0.200	0.900	-5.619	3.431
Mutual	828	0.211	0.409	0	1
Direct	828	0.071	0.257	0	1
Agency	828	0.809	0.393	0	1
Rating1	828	0.464	0.499	0	1
Rating2	828	0.470	0.499	0	1
Rating3	828	0.051	0.220	0	1
Rating4	828	0.011	0.104	0	1
Long Tail Lines	828	0.768	0.135	0.311	1.000
Product Herfindahl	828	0.251	0.125	0.108	0.801
Geographic Herfindahl	828	0.232	0.248	0.036	1
ROA	828	0.027	0.030	-0.071	0.122
Age	828	3.822	0.860	0	5.328
Lead Company	828	0.350	0.477	0	1
Year	828	1997.514	1.685	1995	2000

[a]The following variables are winsorized at the 1st and 99th percentiles: loss ratio ceded, loss ratio ceded$_{t-1}$, product liability reinsurance, experience rating$_{t-1}$, retention limit$_{t-1}$, product liability premiums growth rate, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, and ROA.

Matching Estimators - Private Passenger Auto Liability Reinsurance

Table 6A: (Full Sample without SUSTAIN and RHERF)

Dependent Variable: Loss Ratio Ceded of Private Passenger Auto Liability Reinsurance

Loss Ratio Ceded	Coeff.	Std. Err.	Z	P > |Z|	[95% Confidence Interval]	
Sample Average Treatment Effect	0.978	0.118	8.320	0.000	0.748	1.209
Number of Observations	2512			Number of Matches		4

Note: Treatment variable is group affiliation. Matching variables are external auto liability reinsurance ratio, loss ratio ceded$_{t-1}$, experience rating$_{t-1}$, retention limit$_{t-1}$, firm size, auto liability concentration, auto liability premiums growth rate, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, ROA, and lead company. STATA command *nnmatch* is used to estimate the sample average treatment effect, and the bias-corrected matching estimator and heteroskedasticity-consistent standard errors are used.

Table 6B: (Sample with SUSTAIN and RHERF)

Dependent Variable: Loss Ratio Ceded of Private Passenger Auto Liability Reinsurance

Loss Ratio Ceded	Coeff.	Std. Err.	Z	P > |Z|	[95% Confidence Interval]	
Sample Average Treatment Effect	0.694	0.092	7.550	0.000	0.514	0.874
Number of Observations	2050			Number of Matches		4

Note: Treatment variable is group affiliation. Matching variables are external auto liability reinsurance ratio, loss ratio ceded$_{t-1}$, experience rating$_{t-1}$, retention limit$_{t-1}$, SUSTAIN, RHERF, firm size, auto liability concentration, auto liability premiums growth rate, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, ROA, and lead company. STATA command *nnmatch* is used to estimate the sample average treatment effect, and the bias-corrected matching estimator and heteroskedasticity-consistent standard errors are used.

Matching Estimators - Homeowners Reinsurance

Table 7A: (Full Sample without SUSTAIN and RHERF)

Dependent Variable: Loss Ratio Ceded of Homeowners Reinsurance

Loss Ratio Ceded	Coeff.	Std. Err.	Z	P > |Z|	[95% Confidence Interval]	
Sample Average Treatment Effect	-0.226	0.069	-3.280	0.001	-0.361	-0.091
Number of Observations	2463			Number of Matches		4

Note: Treatment variable is group affiliation. Matching variables are external homeowners reinsurance ratio, loss ratio ceded$_{t-1}$, experience rating$_{t-1}$, retention limit$_{t-1}$, firm size, homeowners concentration, homeowners premiums growth rate, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, ROA, coastal states, and lead company. STATA command *nnmatch* is used to estimate the sample average treatment effect, and the bias-corrected matching estimator and heteroskedasticity-consistent standard errors are used.

Table 7B: (Sample with SUSTAIN and RHERF)

Dependent Variable: Loss Ratio Ceded of Homeowners Reinsurance

Loss Ratio Ceded	Coeff.	Std. Err.	Z	P > |Z|	[95% Confidence Interval]	
Sample Average Treatment Effect	-0.025	0.059	-0.420	0.677	-0.141	0.091
Number of Observations	1997			Number of Matches		4

Note: Treatment variable is group affiliation. Matching variables are external homeowners reinsurance ratio, loss ratio ceded$_{t-1}$, experience rating$_{t-1}$, retention limit$_{t-1}$, SUSTAIN, RHERF, firm size, homeowners concentration, homeowners premiums growth rate, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, ROA, coastal states, and lead company. STATA command *nnmatch* is used to estimate the sample average treatment effect, and the bias-corrected matching estimator and heteroskedasticity-consistent standard errors are used.

Table 8A: Test for Moral Hazard - Private Passenger Auto Liability Reinsurance

Fixed-effects GLS regression with robust standard errors

Dependent Variable: loss ratio ceded of private passenger auto liability reinsurance

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	51.128	2.29**	46.977	1.77*
External Auto Reinsurance Ratio	-0.026	-0.17	-0.045	-0.37
Loss Ratio Ceded$_{t-1}$	0.292	1.40	0.053	0.22
Experience Rating$_{t-1}$	1.047	1.46	0.590	0.99
Retention Limit$_{t-1}$	0.538	0.52	-0.151	-0.16
Sustain			-0.370	-0.77
Rherf			-1.510	-1.09
Firm size	-2.625	-2.31**	-2.261	-1.66*
Auto Liab. Concentration	-10.047	-3.32***	-7.753	-2.69***
Auto premium growth rate	0.257	0.71	0.105	0.32
Firm premium growth rate	-1.177	-1.80*	-0.427	-0.59
Leverage	-0.007	-0.02	-0.359	-1.08
Tax rate	-0.203	-1.44	0.059	0.45
Long Tail Lines	1.717	0.58	2.906	0.86
Product Herfindahl	5.311	1.94*	-1.235	-0.67
Geographic Herfindahl	1.203	0.74	0.233	0.13
ROA	3.639	1.03	6.199	1.67*
Lead Company	1.083	2.52**	0.502	1.30
year1995	-2.998	-5.36***	-1.716	-2.96***
year1996	-2.553	-5.66***	-1.299	-2.87***
year1997	-1.683	-4.05***	-0.639	-1.53
year1998	-1.223	-3.09***	-0.295	-0.80
year1999	-1.233	-3.76***	-0.122	-0.45
R^2 (within)	8.68%		6.03%	
N	2121		1661	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Exogeneity Test for External Auto Liability Reinsurance Ratio

Table 8B: Fixed-effects GLS regression with robust standard errors

Dependent Variable: external auto liability reinsurance ratio

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	0.160	0.06	1.842	0.55
Loss Ratio Ceded$_{t-1}$	-0.009	-1.08	-0.003	-0.35
Experience Rating$_{t-1}$	-0.124	-1.27	-0.137	-1.22
Retention Limit$_{t-1}$	-0.046	-0.19	-0.037	-0.13
Sustain			0.151	1.65
Rherf			0.132	1.23
Firm size	0.120	1.33	0.021	0.18
Mutual	0.767	4.14***	0.644	3.89***
Direct	-0.067	-0.93	-0.061	-0.77
Agency	0.072	1.33	0.051	0.91
Rating1	-1.355	-1.17	-1.268	-1.13
Rating2	-1.283	-1.10	-1.255	-1.11
Rating3	-1.264	-1.05	-1.228	-1.04
Rating4	-1.714	-1.08	-1.700	-1.08
Age	-0.172	-1.53	-0.142	-1.10
Lead Company	0.108	0.87	0.132	1.05
R^2 (within)	6.51%		7.47%	
N	2121		1661	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

[c]The instrumental variables for *External Auto Liability Reinsurance Ratio* are mutual, direct, agency, A.M.Best's rating dummies, age, and lead company.

Exogeneity Test for External Auto Liability Reinsurance Ratio

Table 8C: Fixed-effects GLS regression with robust standard errors

Dependent Variable: loss ratio ceded of private passenger auto liability reinsurance				
	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	51.591	2.30**	46.427	1.77*
External Auto Reinsurance Ratio	0.496	1.02	0.491	1.07
Loss Ratio $Ceded_{t-1}$	0.295	1.42	0.054	0.22
Experience $Rating_{t-1}$	1.107	1.53	0.659	1.10
Retention $Limit_{t-1}$	0.536	0.52	-0.153	-0.17
Sustain			-0.465	-0.92
Rherf			-1.570	-1.12
Firm size	-2.669	-2.33**	-2.249	-1.66*
Auto Liab. Concentration	-10.114	-3.32***	-7.871	-2.71***
Auto premium growth rate	0.258	0.71	0.110	0.33
Firm premium growth rate	-1.176	-1.80*	-0.429	-0.59
Leverage	-0.013	-0.04	-0.364	-1.09
Tax rate	-0.202	-1.43	0.061	0.46
Long Tail Lines	1.777	0.60	2.979	0.88
Product Herfindahl	5.226	1.90*	-1.373	-0.74
Geographic Herfindahl	1.252	0.76	0.289	0.16
ROA	3.664	1.04	6.213	1.68*
Lead Company	1.029	2.39**	0.438	1.13
year1995	-3.010	-5.36***	-1.720	-2.96***
year1996	-2.568	-5.68***	-1.308	-2.89***
year1997	-1.695	-4.07***	-0.644	-1.54
year1998	-1.235	-3.11***	-0.302	-0.82
year1999	-1.233	-3.75***	-0.122	-0.45
Residuals[c]	-0.556	-1.00	-0.572	-1.10
R^2 (within)	8.71%		6.07%	
N	2121		1661	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

[c]Residuals are the combined residuals from the fixed-effects GLS regression of *External Auto Liability Reinsurance Ratio* reported in Table 8C. If the coefficient on *Residuals* is not significant, we find evidence that *External Auto Liability Reinsurance Ratio* is exogenous in the fixed-effects GLS regression of *Loss Ratio Ceded*. This exogeneity test is used by Laffont and Matoussi (1995).

Table 9A: Test for Moral Hazard - Homeowners Reinsurance

Fixed-effects GLS regression with robust standard errors

Dependent Variable: loss ratio ceded of homeowners reinsurance	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	0.692	0.21	0.993	0.21
External Ho. Reinsurance Ratio	0.089	0.42	0.105	0.49
Loss Ratio Ceded$_{t-1}$	-0.221	-4.54***	-0.280	-6.10***
Experience Rating$_{t-1}$	-0.124	-1.65*	-0.181	-2.20**
Retention Limit$_{t-1}$	0.102	0.56	0.139	0.63
Sustain			0.145	1.46
Rherf			0.011	0.04
Firm size	-0.007	-0.04	-0.024	-0.10
Homeowners Concentration	-0.241	-0.44	-0.264	-0.40
Ho. premium growth rate	-0.115	-1.11	-0.082	-0.57
Firm premium growth rate	0.050	0.44	0.063	0.39
Leverage	-0.095	-1.30	-0.123	-1.34
Tax rate	-0.040	-1.12	0.000	-0.01
Long Tail Lines	0.817	1.34	0.830	1.07
Product Herfindahl	-0.075	-0.20	0.391	0.63
Geographic Herfindahl	0.127	0.31	-0.018	-0.04
ROA	-5.191	-5.02***	-4.953	-4.41***
Lead Company	0.119	0.54	0.047	0.20
Coastal States	-0.323	-1.73*	-0.274	-1.91*
year1995	-0.139	-1.49	-0.090	-0.75
year1996	0.002	0.03	0.014	0.15
year1997	-0.173	-2.87***	-0.183	-2.49**
year1998	0.178	2.39**	0.187	2.19**
year1999	0.081	1.33	0.048	0.74
R^2 (within)	11.14%		12.68%	
N	1864		1402	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Exogeneity Test for External Homeowners Reinsurance Ratio

Table 9B: Fixed-effects GLS regression with robust standard errors

Dependent Variable: external homeowners reinsurance ratio

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.765	2.18**	3.166	3.13***
Loss Ratio Ceded$_{t-1}$	0.005	0.86	0.009	1.18
Experience Rating$_{t-1}$	0.004	0.15	0.014	0.47
Retention Limit$_{t-1}$	0.149	2.29**	0.190	2.65***
Sustain			0.023	0.91
Rherf			0.045	0.66
Firm size	-0.067	-1.57	-0.138	-2.60***
Mutual	-0.069	-7.73***	-0.075	-7.12***
Direct	0.050	0.68	0.042	0.54
Agency	0.075	1.25	0.064	1.03
Rating1	-0.232	-2.11**	-0.178	-1.69*
Rating2	-0.207	-1.88*	-0.143	-1.37
Rating3	-0.182	-1.76*	-0.151	-1.55
Rating4	-0.224	-2.15**	-0.216	-2.16***
Age	-0.018	-0.77	-0.024	-0.98
Lead Company	0.170	0.83	0.159	0.77
Coastal States	-0.005	-0.59	-0.024	-1.46
R^2 (within)	6.22%		7.99%	
N	1864		1402	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

[c]The instrumental variables for *External Homeowners Reinsurance Ratio* are mutual, direct, agency, A.M.Best's rating dummies, and age.

Exogeneity Test for External Homeowners Reinsurance Ratio

Table 9C: Fixed-effects GLS regression with robust standard errors

Dependent Variable: loss ratio ceded of homeowners reinsurance

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	-0.545	-0.14	-3.299	-0.53
External Ho. Reinsurance Ratio	0.739	0.91	1.391	1.20
Loss Ratio Ceded$_{t-1}$	-0.226	-4.55***	-0.294	-6.27***
Experience Rating$_{t-1}$	-0.126	-1.67*	-0.198	-2.35**
Retention Limit$_{t-1}$	0.002	0.01	-0.103	-0.36
Sustain			0.110	1.01
Rherf			-0.041	-0.15
Firm size	0.049	0.26	0.180	0.59
Homeowners Concentration	-0.221	-0.41	-0.243	-0.37
Ho. premium growth rate	-0.112	-1.08	-0.078	-0.53
Firm premium growth rate	0.052	0.45	0.067	0.42
Leverage	-0.097	-1.32	-0.128	-1.38
Tax rate	-0.040	-1.13	-0.002	-0.06
Long Tail Lines	0.819	1.35	0.813	1.05
Product Herfindahl	-0.068	-0.18	0.374	0.61
Geographic Herfindahl	0.136	0.33	0.001	0
ROA	-5.206	-5.03***	-4.984	-4.43***
Lead Company	0.017	0.07	-0.147	-0.51
Coastal States	-0.313	-1.66*	-0.242	-1.62
year1995	-0.141	-1.50	-0.085	-0.71
year1996	0.000	0	0.015	0.17
year1997	-0.175	-2.88***	-0.182	-2.48**
year1998	0.176	2.36**	0.187	2.19**
year1999	0.080	1.32	0.046	0.72
Residuals[c]	-0.663	-0.79	-1.307	-1.11
R^2 (within)	11.17%		12.76%	
N	1864		1402	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

[c]Residuals are the combined residuals from the fixed-effects GLS regression of *External Homeowners Reinsurance Ratio* reported in Table 9C. If the coefficient on *Residuals* is not significant, we find evidence that *External Homeowners Reinsurance Ratio* is exogenous in the fixed-effects GLS regression of *Loss Ratio Ceded*. This exogeneity test is used by Laffont and Matoussi (1995).

Table 10A: Test for Moral Hazard - Product Liability Reinsurance

Fixed-effects GLS regression with robust standard errors

Dependent Variable: loss ratio ceded of product liability reinsurance

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	33.179	1.32	-10.228	-0.53
External Prod. Reinsurance Ratio	0.095	0.31	0.403	1.04
Loss Ratio Ceded$_{t-1}$	0.321	2.06**	0.170	0.95
Experience Rating$_{t-1}$	0.143	1.24	0.032	0.28
Retention Limit$_{t-1}$	2.579	1.82*	2.903	1.74*
Sustain			0.693	1.00
Rherf			-0.048	-0.06
Firm size	-1.644	-1.27	0.592	0.59
Prod. Liab. Concentration	-1.980	-0.17	8.970	1.14
Prod. premium growth rate	0.035	0.16	0.087	0.23
Firm premium growth rate	1.249	1.20	2.397	2.11**
Leverage	-0.163	-0.21	-0.059	-0.07
Tax rate	0.052	0.66	0.030	0.28
Long Tail Lines	-1.085	-0.32	-5.148	-1.52
Product Herfindahl	2.942	0.89	0.908	0.33
Geographic Herfindahl	-2.402	-1.07	-1.476	-0.67
ROA	2.981	0.68	2.108	0.41
Lead Company	1.473	1.23	0.953	0.91
year1995	-1.145	-2.07**	-0.158	-0.28
year1996	-0.789	-1.28	0.072	0.11
year1997	0.089	0.17	1.029	1.92*
year1998	-0.020	-0.04	0.860	1.67*
year1999	0.306	0.83	0.803	1.86*
R^2 (within)	8.57%		8.61%	
N	789		563	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Exogeneity Test for External Product Liability Reinsurance Ratio

Table 10B: Fixed-effects GLS regression with robust standard errors

Dependent Variable: external product liability reinsurance ratio

Independent Variables	Without SUSTAIN and RHERF Coeff.	Without SUSTAIN and RHERF z-Stat	With SUSTAIN and RHERF Coeff.	With SUSTAIN and RHERF z-Stat
Intercept	-1.833	-1.35	-2.234	-1.32
Loss Ratio Ceded$_{t-1}$	-0.004	-0.76	-0.006	-1.14
Experience Rating$_{t-1}$	-0.002	-0.26	0.004	0.46
Retention Limit$_{t-1}$	0.364	3.02***	0.084	0.69
Sustain			0.013	0.22
Rherf			-0.036	-0.41
Firm size	0.042	0.59	0.066	0.81
Mutual	-0.001	-0.06	0.022	1.04
Direct	0.150	3.21***	0.106	1.61
Agency	0.231	3.09***	0.249	2.37**
Rating1	0.073	0.40	(dropped)	
Rating2	0.108	0.60	0.130	2.40**
Rating3	(dropped)		0.033	0.19
Rating4	(dropped)		(dropped)	
Age	0.320	1.87*	0.350	1.55
Lead Company	-0.203	-1.91*	-0.176	-1.40
R^2 (within)	3.92%		3.23%	
N	789		563	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

[c]The instrumental variables for *External product Liability Reinsurance Ratio* are mutual, direct, agency, A.M.Best's rating dummies, and age.

Exogeneity Test for External Product Liability Reinsurance Ratio

Table 10C: Fixed-effects GLS regression with robust standard errors

Dependent Variable: loss ratio ceded of product liability reinsurance				
	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	33.668	1.32	-8.928	-0.45
External Prod. Reinsurance Ratio	0.768	0.09	3.418	0.57
Loss Ratio Ceded$_{t-1}$	0.324	2.12**	0.186	1.06
Experience Rating$_{t-1}$	0.144	1.23	0.023	0.20
Retention Limit$_{t-1}$	2.336	0.74	2.536	1.60
Sustain			0.580	0.93
Rherf			0.032	0.04
Firm size	-1.688	-1.22	0.425	0.40
Prod. Liab. Concentration	-2.002	-0.17	8.872	1.12
Prod. premium growth rate	0.033	0.15	0.077	0.20
Firm premium growth rate	1.245	1.20	2.349	2.10**
Leverage	-0.172	-0.23	-0.089	-0.11
Tax rate	0.053	0.66	0.037	0.34
Long Tail Lines	-1.085	-0.32	-5.343	-1.54
Product Herfindahl	3.024	0.87	1.169	0.38
Geographic Herfindahl	-2.355	-1.00	-1.226	-0.53
ROA	2.909	0.67	1.878	0.37
Lead Company	1.589	0.89	1.392	1.08
year1995	-1.117	-1.61	-0.029	-0.05
year1996	-0.767	-1.11	0.184	0.27
year1997	0.106	0.18	1.090	1.98**
year1998	-0.012	-0.02	0.900	1.70*
year1999	0.311	0.79	0.826	1.87*
Residuals[c]	-0.677	-0.08	-3.073	-0.51
R^2 (within)	8.57%		8.78%	
N	789		563	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

[c]Residuals are the combined residuals from the fixed-effects GLS regression of *External Product Liability Reinsurance Ratio* reported in Table 10C. If the coefficient on *Residuals* is not significant, we find evidence that *External Product Liability Reinsurance Ratio* is exogenous in the fixed-effects GLS regression of *Loss Ratio Ceded*. This exogeneity test is used by Laffont and Matoussi (1995).

Table 11A: Test for Adverse Selection - Private Passenger Auto Liability Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of private passenger auto liability reinsurance

Risk of primary insurer is measured by *future loss ratio volatility*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.704	8.53***	1.272	6.83***
Future loss ratio volatility	0.070	0.62	0.052	0.51
Sustain			-0.009	-0.67
Rherf			-0.002	-0.07
Experience Rating$_{t-1}$	0.010	0.36	0.027	1.02
Retention Limit$_{t-1}$	-0.318	-6.27***	-0.354	-7.34***
Firm size	-0.054	-8.45***	-0.038	-5.57***
Auto Concentration	0.294	2.48**	0.094	1.16
Auto premium growth rate	0.006	0.20	-0.012	-0.52
Firm premium growth rate	0.121	2.98***	0.130	3.59***
Leverage	-0.076	-7.46***	-0.068	-5.58***
Tax rate	0.004	0.72	0.002	0.33
Long Tail Lines	-0.045	-0.34	0.026	0.22
Product Herfindahl	-0.180	-1.22	-0.003	-0.02
Geographic Herfindahl	-0.152	-4.04***	-0.047	-1.37
ROA	0.288	2.20**	0.109	0.88
Lead Company	-0.070	-2.47**	-0.040	-1.57
year1995	0.006	0.39	0.018	1.38
year1996	-0.009	-0.68	0.007	0.61
year1997	-0.023	-1.73*	-0.012	-1.08
year1998	-0.016	-1.47	-0.015	-1.52
year1999	-0.018	-2.07**	-0.015	-1.97**
N	2419 (262 observations left-censored at 0, and 2157 uncensored)		1957 (110 observations left-censored at 0, and 1857 uncensored)	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 11B: Test for Adverse Selection - Homeowners Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of homeowners reinsurance

Risk of primary insurer is measured by *future loss ratio volatility*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.412	8.10***	1.037	7.58***
Future loss ratio volatility	0.028	1.13	0.039	1.70*
Sustain			-0.007	-0.50
Rherf			0.024	0.88
Experience Rating$_{t-1}$	0.019	2.52**	0.023	3.17***
Retention Limit$_{t-1}$	-0.192	-6.08***	-0.216	-6.98***
Firm size	-0.041	-4.94***	-0.025	-4.80***
Homeowners Concentration	-0.052	-0.60	-0.071	-1.01
Ho. premium growth rate	-0.002	-0.06	-0.031	-1.13
Firm premium growth rate	0.082	2.23**	0.151	3.30***
Leverage	-0.071	-5.57***	-0.064	-5.05***
Tax rate	-0.001	-0.13	0.002	0.57
Long Tail Lines	-0.003	-0.04	-0.049	-0.60
Product Herfindahl	-0.186	-2.10**	-0.118	-1.31
Geographic Herfindahl	-0.079	-2.06**	-0.017	-0.60
ROA	0.293	2.43**	0.201	1.78*
Lead Company	-0.109	-3.89***	-0.076	-2.99***
Coastal States	0.016	0.89	0.035	2.05**
year1995	0.013	1.31	0.023	2.31**
year1996	0.011	1.27	0.014	1.54
year1997	0.004	0.41	0.018	2.12**
year1998	-0.007	-0.81	0.000	0.05
year1999	-0.010	-1.44	-0.007	-1.06
N	2208(144 observations left-censored at 0, and 2064 uncensored)		1809 (46 observations left-censored at 0, and 1763 uncensored)	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 11C: Test for Adverse Selection - Product Liability Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of produt liability reinsurance

Risk of primary insurer is measured by *future loss ratio volatility*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.388	3.54***	-0.064	-1.47
Future loss ratio volatility	0.028	0.48	-0.040	-0.96
Sustain			-0.106	-1.89*
Rherf			0.000	-0.01
Experience Rating$_{t-1}$	0.004	0.89	-0.344	-4.37***
Retention Limit$_{t-1}$	-0.345	-3.57***	-0.047	-3.12***
Firm size	-0.040	-2.17**	0.363	0.33
Prod. Liab. Concentration	0.494	0.79	-0.006	-0.78
Prod. premium growth rate	0.004	0.25	0.017	0.45
Firm premium growth rate	0.074	1.28	-0.130	-3.29***
Leverage	-0.172	-4.62***	0.004	0.51
Tax rate	0.002	0.27	0.116	0.54
Long Tail Lines	0.300	1.56	-0.336	-2.85***
Product Herfindahl	-0.504	-3.41***	-0.152	-1.81*
Geographic Herfindahl	-0.169	-1.91**	0.301	0.99
ROA	0.154	0.53	-0.061	-1.39
Lead Company	-0.037	-0.92	0.055	2.49**
year1995	0.087	2.59***	0.027	1.35
year1996	0.052	1.73*	0.012	0.62
year1997	0.038	1.34	-0.014	-1.04
year1998	-0.008	-0.40	-0.025	-2.21**
year1999	-0.042	-2.72***	1.712	4.84***
N	638 (120 observations left-censored at 0, and 518 uncensored)		492 (39 observations left-censored at 0, and 453 uncensored)	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 12A: Test for Adverse Selection - Private Passenger Auto Liability Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of private passenger auto liability reinsurance

Risk of primary insurer is measured by *loss ratio difference*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.726	8.83***	1.290	7.07***
Loss ratio difference	-0.084	-1.38	-0.088	-1.30
Sustain			-0.009	-0.67
Rherf			-0.001	-0.04
Experience Rating$_{t-1}$	0.005	0.17	0.020	0.73
Retention Limit$_{t-1}$	-0.319	-6.36***	-0.352	-7.33***
Firm size	-0.053	-8.03***	-0.037	-5.32***
Auto Concentration	0.273	2.44**	0.075	0.99
Auto premium growth rate	0.008	0.27	-0.011	-0.45
Firm premium growth rate	0.117	2.87***	0.126	3.56***
Leverage	-0.078	-7.63***	-0.070	-5.60***
Tax rate	0.003	0.65	0.002	0.34
Long Tail Lines	-0.055	-0.43	0.014	0.12
Product Herfindahl	-0.168	-1.20	0.007	0.07
Geographic Herfindahl	-0.150	-3.90***	-0.044	-1.27
ROA	0.229	1.61	0.043	0.31
Lead Company	-0.071	-2.52**	-0.042	-1.70*
year1995	0.006	0.43	0.020	1.46
year1996	-0.011	-0.86	0.006	0.49
year1997	-0.023	-1.79*	-0.011	-1.08
year1998	-0.017	-1.63	-0.015	-1.61
year1999	-0.019	-2.31**	-0.016	-2.25**
N	2419 (262 observations left-censored at 0, and 2157 uncensored)		1957 (110 observations left-censored at 0, and 1857 uncensored)	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 12B: Test for Adverse Selection - Homeowners Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of homeowners reinsurance

Risk of primary insurer is measured by *loss ratio difference*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.422	8.06***	1.056	7.75***
Loss ratio difference	0.036	1.89*	0.029	2.20**
Sustain			-0.007	-0.51
Rherf			0.023	0.84
Experience Rating$_{t-1}$	0.017	2.29**	0.022	3.01***
Retention Limit$_{t-1}$	-0.192	-6.18***	-0.213	-6.68***
Firm size	-0.041	-4.93***	-0.025	-4.92***
Homeowners Concentration	-0.054	-0.62	-0.073	-1.06
Ho. premium growth rate	0.000	-0.01	-0.029	-1.07
Firm premium growth rate	0.084	2.26**	0.154	3.33***
Leverage	-0.070	-5.63***	-0.064	-5.11***
Tax rate	0.000	-0.06	0.002	0.63
Long Tail Lines	-0.005	-0.07	-0.053	-0.66
Product Herfindahl	-0.183	-2.05**	-0.107	-1.17
Geographic Herfindahl	-0.079	-2.06**	-0.018	-0.65
ROA	0.362	2.60***	0.261	2.15**
Lead Company	-0.109	-3.94***	-0.075	-2.98***
Coastal States	0.018	0.99	0.037	2.19**
year1995	0.020	1.81*	0.028	2.55**
year1996	0.008	0.91	0.011	1.24
year1997	0.007	0.73	0.019	2.40**
year1998	-0.008	-0.96	-0.002	-0.20
year1999	-0.008	-1.14	-0.005	-0.82
N	2208(144 observations left-censored at 0, and 2064 uncensored)		1809 (46 observations left-censored at 0, and 1763 uncensored)	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 12C: Test for Adverse Selection - Product Liability Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of produt liability reinsurance

Risk of primary insurer is measured by *loss ratio difference*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.402	3.66***	1.674	4.98***
Loss ratio difference	0.002	0.07	0.002	0.11
Sustain			-0.041	-0.99
Rherf			-0.100	-1.82*
Experience Rating$_{t-1}$	0.004	0.93	0.001	0.15
Retention Limit$_{t-1}$	-0.342	-3.50***	-0.347	-4.41***
Firm size	-0.040	-2.22**	-0.046	-3.19***
Prod. Liab. Concentration	0.490	0.75	0.385	0.36
Prod. premium growth rate	0.003	0.24	-0.006	-0.69
Firm premium growth rate	0.074	1.27	0.017	0.45
Leverage	-0.172	-4.45***	-0.129	-3.26***
Tax rate	0.002	0.26	0.004	0.53
Long Tail Lines	0.294	1.55	0.132	0.61
Product Herfindahl	-0.502	-3.37***	-0.339	-2.89***
Geographic Herfindahl	-0.167	-1.81*	-0.156	-1.81*
ROA	0.151	0.52	0.308	1.01
Lead Company	-0.037	-0.92	-0.064	-1.46
year1995	0.088	2.47**	0.051	2.39**
year1996	0.053	1.68*	0.023	1.24
year1997	0.039	1.36	0.009	0.51
year1998	-0.008	-0.36	-0.016	-1.22
year1999	-0.042	-2.60***	-0.027	-2.40***
N	638 (120 observations left-censored at 0, and 518 uncensored)		492 (39 observations left-censored at 0, and 453 uncensored)	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 13A: Descriptive Statistics

Sample of All-Line Reinsurance for Adverse Selection Test

Variables	Obs	Mean	Std. Dev.	Min	Max
All-Line Reinsurance	9013	0.368	0.338	0.000	1.000
Loss reserve error	8177	0.044	0.465	-0.933	2.886
Loss ratio volatility	9013	0.137	0.160	0.021	1.166
Loss ratio difference	9013	-0.032	0.230	-0.671	0.861
Sustain	6999	0.640	0.384	0.000	1.000
Rherf	6999	0.473	0.305	0.018	1.000
Experience Rating$_{t-1}$	9013	1.585	0.930	0.584	7.516
Retention Limit$_{t-1}$	9013	0.685	0.323	0.000	1.000
Firm size	9013	17.863	1.932	13.058	25.107
Firm premium growth rate	9013	0.156	0.570	-0.542	4.274
Leverage	9013	1.107	0.933	0.000	4.400
Tax rate	9013	0.289	0.656	-2.902	3.625
Long Tail Lines	9013	0.675	0.290	0	1
Product Herfindahl	9013	0.499	0.272	0.135	1
Geographic Herfindahl	9013	0.585	0.384	0.043	1
ROA	9013	0.032	0.046	-0.126	0.186
Lead Company	8950	0.419	0.493	0	1
Year	9013	1997.501	1.708	1995	2000

[a]The following variables are winsorized at the 1st and 99th percentiles: all-line reinsurance, loss reserve error, loss ratio volatility, experience rating$_{t-1}$, retention limit$_{t-1}$, firm premiums growth rate, leverage, product Herfindahl, geographic Herfindahl, long tail lines, and tax rate.

Table 13B: Test for Adverse Selection - All-Line Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of all-line reinsurance

Risk of primary insurer is measured by *loss reserve error*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	1.663	16.44***	1.487	21.53***
Loss reserve error	0.031	5.21***	0.029	4.89***
Sustain			0.010	1.49
Rherf			-0.009	-0.78
Experience Rating$_{t-1}$	0.014	2.77***	0.015	3.33***
Retention Limit$_{t-1}$	-0.358	-17.67***	-0.380	-15.64***
Firm size	-0.051	-10.02***	-0.042	-11.62***
Firm premium growth rate	0.007	1.50	0.010	1.27
Leverage	-0.091	-15.40***	-0.078	-12.12***
Tax rate	0.001	0.21	0.002	0.63
Long Tail Lines	0.137	6.15***	0.076	3.16***
Product Herfindahl	-0.177	-6.25***	-0.129	-6.03***
Geographic Herfindahl	-0.153	-7.12***	-0.078	-3.92***
ROA	0.243	4.08***	0.182	2.99***
Lead Company	-0.053	-4.45***	-0.052	-4.72***
year1995	0.018	2.99***	0.014	2.08**
year1996	0.012	2.32**	0.007	1.35
year1997	0.006	1.11	0.004	0.84
year1998	0.001	0.20	0.000	-0.06
year1999	-0.008	-1.85*	-0.010	-2.53**
N	8116 (668 observations left-censored at 0, 7446 observations uncensored, and 2 right-censored at 1).		6622 (121 observations left-censored at 0, and 6500 observations uncensored.	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 13C: Test for Adverse Selection - All-Line Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of all-line reinsurance

Risk of primary insurer is measured by *future loss ratio volatility*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	2.130	21.48***	1.762	22.89***
Future loss ratio volatility	0.050	1.96**	0.064	2.24**
Sustain			0.000	-0.07
Rherf			0.001	0.10
Experience Rating$_{t-1}$	0.012	2.97***	0.013	2.76***
Retention Limit$_{t-1}$	-0.426	-18.74***	-0.407	-19.58***
Firm size	-0.069	-12.60***	-0.053	-13.15***
Firm premium growth rate	0.005	0.87	0.007	1.10
Leverage	-0.124	-21.93***	-0.105	-16.76***
Tax rate	-0.001	-0.49	0.000	-0.13
Long Tail Lines	0.145	4.99***	0.088	3.48***
Product Herfindahl	-0.193	-8.32***	-0.131	-5.57***
Geographic Herfindahl	-0.168	-7.47***	-0.103	-5.69***
ROA	0.373	5.63***	0.305	4.96***
Lead Company	-0.082	-7.19***	-0.070	-5.46***
year1995	0.018	2.64***	0.010	1.51
year1996	0.014	2.09**	0.007	1.19
year1997	0.005	0.89	0.002	0.46
year1998	0.000	-0.09	-0.002	-0.32
year1999	-0.009	-2.14**	-0.012	-2.83***
N	8950 (668 observations left-censored at 0, 7447 observations uncensored, and 835 right-censored at 1).		6956 (121 observations left-censored at 0, 6500 observations uncensored, and 335 right-censored at 1.	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 13D: Test for Adverse Selection - All-Line Reinsurance

Random-effects Tobit regression with bootstrap standard errors

Dependent Variable: net amount of all-line reinsurance

Risk of primary insurer is measured by *loss ratio difference*

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	2.170	22.55***	1.822	23.47***
Loss ratio difference	0.064	4.58***	0.068	6.44***
Sustain			0.000	0.02
Rherf			-0.002	-0.20
Experience Rating$_{t-1}$	0.014	3.20***	0.015	3.06***
Retention Limit$_{t-1}$	-0.427	-18.58***	-0.408	-19.34***
Firm size	-0.071	-13.30***	-0.055	-13.53***
Firm premium growth rate	0.006	0.90	0.008	1.14
Leverage	-0.123	-21.78***	-0.104	-17.07***
Tax rate	-0.001	-0.38	0.000	0.04
Long Tail Lines	0.137	4.61***	0.079	3.11***
Product Herfindahl	-0.192	-8.28***	-0.130	-5.54***
Geographic Herfindahl	-0.170	-7.72***	-0.105	-5.73***
ROA	0.442	6.24***	0.384	5.79***
Lead Company	-0.082	-7.16***	-0.070	-5.44***
year1995	0.017	2.43**	0.008	1.26
year1996	0.010	1.41	0.002	0.40
year1997	0.004	0.76	0.001	0.22
year1998	-0.004	-0.76	-0.006	-1.11
year1999	-0.010	-2.31**	-0.013	-3.06***
N	8950 (668 observations left-censored at 0, 7447 observations uncensored, and 835 right-censored at 1).		6956 (121 observations left-censored at 0, 6500 observations uncensored, and 335 right-censored at 1.	

[a]STATA command *xttobit* is used here to exploit the panel data feature of our dataset.

[b]Z-statistics are calculated with bootstrap standard errors.

[c]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Table 14A: Descriptive Statistics

Sample of All-Line Reinsurance for Moral Hazard Test

Variables	Obs	Mean	Std. Dev.	Min	Max
Loss Ratio Ceded	8286	1.103	2.047	0	16.499
Loss Ratio Cededt-1	8286	0.692	0.563	0	3.808
All-Line Reinsurance	8286	0.323	0.285	0	0.976
External Reinsurance Ratio	8286	0.744	0.500	-18.960	19.329
Sustain	6993	0.658	0.373	0	1
Rherf	6993	0.472	0.306	0.018	1
Experience Ratingt-1	8286	1.570	0.868	0.651	7.114
Retention Limitt-1	8286	0.613	0.282	0.000	0.998
Firm size	8286	18.066	1.893	12.797	25.107
Firm premium growth rate	8286	0.141	0.483	-0.518	3.480
Leverage	8286	1.217	0.893	0.009	4.401
Tax rate	8286	0.294	0.708	-3.201	3.909
Mutual	8286	0.292	0.455	0	1
Direct	8286	0.202	0.402	0	1
Agency	8286	0.649	0.477	0	1
Rating1	8286	0.229	0.420	0	1
Rating2	8286	0.448	0.497	0	1
Rating3	8286	0.126	0.332	0	1
Rating4	8286	0.041	0.198	0	1
Long Tail Lines	8286	0.686	0.284	0	1
Product Herfindahl	8286	0.491	0.271	0.133	1
Geographic Herfindahl	8286	0.572	0.384	0.043	1
ROA	8286	0.029	0.046	-0.132	0.175
Age	8286	3.337	1.078	0	5.338
Lead Company	8218	0.454	0.498	0	1
Year	8286	1997.477	1.708	1995	2000

[a]The following variables are winsorized at the 1st and 99th percentiles: loss ratio ceded, loss ratio ceded$_{t-1}$, all-line reinsurance, experience rating$_{t-1}$, retention limit$_{t-1}$, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, and ROA.

Matching Estimators - All-Line Reinsurance

Table 14B-1: (Full Sample without SUSTAIN and RHERF)

Dependent Variable: Loss Ratio Ceded of All-Line Reinsurance

Loss Ratio Ceded	Coeff.	Std. Err.	Z	P > |Z|	[95% Confidence Interval]	
Sample Average Treatment Effect	0.032	0.018	1.730	0.084	-0.004	0.068
Number of Observations	8209			Number of Matches		4

Note: Treatment variable is group affiliation. Matching variables are external reinsurance ratio, loss ratio ceded$_{t-1}$, experience rating$_{t-1}$, retention limit$_{t-1}$, firm size, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, ROA, and lead company. STATA command *nnmatch* is used to estimate the sample average treatment effect, and the bias-corrected matching estimator and heteroskedasticity-consistent standard errors are used.

Table 14B-2: (Sample with SUSTAIN and RHERF)

Dependent Variable: Loss Ratio Ceded of All-Line Reinsurance

Loss Ratio Ceded	Coeff.	Std. Err.	Z	P > |Z|	[95% Confidence Interval]	
Sample Average Treatment Effect	0.022	0.019	1.170	0.240	-0.015	0.059
Number of Observations	6928			Number of Matches		4

Note: Treatment variable is group affiliation. Matching variables are external reinsurance ratio, loss ratio ceded$_{t-1}$, experience rating$_{t-1}$, retention limit$_{t-1}$, SUSTAIN, RHERF, firm size, firm premiums growth rate, leverage, tax rate, long-tail lines, product Herfindahl, geographic Herfindahl, ROA, and lead company. STATA command *nnmatch* is used to estimate the sample average treatment effect, and the bias-corrected matching estimator and heteroskedasticity-consistent standard errors are used.

Exogeneity Test for External All-Line Reinsurance Ratio

Table 14C: Fixed-effects GLS regression with robust standard errors

Dependent Variable: loss ratio ceded of all-line reinsurance

Independent Variables	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	0.226	0.36	0.358	0.46
External Reinsurance Ratio	-0.030	-0.51	0.005	0.09
Loss Ratio Ceded$_{t-1}$	-0.038	-0.81	-0.019	-0.39
Experience Rating$_{t-1}$	-0.027	-0.94	0.007	0.22
Retention Limit$_{t-1}$	0.087	1.33	0.117	1.67*
Sustain			-0.026	-0.92
Rherf			0.021	0.25
Firm size	0.034	1.03	0.027	0.66
Firm premium growth rate	-0.018	-0.92	-0.021	-1.15
Leverage	-0.006	-0.35	-0.024	-1.33
Tax rate	-0.007	-0.67	-0.007	-0.52
Long Tail Lines	-0.051	-0.37	-0.119	-0.89
Product Herfindahl	0.074	0.58	0.171	0.98
Geographic Herfindahl	-0.113	-0.95	-0.256	-1.75*
ROA	-1.391	-5.71***	-1.431	-5.19***
Lead Company	0.116	1.17	0.110	1.18
year1995	-0.104	-4.19***	-0.099	-3.17***
year1996	-0.079	-3.39***	-0.076	-2.72***
year1997	-0.114	-6.07***	-0.118	-5.26***
year1998	0.047	2.15**	0.057	2.28**
year1999	0.018	1.06	-0.003	-0.18
R^2 (within)	4.38%		4.61%	
N	5721		4547	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

Exogeneity Test for External All-Line Reinsurance Ratio

Table 14D: Fixed-effects GLS regression with robust standard errors

Dependent Variable: external all-line reinsurance ratio

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	0.600	1.70*	0.799	1.77*
Loss Ratio Ceded $_{t-1}$	-0.009	-1.34	-0.007	-0.87
Experience Rating $_{t-1}$	0.006	0.76	0.005	0.52
Retention Limit$_{t-1}$	0.160	4.86***	0.197	5.09***
Sustain			0.057	3.75***
Rherf			0.062	1.55
Firm size	-0.001	-0.04	-0.008	-0.32
Mutual	0.045	0.32	0.029	0.23
Direct	0.015	0.39	0.022	0.53
Agency	0.021	0.44	0.034	0.61
Rating1	-0.188	-4.23***	-0.187	-3.76***
Rating2	-0.160	-3.77***	-0.147	-3.19***
Rating3	-0.100	-2.42**	-0.092	-2.04**
Rating4	-0.100	-2.03**	-0.103	-2.07**
Age	-0.043	-2.31**	-0.068	-2.77***
Lead Company	0.076	1.24	0.094	1.61
R^2 (within)	4.29%		5.98%	
N	5721		4547	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

[c]The instrumental variables for *External All-Line Reinsurance Ratio* are mutual, direct, agency, A.M.Best's rating dummies, and age.

Exogeneity Test for External All-Line Reinsurance Ratio

Table 14E: Fixed-effects GLS regression with robust standard errors

Dependent Variable: loss ratio ceded of all-line reinsurance

	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	0.028	0.04	-0.175	-0.22
External Reinsurance Ratio	0.321	0.95	0.696	2.21**
Loss Ratio Ceded$_{t-1}$	-0.035	-0.74	-0.016	-0.32
Experience Rating$_{t-1}$	-0.029	-1.05	0.001	0.04
Retention Limit$_{t-1}$	0.029	0.36	-0.027	-0.28
Sustain			-0.064	-1.83*
Rherf			-0.025	-0.29
Firm size	0.039	1.19	0.045	1.09
Firm premium growth rate	-0.019	-0.95	-0.022	-1.21
Leverage	-0.008	-0.43	-0.028	-1.55
Tax rate	-0.007	-0.64	-0.007	-0.51
Long Tail Lines	-0.053	-0.38	-0.125	-0.94
Product Herfindahl	0.069	0.54	0.170	0.97
Geographic Herfindahl	-0.115	-0.97	-0.268	-1.83*
ROA	-1.394	-5.72***	-1.447	-5.24***
Lead Company	0.092	0.91	0.050	0.52
year1995	-0.110	-4.22***	-0.111	-3.45***
year1996	-0.084	-3.53***	-0.088	-3.06***
year1997	-0.119	-6.14***	-0.128	-5.58***
year1998	0.044	2.00**	0.050	2.01**
year1999	0.016	0.94	-0.008	-0.43
Residuals[c]	-0.358	-1.07	-0.704	-2.22**
R^2 (within)	4.42%		4.75%	
N	5721		4547	

[a]Z-statistics are calculated with White standard errors, which are corrected for cross-sectional heterogeneity.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.

[c]Residuals are the combined residuals from the fixed-effects GLS regression of *External All-Line Reinsurance Ratio* reported in Table 12D. If the coefficient on *Residuals* is not significant, we find evidence that *External All-Line Reinsurance Ratio* is exogenous in the fixed-effects GLS regression of *Loss Ratio Ceded*. This exogeneity test is used by Laffont and Matoussi (1995).

Table 14F: Test for Moral Hazard - All-Line Reinsurance

Two stage least squares for panel data models with bootstrap standard errors

Dependent Variable: loss ratio ceded of all-line reinsurance				
	Without SUSTAIN and RHERF		With SUSTAIN and RHERF	
Independent Variables	Coeff.	z-Stat	Coeff.	z-Stat
Intercept	-0.021	-0.03	-0.163	-0.18
External Reinsurance Ratio	0.377	0.95	0.769	1.98**
Loss Ratio Ceded$_{t-1}$	-0.034	-0.77	-0.016	-0.32
Experience Rating$_{t-1}$	-0.030	-0.82	-0.001	-0.04
Retention Limit$_{t-1}$	0.019	0.25	-0.043	-0.36
Sustain			-0.062	-2.01**
Rherf			-0.034	-0.36
Firm size	0.042	1.02	0.046	0.96
Firm premium growth rate	-0.009	-0.38	0.000	0
Leverage	-0.014	-0.68	-0.039	-1.88*
Tax rate	-0.007	-0.52	-0.003	-0.20
Long Tail Lines	-0.070	-0.45	-0.173	-1.06
Product Herfindahl	0.055	0.38	0.145	0.84
Geographic Herfindahl	-0.111	-0.88	-0.272	-1.79*
ROA	-1.286	-5.53***	-1.159	-4.26***
Lead Company	0.087	0.87	0.042	0.38
year1995	-0.115	-3.22***	-0.128	-3.24***
year1996	-0.084	-2.83***	-0.090	-2.57***
year1997	-0.114	-4.88***	-0.116	-4.03***
year1998	0.048	1.95*	0.061	2.68***
year1999	0.018	0.90	-0.003	-0.14
R^2 (within)	2.22%			
N	5721		4547	
Instrumented:	external reinsurance ratio			
Instuments:	mutual, direct, agency, age, and rating dummies.			

[a]Z-statistics are calculated with bootstrap standard errors.

[b]***Significant at 1% level; **significant at 5% level; *significant at 10% level.