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

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Outline

- Introduction and Motivation
- Overview of Results
- Related Literature
- Theory
- Empirical Tests
- Conclusion

Introduction and Motivation

- Very few papers examine the adverse selection and moral hazard problems simultaneously.
  - Stewart (1994)
  - Chassagnon and Chiappori (1997)
- Very few papers investigate empirically the adverse selection and moral hazard problems in reinsurance markets.
  - Doherty and Smetters (2005)
  - Garven and Grace (2007)

Introduction and Motivation

- Catastrophic events in recent years reinforce the importance of reinsurance markets:
  - Gross reinsurance premiums ceded by North American insurers increased dramatically from 41.7 billion in 1995 to 98.7 billion dollars in 2005. (Sources: Swiss Re)
  - In 2006, property and liability insurers ceded 492 billion dollars premiums. (Source: the NAIC)

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Purposes

- Build a principal-agent model to examine the adverse selection and moral hazard problems jointly, and characterize the separating Nash equilibria;
- Investigate the existence of the adverse selection and moral hazard problems in reinsurance markets.

Overview of Results

- In the simultaneous presence of adverse selection and moral hazard, we find that
  - there are several forms of separating Nash equilibria
  - separating Nash equilibria may not exist
  - the moral hazard problem dominates
  - no agent is offered full coverage
  - the positive correlation property between insurance coverage and risk types of agents still holds

Overview of Results

- Empirical findings in reinsurance markets
  - Existence of adverse selection and moral hazard;
  - Experience rating is effective in controlling both adverse selection and moral hazard,
  - Long-term contracting relationship is effective in controlling both adverse selection and moral hazard
  - Monitoring is not an effective way in mitigating the moral hazard problem.

Related Literature

- Theoretical Literature
  - Stewart (1994)
    - Agents with identical continuous loss probability function;
    - Agents differ in their cost of self-protection;
    - Riley's reactive equilibria are derived.
  - Chassagnon and Chiappori (1997)
    - Agents with discrete loss probability function;
    - Rothschild and Stiglitz's Nash equilibria are characterized;
    - The existence conditions of equilibrium are derived.

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Related Literature

- Empirical Literature
  - Doherty and Smetters (2005)
    - Run a regression of reinsurance price;
    - Find evidence of moral hazard;
    - Price incentive used by both affiliates and non-affiliates;
    - Monitoring mainly used by affiliates.
  - Garven and Grace (2007)
    - Test implications of a adverse selection model;
    - Empirical findings largely consistent.

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A Principal-Agent Model

- The Model Framework
  - Risk-averse agents and risk-neutral principals in a competitive market;
  - Two types of agents, $\theta \in \{\underline{\theta},\ \overline{\theta}\}$;
  - Concave utility function u(·) separable in wealth and effort;
  - Binary effort level, $e \in \{0,\ 1\}$, with cost of effort $\psi(e)$;

A Principal-Agent Model

- The Model Framework (cont.)
  - Discrete loss probability function $1-\pi(\theta,\ e)$,

    with $\pi(\underline{\theta},\ e) > \pi(\bar{\theta},\ e)$ for every $e \in \{0,\ 1\}$, and $\pi(\underline{\theta},\ 0) \neq \pi(\bar{\theta},\ 1)$;
  - Agents' initial wealth is *W*, and the loss severity is *L*, with *W*>*L*;
  - *L* is large enough such that principals induce effort;
  - The high risk agent is more efficient in expending effort, that is,

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

A Principal-Agent Model

- Denote by $(\overline{P}, \overline{I})$ and $(\underline{P}, \underline{I})$ the optimal contracts;
- The mathematical techniques to derive optimal contracts
  - the change-of-variable method by Laffont and Martimort (2002);

$$\overline{u}_a \equiv u(W - L + \overline{I}),\ \overline{u}_n \equiv u(W - \overline{P}),$$
$$\underline{u}_a \equiv u(W - L + \underline{I}),\ \underline{u}_n \equiv u(W - \underline{P});$$

  - The Kuhn-Tucker conditions.

Proposition 1

In a competitive reinsurance market with the simultaneous presence of adverse selection and moral hazard, there are several forms of Nash equilibria:

- Pure Adverse Selection
- Pure Moral Hazard
- Strong Adverse Selection
- Strong Moral Hazard
- Local Asymmetric Information

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, the high risk agent is offered a larger amount of coverage at a higher unitary price.

Testable Hypotheses

- Testable Hypothesis of Adverse Selection

  Everything else equal, high risk primary insurers purchase a larger amount of reinsurance.

- Testable Hypothesis of Moral Hazard

  Everything else equal, primary insurers with internal reinsurance coverage have more favorable loss experience.

Empirical Strategy

- Test for Adverse Selection
  - Test the positive correlation property
  - Dependent Variable: net amount of reinsurance ceded
  - Key independent variable: risk measure
    - Loss Ratio Volatility
    - Loss Reserve Error / Loss Forecast Revision

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Summary of Hypothesis for Adverse Selection

H_0: high risk insurers purchase more reinsurance.

Variable	Impact on REIN	Definition
Future loss ratio volatility	+	The volatility of future loss ratio of direct and assumed business
Loss reserve error	+	(Developed incurred losses at of year t+5 – reported incurred losses in year t) / reported incurred losses in year t
Experience Rating	+	Lag of total premiums earned / lag of total losses incurred
Retention Limit	–	Lag of retained losses / lag of total losses
SUSTAIN	+ / –	Percentage of premiums ceded over a three-year period to external reinsurers present in all three years
RHERF	+ / –	Herfindahl index of reinsurance premiums ceded to external reinsurers

Empirical Test for Adverse Selection

- The Random Effects Model on Panel Data

$$\text{REINS}_{i,t} = \alpha + \beta_1 \text{RISK}_{i,t} + \beta_2 (\text{Experience Rating})_{\text{i,t-1}}$$
$$+\beta_3 (\text{Retention Limit})_{\text{i,t-1}} + \beta_4 \text{Sustain}_{\text{i,t}} + \beta_5 \text{Rherf}_{\text{i,t}} + \sum \gamma \text{X}_{\text{i,t}} + \varepsilon_{\text{i,t}}$$

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Empirical Results for Adverse Selection – Auto Liability

Dependent variable: net amount of auto liability reinsurance				
Econometric specifications:	Model 1	Model 2	Model 3	Model 4
	coefficient	coefficient	coefficient	coefficient
Loss ratio volatility	0.017		0.052	
Loss reserve error		**0.056****		**0.055***
Experience rating $_{t-1}$	0.012	0.009	0.028	0.021
Retention limit $_{t-1}$	**-0.279*****	**-0.284*****	**-0.329*****	**-0.330*****
SUSTAIN			-0.013	-0.012
RHERF			-0.004	-0.008
R^2	30.11%	30.40%	37.39%	37.58%
N	2420	2420	1958	1958
a) ***significant at 1% level; **significant at 5% level; *significant at 10% level.				
b) Random effects GLS regression with robust standard errors.				

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Empirical Results for Adverse Selection – Homeowners

Dependent variable: net amount of homeowners reinsurance				
Econometric specifications:	Model 1	Model 2	Model 3	Model 4
	coefficient	coefficient	coefficient	coefficient
Loss ratio volatility	0.022		**0.038****	
Loss reserve error		**0.038****		0.015
Experience rating $_{t-1}$	**0.018****	**0.016***	**0.025****	**0.022*****
Retention limit $_{t-1}$	**-0.206*****	**-0.209*****	**-0.236*****	**-0.235*****
SUSTAIN			-0.008	-0.007
RHERF			0.021	0.021
R^2 N	26.82% 2211	26.58% 2205	26.17% 1812	25.62% 1806

a) ***significant at 1% level; **significant at 5% level; *significant at 10% level.
b) Random effects GLS regression with robust standard errors.

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Empirical Results for Adverse Selection – Product Liability

Dependent variable: net amount of product liability reinsurance				
Econometric specifications:	Model 1	Model 2	Model 3	Model 4
	coefficient	coefficient	coefficient	coefficient
Loss ratio volatility	0.000		-0.051	
Loss reserve error		0.003		-0.004
Experience rating $_{t-1}$	0.002	0.001	0.000	0.002
Retention limit $_{t-1}$	**-0.293*****	**-0.304*****	**-0.311*****	**-0.321*****
SUSTAIN			-0.038	-0.031
RHERF			-0.078	-0.067
R^2	30.02%	30.00%	36.48%	36.81%
N	638	638	492	492
a) ***significant at 1% level; **significant at 5% level; *significant at 10% level. b) Random effects GLS regression with robust standard errors.				

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Empirical Strategies

- Test for Moral Hazard
  - coexistence of internal and external reinsurance;
  - test for the higher degree of the moral hazard problem in external reinsurance markets;
  - Dependent variable: loss ratio of ceded reinsurance;
  - Key independent variable: external reinsurance ratio.

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Summary of Hypothesis for Moral Hazard

H_0: the moral hazard problem is more severe in external reinsurance markets than in internal reinsurance markets.

Variable	Impact on *Loss Ratio Ceded*	Definition
External Reinsurance Ratio	+	The ratio of external reinsurance premiums ceded to total reinsurance premiums ceded
Experience Rating	+	Lag of total premiums earned / lag of total losses incurred
Retention Limit	+	Lag of retained losses / lag of total losses
SUSTAIN	–	Percentage of premiums ceded over a three-year period to external reinsurers present in all three years
RHERF	–	Herfindahl index of reinsurance premiums ceded to external reinsurers

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Empirical Tests for Moral Hazard

- Matching Estimators Methodology
  - Denote by $Y_i(0)$ the outcome obtained if under the control group;
  - Denote by $Y_i(1)$ the outcome obtained if under the treatment group;
  - For each i, we can observe either $Y_i(0)$ or $Y_i(1)$;

Empirical Tests for Moral Hazard

- Matching Estimators Methodology (cont.)
  - For each i, find the closest matches in the opposite group by matching covariates X;
  - Estimate the unobserved potential outcome for each i by using the average outcomes of these closest matches;
  - Calculate the sample average treatment effect (SATE):

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

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Empirical Tests for Moral Hazard

- Matching Estimators Method
  - Dependent variable is *Loss Ratio Ceded*;
  - Treatment variable is *group affiliation*;
  - Non-affiliated insurers as control group;
  - Affiliated insurers as treatment group;

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Empirical Results of Matching Estimators – Auto Liability

Dependent Variable: Loss Ratio Ceded of Auto Liability Reinsurance (Full sample without SUSTAIN and RHERF)				
Loss ratio ceded	Coefficient	Std. Err.	Z	P>|Z|
Sample average treatment effect	1.136	0.135	8.420	0.000
Number of observations	2512	Number of matches		4

Dependent Variable: Loss Ratio Ceded of Auto Liability Reinsurance (Sample with SUSTAIN and RHERF)				
Loss ratio ceded	Coefficient	Std. Err.	Z	P>|Z|
Sample average treatment effect	0.815	0.127	6.420	0.000
Number of observations	2050	Number of matches		4

Empirical Results of Matching Estimators – Homeowners

Dependent Variable: Loss Ratio Ceded of Homeowners Reinsurance (Full sample without SUSTAIN and RHERF)				
Loss ratio ceded	Coefficient	Std. Err.	Z	P>|Z|
Sample average treatment effect	0.092	0.073	1.260	0.208
Number of observations	2465	Number of matches		4

Dependent Variable: Loss Ratio Ceded of Homeowners Reinsurance (Sample with SUSTAIN and RHERF)				
Loss ratio ceded	Coefficient	Std. Err.	Z	P>|Z|
Sample average treatment effect	0.287	0.072	4.000	0.000
Number of observations	1999	Number of matches		4

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Empirical Tests for Moral Hazard

- The Random Effects Model on Panel Data

$$\begin{aligned}(\text{Loss Ratio Ceded})_{it} = \alpha + \beta_1 (\text{External Reinsurance Ratio})_{it} \\ + \beta_2 (\text{Experience Rating})_{it} + \beta_3 (\text{Retention Limit})_{it} \\ + \beta_4 \text{Sustain}_{it} + \beta_5 \text{Rherf}_{it} + \sum \gamma \text{X}_{it} + \varepsilon_{it}\end{aligned}$$

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Empirical Results for Moral Hazard – Auto Liability

Dependent variable: loss ratio ceded of auto liability reinsurance		
Econometric specifications:	Model 1	Model 2
	coefficient	coefficient
External Reinsurance Ratio	-0.149	-0.130
Loss ratio ceded $_{t-1}$	**0.567*** **	**0.355** **
Experience rating $_{t-1}$	**1.510*** **	0.916
Retention limit $_{t-1}$	**1.560*** **	**1.181** **
SUSTAIN		-0.526
RHERF		0.338
R^2 N	12.16% 2121	7.66% 1661
a) ***significant at 1% level; **significant at 5% level; *significant at 10% level. b) Random effects GLS regression with robust standard errors.		

Empirical Results for Moral Hazard – Homeowners

Dependent variable: loss ratio ceded of homeowners reinsurance		
Econometric specifications:	Model 1	Model 2
	coefficient	coefficient
External Reinsurance Ratio	-0.114	-0.158
Loss ratio ceded $_{t-1}$	-0.014	-0.023
Experience rating $_{t-1}$	**-0.328*** **	**-0.371*** **
Retention limit $_{t-1}$	**0.564*** **	**0.709*** **
SUSTAIN		0.088
RHERF		-0.082
R^2	9.04%	10.34%
N	1865	1403
a) ***significant at 1% level; **significant at 5% level; *significant at 10% level. b) Random effects GLS regression with robust standard errors.		

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Empirical Results for Moral Hazard – Product Liability

Dependent variable: loss ratio ceded of product liability reinsurance		
Econometric specifications:	Model 1	Model 2
	coefficient	coefficient
External Reinsurance Ratio	-0.344	0.049
Loss ratio ceded $_{t-1}$	**0.338*** **	0.176
Experience rating $_{t-1}$	0.082	0.080
Retention limit $_{t-1}$	**2.040*** **	0.575
SUSTAIN		0.322
RHERF		**-1.233***
R^2	12.96%	11.42%
N	789	563

a) ***significant at 1% level; **significant at 5% level; *significant at 10% level.
b) Random effects GLS regression with robust standard errors.

Exogeneity Test on External Reinsurance Ratio

- Test design (Laffont and Matoussi, 1995)
  - Step 1: run the first regression,

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

  - Step 2:run the second regression,

$$(\text{External Reinsurance Ratio})_{it} = \alpha + \beta Z_{it} + \sum \gamma (X1)_{it} + \text{Residuals}_{it}$$

Exogeneity Test on External Reinsurance Ratio

- Test design (cont.)
  - Step 3: run the third regression,

$$(\text{Loss Ratio Ceded})_{\text{it}} = \alpha+\beta(\text{External Reinsurance Ratio})_{\text{it}} + \sum \gamma \text{X}_{\text{it}} + \lambda \text{Residuals}_{\text{it}} + \upsilon_{\text{it}}$$

  - Step 4: if Residuals in the third regression insignificant, then External Reinsurance Ratio is exogenous to the dependent variable.

Empirical Results of Exogeneity Tests

Dependent variable: loss ratio ceded of auto liability reinsurance				
Independent variable	Sample without SUSTAIN and RHERF		Sample with SUSTAIN and RHERF	
	Coefficient	z-Stat	Coefficient	z-Stat
Residuals	0.959	1.30	-0.023	-0.02

Dependent variable: loss ratio ceded of homeowners reinsurance				
Independent variable	Sample without SUSTAIN and RHERF		Sample with SUSTAIN and RHERF	
	Coefficient	z-Stat	Coefficient	z-Stat
Residuals	-0.113	-0.44	0.149	0.36

Dependent variable: loss ratio ceded of product liability reinsurance				
Independent variable	Sample without SUSTAIN and RHERF		Sample with SUSTAIN and RHERF	
	Coefficient	z-Stat	Coefficient	z-Stat
Residuals	0.559	0.35	2.397	1.06

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Conclusions

- In the simultaneous presence of adverse selection and moral hazard, we find
  - there are several forms of separating Nash equilibria;
  - separating Nash equilibria may not exist;
  - the moral hazard problem dominates
  - the positive correlation property holds;
- Both adverse selection and moral hazard are present in the private passenger auto liability reinsurance market, but not present in the homeowners and product liability reinsurance markets;

Conclusions

- Experience rating is effective in controlling both adverse selection and moral hazard, especially in mitigating the adverse selection problem in the homeowners reinsurance market;
- Long-term contracting relationship is effective in controlling both adverse selection and moral hazard, especially in reducing the moral hazard problem in the product liability reinsurance market;
- Monitoring is not an effective way in mitigating the moral hazard problem.

Proposed Research

- Theoretical Study
  - Conduct comparative studies on the equilibrium contracts;
  - Establish a more solid link between theoretical model and empirical work
- Empirical Study
  - Conduct robust tests using firm-level data;
  - Include the effect of heterogeneous state regulations into our regression models.

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