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MORAL HAZARD IN REINSURANCE MARKETS

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ABSTRACT

This paper attempts to identify moral hazard in the traditional reinsurance market. We build a multi-period principle agent model of the reinsurance transaction from which we derive predictions on premium design, monitoring, loss control and insurer risk retention. We then use panel data on U.S. property liability reinsurance to test the model. The empirical results are consistent with the model's predictions. In particular, we find evidence for the use of loss sensitive premiums when the insurer and reinsurer are not affiliates (i.e., not part of the same financial group), but little or no use of monitoring. In contrast, we find evidence for the use of monitoring when the insurer and reinsurer are affiliates, where monitoring costs are lower, but little use of price controls.

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I. Introduction

Insurance companies whose book of business is exposed to high risk, such as hurricane or earthquake losses or class action product liability lawsuits, have traditionally hedged the right tail of this exposure through reinsurance. Like primary insurance, reinsurance contracts encounter moral hazard. It is costly for the reinsurer to monitor the underwriting activities of the primary insurer and how the latter settles claims with its own policyholders. Consequently, reinsurance relaxes incentive for the primary to engage in careful underwriting and loss mitigation activities. This problem can be especially severe after a natural catastrophe where the primary insurer is overwhelmed with flood or earthquake claims, and is able to pass on the cost of settlements to the reinsurer.

Traditional reinsurance includes price controls against moral hazard, including deductibles, copayments, and "*ex-post* settling up" which is a retrospective adjustment of the premium based on losses incurred during the policy period, known as "retrospective rating." Less formal and longer-term controls are also in place. Reinsurance is usually conducted as a long-term relationship. Experience bonds parties together and increases the cost of opportunistic behavior. The primary insurer gets continuity of access to reinsurance while the reinsurer can use the relationship's duration to increase the effectiveness of its monitoring, and can use experience to set future prices and terms.[1]

Controlling moral hazard via long-term relationships can be costly. Froot and O'Connell (1997) have documented the costs of catastrophe reinsurance and show that the ratio of premium to expected loss increases dramatically at higher layers of coverage (i.e. for reinsurance in the right hand tail of the loss distribution). Since moral hazard will increase in intensity the greater the level of reinsurance, this pricing pattern is quite consistent with moral hazard. Moreover, the shear size

[1]See Allen and Gale (1997) for variations of the role of long term relationships in financial intermediation.

of these premium loading suggests that addressing moral hazard in this way is expensive.[2] These large premium loads are relevant today as both insured property and claims have increased significantly the past few decades.[3]

Monitoring can also redress moral hazard.[4] Williamson (1985) argued that, whereas markets use price incentives to resolve agency conflicts between separate organizations, monitoring can be a more efficient way to resolve conflicts within organizations where there is greater access to information. This idea has been developed into models of vertical integration by Riordan (1990*a*,*b*) and Cremer (1993, 1995). These papers show that for transactions within firms, where monitoring is relatively cheap, more emphasis should be placed on monitoring and less on contractual incentives. The opposite is true for transactions between firms where monitoring costs are higher.

In the last few years, insurers have begun to use new hedge instruments in which tail risk is transferred directly to investors. These instruments, known as "insurance-linked securities," include catastrophe bonds, cat options and cat equity puts. The normal rationale for securitizing this risk, instead of transferring it with reinsurance, is that very large losses can be absorbed much easier in a multi-trillion dollar capital market than in a multi-billion dollar insurance market, especially as

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[2] Another explanation for Froot and O'Connell's result is that, since the tail is thin, the coefficient of variation for high levels of coverage is high and therefore reinsurers are extracting an appropriate risk premium. But this explanation does not fit well with the portfolio theory. If this risk is of low beta as they show, then why the risk premium? To support this explanation, one would need to show, not that the coefficient of variation was high for high layers *contracts*, but that such contracts greatly increased the *portfolio* risk of the reinsurer.

[3] Until the late 1980s, insured catastrophic losses were typically not very large. The only category five hurricane to hit the United States in the 20th century was hurricane Camille in August, 1969. It scored a 6.3 "PCS Index Settlement Value" as calculated by the Chicago Board of Trade (1995) where Property Claim Services cat options began trading in 1994. This index corresponds to $630 million in insured losses in 1994 dollars. The actual insured losses were even less than this amount but the CBOT, in creating a simulated index value for historical losses, adjusted the number upward for population growth between 1969 and 1994. In sharp contrast, hurricane Andrew of August 1992, scored a significant 173.2, or $17.32 billion in 1994 dollars. Earthquake losses in previous years have also increased as more residential and commercial development takes place in higher-risk land as the population size grows.

[4] See Bond and Crocker (1997) and Crocker and Morgan (1998) for insurance models.

these risks tend not to be highly correlated with market returns (low beta).[5]

But another explanation for securitizing insurance risk is that is has introduced new controls for moral hazard. Whereas reinsurance is normally an indemnity-based contract tied to the primary insurer's specific losses, the payoff of insurance-linked securities are typically tied to an index or parameter that is outside of the primary insurer's direct control, thus reducing moral hazard. For example, an "index trigger" cat security, such as cat options traded on the CBOT and cat bonds, link the payout to an index of aggregate losses across many insurers. "Parametric triggers" securities link a payout to a physical description of disaster (e.g., intensity of the earthquake).[6] Both of these trigger mechanisms are, in effect, "*instrument variables"* for the insurer's losses since they are intended to be highly correlated with the insurer's losses but are outside the insurer's control.[7]

This paper focuses on the moral hazard in the reinsurance market which we believe might help to explain the emergence of securitized insurance instruments. The idea that insurance – and, by extension, reinsurance – might lead to moral hazard is, of course, not new. This paper, however, provides empirical evidence of moral hazard in the reinsurance market. We test to see if reinsurers control for moral hazard either by using loss sensitive future premiums and/or by monitoring.

We not only find evidence for moral hazard in the reinsurance market, we also find that the methods that reinsurers use to address moral hazard across types of business relationships are

[5] Chicago Board of Trade (1995, Chapter 6).

[6] For example, in a recent bond issued on behalf of the Tokyo Fire and Marine Insurance company, the payout is related to the intensity and location of an earthquake. Sometimes "modeled" triggers are used as well which base the payout on the output of a simulation model which uses parametric inputs.

[7] To be sure, since any one firm's losses are less than perfectly correlated with the index, the insurer that purchases the security now faces some "basis risk" in exchange for less moral hazard inefficiency. However, the basis risk goes to zero as the insurer's portfolio mix of losses approaches that of the market, or, in the case of parametric triggers, if historic correlations between losses and parameters continue to hold. Cummins, Lalonde, and Phillips (1999) demonstrates that the basis risk is typically very small empirically. Doherty (2000) analytically derives a firm's basis risk as a function of its portfolio composition and market share.

consistent with the principal-agent model. In particular, we find strong evidence for the use of loss sensitive premiums when the insurer and reinsurer are not affiliates (i.e., not part of the same financial group) but little or no use of monitoring. In contrast, we find strong evidence for the use of monitoring when the insurer and reinsurer are affiliates but little use of price controls. Since monitoring is relatively cheap among affiliates, the model predicts that monitoring is more likely to be used when the contracting parties are related.

Section II develops our model. Section III derives an estimating equation from the model and tests it on a panel data set we have put together by combining Best's and National Association of Insurance Commissioners data. Section IV concludes.

II. A Principal Agent Model of Reinsurance

We develop a two-period principle-agent model with three risk-sharing mechanisms: a deductible, retrospective rating and experience rating.[8] Retrospective rating adjusts the insurance premium that is paid over one period for losses in the same period. Experience rating adjusts premiums based on losses in *previous* periods. We also include monitoring. With costless monitoring, the first-best solution could be attained. But, in reality, monitoring is presumably more costly between non-affiliates than between affiliates.

The existence of reinsurance requires that even a publically-held primary insurer is averse to risk in its loss portfolio. An large literature shows how the value of a firm is affected by the riskiness of its cash flows. More risk raises the costs of financial distress, enhances agency problems between the main stakeholders and can lead to under-investment in new projects when external capital is costly.[9] Since these costs increase with risk, the firm's value function is concave, as shown

[8] Co-insurance, where only a fraction of the loss is indemnified, is equivalent to retrospective rating.

[9] See Smith and Stulz (1985), Froot, Scharfstein and Stein (1992), Tufano (1996) and Doherty (2000).

by Greenwald and Stiglitz, 1990.

Moreover, reinsurance can be efficient only if the cost of risk bearing to the reinsurer is less than cost to the primary insurer, a condition that can be met if the reinsurer is more diversified. For example, insurance of natural catastrophes is often undertaken by regional or national primary insurers and reinsured by national or international reinsurance firms. Since correlations between catastrophes in different parts of the world are low, the reinsurer can provide coverage to primaries operating in many different locations. Reinsurance exploits comparative advantage in diversification by re-assigning risk between parties for whom the costs of bearing risk differ (Borch, 1962). This transaction can be captured with a risk-averse primary insurer and a risk-neutral reinsurer, an approach taken in most modern reinsurance models. In the next sub section, we present a standard principal agent model. However, while the basic model is unoriginal (and we do not go through complete proofs), we have added detail on the types of moral hazard controls in order to draw out the empirical predictions.

The Primary (Ceding) Insurer's Problem

The primary insurer in period t, $t \in \{1,2\}$, has a value W_t, given its direct insurance portfolio. W_t does not reflect any reinsurance transactions or any actions taken to control aggregate loss claims. In period t, the primary insurer chooses action a_t that affects the probability distribution over its aggregate losses, L_t. Action a_t can be a property inspection, offering financial incentives to policyholders to mitigate risk, or a more economical settlement of claims. The mean of L_t is decreasing in a_t. The choice of a_t also generates a signal m that is imperfectly correlated with a, but still conveys valuable information to the reinsurer. The primary insurer pays a premium P_t to the reinsurer for a reinsurance contract that is subject to a deductible (or "stop loss") of S_t. Under this contract, the reinsurer compensates the primary insurer in period t for $max[0, L_t - S_t]$. Let $f(m, L \mid$

a) be the joint probability density of event $\{m, L\}$, conditional on a.

The first-year reinsurance premium is a function of the loss during this period (retrospective rating), the deductible and the signal: $P_1(\cdot) = P_1(L_1, S_1, m_1)$. The second-year premium depends on the second-year coverage signal and loss but also depends on losses during the first year (experience rating): $P_2(\cdot) = P_2(L_1, L_2, S_2, m_2)$.

In any period t, the primary's wealth is $W_t - P_t - L_t$ if the loss, L_t, is below the deductible, S_t, and $W_t - P_t - S_t$ if L_t exceeds S_t. Assuming a zero risk-free rate to reduce notation, the primary (ceding) insurer's expected utility is,

(1)

$$
\begin{aligned}
C = &\int \int_0^{S1} U_1\left[W_1 - P_1\left(L_1;S_1;m_1\right) - L_1\right] f\left(m_1, L_1 | a_1\right) dL_1 dm_1 \\
&+ \int \int_{S1}^{\infty} U_1\left[W_1 - P_1\left(L_1;S_1;m_1\right) - S_1\right] f\left(m_1, L_1 | a_1\right) dL_1 dm_1 - a_1 \\
&+ \int \int \left\{ \int \int_0^{S2} U_2\left[W_2 - P_2\left(L_1;L_2;S_2;m_2\right) - L_2\right] f\left(m_2, L_2 | a_2(L_1)\right) dL_2 dm_2 - a_2(L_1) \right\} f\left(m_1, L_1 | a_1\right) dL_1 dm_1 \\
&+ \int \int \left\{ \int \int_{S2}^{\infty} U_2\left[W_2 - P_2\left(L_1;L_2;S_2;m_2\right) - S_2\right] f\left(m_2, L_2 | a_2(L_1)\right) dL_2 dm_2 - a_2(L_1) \right\} f\left(m_1, L_1 | a_1\right) dL_1 dm_1
\end{aligned}
$$

The primary insurer picks the level of effort in the first period, a_1, and the policy function for the level of effort in the second period, $a_2(L_1)$, to maximize its expected utility, C. Representing the primary insurer's problem in equation (1) as a concave programming problem reflects the assumption of risk aversion, discussed above, that motivates the presence of reinsurance.

<u>The Re-Insurer's Problem</u>

The reinsurer incurs a monitoring cost of c and we assume that organizational features makes this cost fixed per reinsurance contract but different between firms. In particular, c is high for reinsurance transactions between unrelated insurers and low for reinsurance between members of the same corporate family (see Williamson 1985, Riordan 1990*a*,*b*, and Cremer 1993, 1995). This discrete structure highlights the dichotomous effects of organization structure on contract design.

The reinsurer picks premium functions in years 1 and 2, $P_1(\cdot)$ and $P_2(\cdot)$, to maximize total profit. The reinsurer's contract income, written in period *t*, is the difference between premiums, P_t, and losses, L_t, in excess of the deductible S_t, less monitoring costs in period *t* ($t = 1,2$):

(2)

$$
\begin{aligned}
R = &\int \int_0^{S1} P_1(L_1;S_1;m_1) f(m_1, L_1|a_1) dL_1 dm_1 \\
&+ \int \int_{S1}^{\infty} \left[P_1(L_1;S_1;m_1) - L_1 + S_1\right] f(m_1, L_1|a_1) dL_1 dm_1 \\
&+ \int \int \int \int_0^{S2} P_2(L_1;L_2;S_2;m_2) f(m_2, L_2|a_2(L_1)) f(m_1, L_1|a_1) dL_2 dL_1 dm_2 dm_1 \\
&+ \int \int \int \int_{S2}^{\infty} \left[P_2(L_1;L_2;S_2;m_2) - L_2 + S_2\right] f(m_2, L_2|a_2(L_1)) f(m_1, L_1|a_1) dL_2 dL_1 dm_2 dm_1 \\
&- c_1 - c_2
\end{aligned}
$$

The optimality problem can now be expressed in the normal form:

$$\max_{P_1, P_2, a_1, a_2} R$$

subject to

(3) $$C \geq \hat{C}$$

(4) $$\partial C / \partial a_1 = 0$$

(5) $$\partial C / \partial a_2 = 0$$

where $\hat{C}$ is the primary insurer's "reservation" expected utility that they would have without reinsurance. Equation (3) is the "participation" constraint that ensures that the reinsurance contract,

$\{P_1(\cdot), P_2(\cdot), S_1, S_2\}$, is purchased by the primary insurer. Equations (4) and (5) are the "incentive compatibility constraints" that ensures that the hidden actions, a_t, maximizes the primary insurer's expected utility.[10]

To solve the system of equations (2) - (5), it is quite natural to make use of the special case of Holmstrom (1979) in which the monitoring signal, m, is independent of the loss L.[11] Thus, the joint density can be written as $f(m, L|a) = g(m|a)\, h(L|a)$. Let λ, μ_1 and μ_2 denote the Lagrangian multipliers for constraints (3) through (5). The optimality conditions are obtained using calculus of variations, which in our case, reduce to the following first-order conditions on the integrand:

$$\text{(6)} \qquad \frac{1}{U'(W_1 - P_1 - L_1)} = \lambda + \mu_1 \left(\frac{g'(m_1|a_1)}{g(m_1|a_1)} + \frac{h'(L_1|a_1)}{h(L_1|a_1)} \right) \quad : \quad \text{if } L_1 < S_1$$

$$\text{(7)} \qquad \frac{1}{U'(W_1 - P_1 - S_1)} = \lambda + \mu_1 \left(\frac{g'(m_1|a_1)}{g(m_1|a_1)} + \frac{h'(L_1|a_1)}{h(L_1|a_1)} \right) \quad : \quad \text{if } L_1 \geq S_1$$

$$\text{(8)} \qquad \frac{1}{U'(W_2 - P_2 - L_2)} = \lambda + \mu_1 \left(\frac{g'(m_1|a_1)}{g(m_1|a_1)} + \frac{h'(L_1|a_1)}{h(L_1|a_1)} \right) + \mu_2(L_1) \left(\frac{g'(m_2|a_2)}{g(m_1|a_1)\, g(m_2|a_2)} + \frac{h'(L_2|a_2)}{h(L_1|a_1)\, h(L_2|a_2)} \right) \quad : \quad \text{if } L_2 < S_2$$

$$\text{(9)} \qquad \frac{1}{U'(W_2 - P_2 - S_2)} = \lambda + \mu_1 \left(\frac{g'(m_1|a_1)}{g(m_1|a_1)} + \frac{h'(L_1|a_1)}{h(L_1|a_1)} \right) + \mu_2(L_1) \left(\frac{g'(m_2|a_2)}{g(m_1|a_1)\, g(m_2|a_2)} + \frac{h'(L_2|a_2)}{h(L_1|a_1)\, h(L_2|a_2)} \right) \quad : \quad \text{if } L_2 \geq S_2$$

---

[10] The regularity conditions required to directly use the first-order conditions of the incentive compatibility constraint are discussed in Jewitt (1988).

[11] The independence assumption is standard in the literature and is not restrictive. Recall that the premium paid in any period is already a function of the loss, L, in that period and previous periods. Hence, the value of the second signal, m, arises from its ability to convey *additional* information about the action a that is not already revealed by L.

where $g'(m|a)$ and $h'(L|a)$ are the derivatives of $g(\bullet)$ and $h(\bullet)$ with respect to the action a.

If the reinsurer monitors, it pays the fixed cost in both periods and receives some information about the hidden action, a, of the primary insurer ($c_1 > 0; c_2 > 0$; $m > 0$). If, however, the reinsurer chooses not to monitor then it does not pay the fixed costs and it does not receive any information about the action, a, other than information which can be inferred from the loss realization, L, itself ($c_1 = c_2 = 0$; $m = 0$). The reinsurer chooses to monitor in each period if its profit is higher than without monitoring, i.e., $R_t\left(P_t^m; a_t^m; c_t\right) > R_t\left(P_t^0; a_t^0; c_t\right)$. Affiliated primary insurers and reinsurers (i.e., part of the same financial group) will tend to face lower monitoring costs, c_1 and c_2, and are, therefore, more likely to monitor. The monitoring costs for non-affiliates will tend to be higher, resulting in less use of monitoring.

<u>The Premium Structure Implied by the First-Order Conditions</u>

Equations (6) - (9) implicitly define the optimal premium policy functions used by the reinsurer. But we need to add some additional minimal structure to derive some testable predictions. We use of the standard regularity assumption on the likelihood ratios, as in, e.g., Lambert (1984).

Assumption. (i) $h'(L_1|a_1) / h(L_1|a_1)$ is decreasing in L_1.

(ii) $h'(L_2|a_2) \big/ h(L_1|a_1) \cdot h(L_2|a_2)$ is decreasing in L_2.

These assumptions imply that the Lagrangian multipliers λ, μ_1 and $\mu_2(L_1)$ are positive; see Lambert.

Equations 6 through 9 reveal a two-tier risk-sharing structure. In each period, the premium depends on whether the loss exceeds the deductible (equations 7 and 9) or not (equations 6 and 8). The model yields predictions on price incentives and the use of monitoring to control moral hazard.

Loss sensitive premiums. The model predicts that the price of reinsurance is sensitive to concurrent reinsurance losses and to the prior period's losses total and reinsured losses.

Retrospective Rating. Consider equations 6 and 7 for period one. If the loss is below the deductible (equation 6), the premium must be set so that the primary insurer's marginal utility is increasing (i.e., wealth decreasing) in L. Since the primary's marginal utility depends directly on L (L is below the deductible), this condition can be satisfied with a constant premium. This is not to say the premium should be held constant. Rather, the condition does not require that the premium be retrospectively adjusted to losses because the reinsurer is not exposed to losses below the deductible. More restrictions on $g(\cdot)$ and $h(\cdot)$ are needed to determine if the optimal premium should be held constant or not. For losses above the deductible (equation 7), the primary's marginal utility must again increase (wealth decrease) with losses. Since the premium is now the only argument of utility sensitive to losses, the premium must be retrospectively adjusted for losses above the deductible.

Experience Rating (not interacted with the level of reinsurance purchased). The second period premium structure, equations 8 and 9, is more complicated. Similar arguments can be used to show that second period premiums need not be adjusted to second-period losses below S_2; but an adjustment will occur when losses exceed S_2. But the second-period premium will also depend on first-period losses (experience rating). The second period premium is increasing in first-period losses regardless of whether the first-period and second-period deductibles are pierced. Formally, note that second-period marginal utility is sensitive to first-period losses and the only argument in the first-order conditions (8) and (9) which admits this effect is the premium. Thus, experience rating is accomplished by setting reinsurance premiums with respect to the primary insurer's total past losses above or below the reinsurance deductible. An insurer's total past losses are sometimes call its *direct* losses, as opposed to it's *reinsured* losses. As we will see below, data limitations will impede our effort to detect experience and retrospective rating directly and we will focus more on the model's prediction that price sensitivity is directly related to the level of reinsurance coverage.

Direct Price Control for Moral Hazard. The model predicts that the responsiveness of premiums to prior losses increases as more reinsurance is purchased. Formally, consider equation (9). As first-period losses increase, the likelihood ratio $h'(L_1 | a_1)/h(L_1 | a_1)$ falls (Assumption i). The marginal utility in the denominator on the left side of equation (9), therefore, must increase and so the premium must fall. But notice that the marginal utility also depends on S_2. Given diminishing marginal utility, then the premium responsiveness to larger losses must be higher the lower the level of S_2, i.e., the greater the level of losses passed to the reinsurer. Note that this price control is a direct function of reinsured losses.

Use of Monitoring. The premium also can be sensitive to the monitoring signal *m*. If the monitoring cost to the reinsurer (e.g., a non-affiliate) is sufficiently high so that it chooses not to monitor then, by definition, the "null signal" they observe is unrelated to the primary insurer's action, *a*. In this case, $g'(m_t|a_t) = 0$, $t = \{1,2\}$, and so the monitoring terms drop out from the first-order conditions (6) - (9).[12] The reinsurer will rely exclusively on price incentives to control moral hazard. This outcome also occurs if the monitoring signal is cheap to acquire but non-informative of the action, *a*.

If the cost of the signal is both cheap to acquire (e.g., between affiliates) and informative, then the first-order conditions show that the use of monitoring will tend to reduce the reliance on price controls. In the extreme, if the monitoring signal, *m*, is *perfectly* correlated with the hidden action, *a*, then the revealed loss cannot reveal additional information about the action *a* and price

[12] As in Holmstrom (1979, p. 87), *m* is noninformative $\Leftrightarrow$ $g'(m|a)/g(m|a)$ is constant $\Rightarrow$ $g'(\cdot) = 0$ as $\int g'(\cdot) = 0$.

controls and deductibles will not be used. Perfect monitoring implies that the terms in equations (6) - (9), that multiply each μ term, must sum to zero, resulting in a common single Lagrangian multiplier, λ, for each first-order condition.[13] The optimal insurance contact requires $S_1 = S_2 = 0$.[14] Intuitively, perfect monitoring alone allows for full reinsurance.

Summary of the Reduced-Form Model Predictions

To summarize, our model predicts that the reinsurance premium in period *t* responds as follows to each of the following independent variables:[15]

Direct price control: Negatively related to the *inverse* of *total* (direct) losses by the primary insurer in period *t*-1. The magnitude of this relationship increases in the share of reinsured losses in period *t*.

Retrospective rating: Negatively related to the inverse of amount of *reinsured* losses in period *t*.

Experience rating: Negatively related to the inverse of the amount of *total* (direct) losses by the primary insurer in period *t*-1 (not interacted with the share of reinsured losses)

Monitoring: Increasing in the signal $m(a)$ which, without loss in generality, is negatively

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[13] As in Holmstrom (1979, p. 82), perfect monitoring implies $f'(L,m|a) = 0 \; \forall \, L$, i.e., nothing about the action a can be inferred from the loss, L. Hence, $\frac{f'(L_1,m_1|a_1)}{f(L_1,m_1|a_1)} = \frac{g'(m_1|a_1)}{g(m_1|a_1)} + \frac{h'(L_1|a_1)}{h(L_1|a_1)} = 0$.

[14] To clarify our empirical tests below, our theoretical model includes more structure than is strictly necessary. In particular, the deductible terms, S_1 and S_2, replicate the intercept terms of the premium policy functions, $P_1(\cdot)$ and $P_2(\cdot)$, respectively. In the case of full insurance, the optimal intercept terms are zero.

[15] These relationships could be immediately formalized by first using the implicit function theorem and then applying a first-order Taylor expansion to create a linear relationship between the dependent variable (the reinsurance premium) and all independent variables (direct price controls, experience rating as well as monitoring).

related to the action (i.e., $m'(a) < 0$).

III. Evidence of Moral Hazard in Reinsurance Contracts

This section presents evidence indicating the degree to which reinsurers use price incentives and monitoring to try to limit moral hazard. Since our estimation strategy is moderately constrained by the available data, we first briefly describe the data before turning to our estimation strategy and results.

The Data Set

We constructed a panel data set representing several hundred of the largest property-liability insurers. We have eight years of data for each insurer, from the years 1988 to 1995. For the years 1993 to 1995, NAIC-PL (National Association of Insurance Commissioners — Property and Liability) data are used. For the years 1988 to 1992, Best data are used. A large conversion table was constructed to bridge the data sets to ensure consistency between variable definitions. We therefore impose some very minor restrictions on the data set in order to focus on established entities where experience rating, monitoring and moral hazard are presumably the most relevant.[16] Our resulting data set represents 462 firms, for a total number of 3,696 observations for 1988 - 1995.

Construction of Variables

Our data set has the familiar limitation in that it does not contain explicit contract information. As a result, we must infer relevant contract information from the data that is available.

[16] The firm had to have positive level of assets, policyholder surplus, net premiums, and total reinsurance ceded. Both direct premiums earned and written had to exceed $5 million each year. Direct premiums written had to exceed net premiums written. We also eliminate some special purpose insurers. For example, insurance companies are sometimes established (often as captives) as a tax shield on an ad-hoc basis for specific types of losses (e.g., a liability ruling in which the judgment is known but the timing of payments is not yet decided).

The Dependent Variable. First, there is no easily available reinsurance price measure. Premium income is a revenue measure, combining both the quantity of insurance sold with the price per unit of coverage. To overcome this problem, we adopt the standard strategy of measuring the contract price as the premium per dollar of expected losses incurred and assume that this is measured with random error using actual losses, i.e., P_t^R / L_t^R, where P_t^R and L_t^R are reinsured premiums paid and reinsured losses.[17]

Our model predicts that the ratio of premiums to expected losses will generally differ from unity at a yearly frequency. *Without* controls for moral hazard, the ratio should be unity in a competitive / contestable market setting. However, controls for moral hazard will generate variation in the ratio, which, indeed, is part of our identification strategy taken below. The premium is disconnected from expected losses at a yearly frequency for two reasons. First, the experience rating price control requires *previous* losses to be penalized in future periods with higher premiums, resulting in a higher contemporaneous premium / expected loss ratio. Conversely, unusually low losses are rewarded with a lower premium the next period, resulting in a lower contemporaneous ratio. Second, costly monitoring will increase the insurance premium and reduce the expected losses, causing the ratio to rise.

Experience and retrospective rating Third, the reinsurance premium often includes an initial premium paid at the beginning of the contract period and a retrospective premium that is paid later. But our data set only includes *total* reinsurance premiums paid in a given year, which cannot be decomposed into these two parts. As a result, we can only test for the response of year-to-year premium prices to previous direct losses, i.e., experience rating.

Our model predicts that the reinsurer will "experience rate" the previous *direct* losses of the

[17] This ratio is commonly used in the efficiency literature and was probably first used by Geehan (1977).

primary insurer. Our model predicts a negative relationship *within* a contractual relationship between a given reinsurer and a primary insurer. Specifically, our model predicts a negative relationship between the reinsurance premium price term, P_t^R / L_t^R, and the *inverse* of lagged direct losses, P_{t-1}^D / L_{t-1}^D. The latter term is again normalized by the direct premiums paid to the primary insurer to control for scale effects. However, most of the variation in our panel data set is cross-sectional, not longitudinal. *Between* firms, we would expect a positive relationship between the reinsurance premium price and the inverse of lagged direct losses. The reason is that, even after controlling for scale, primary insurers whose books of business tend to be more risky, would have higher premium- to-loss ratios than firms with less risky books. We do not have enough observations per firm to include a dummy variable for each firm, as with a fixed-effects regression, to allow us to isolate the "within" time-series estimator from the "between" cross-section estimator. As a result, our OLS estimator will be a linear combination of the "within" (longitudinal) estimator and the "between" (cross-sectional) estimator which are predicted to have opposite signs. We, therefore, make no prediction on the relationship between the insurance premium and lagged direct losses. Instead we focus on the direct price control below.

Direct Price Control. Recall that the model predicts that the responsiveness of premiums to prior period losses increases as more reinsurance is purchased. This suggests that we use an interactive explanatory variable, comprising the prior period reinsurance losses which we normalize by *direct* premiums received by the primary insurer from its customers in the previous period, P_{t-1}^D / L_{t-1}^D and a measure of the level of coverage which in the model was indicated by the deductible.[18] Because, deductible levels, are unavailable, we measure the share of a primary insurer's total direct losses that are reinsured as reinsured losses per dollar of the primary insurer's expected direct losses, L_{t-1}^R / L_{t-1}^D , and assume this is measured with random error.[19] Our measure, therefore, of the direct price control for moral hazard is given by $\frac{P_{t-1}^D}{L_{t-1}^D} \cdot \frac{L_{t-1}^R}{L_{t-1}^D}$. Recall that our model predicts a negative relationship between the dependent variable, P_t^R / L_t^R , and $\frac{P_{t-1}^D}{L_{t-1}^D} \cdot \frac{L_{t-1}^R}{L_{t-1}^D}$, since the sensitivity of premium prices to past losses will increase as a greater proportion of the primary's loss today is reinsured. Our model predicts that this relationship should be strong when reinsurance is purchased from a reinsurer that is not part of the same financial group as the primary insurer (non-affiliates) and less strong when both firms are affiliates.

Monitoring. Fourth, our data set does not include direct measures of monitoring. Fortunately, this issue does not pose a serious problem if we assume that reinsurance premium prices are competitively set. Monitoring can be captured by the ratio of reinsured losses over total (direct) losses, L_t^R / L_t^D since, under competitive markets, monitoring costs are anticipated and reflected in the premium price estimated as P_t^R / L_t^R . The reinsured losses are again normalized by direct losses to control for cross-sectional scale differences. However, this specification might cause a spurious correlation because the current period's reinsured losses appear in denominator of the dependent variable and the numerator of the explanatory variable.[20] To avoid such problems we will use the lagged ratio of reinsured to direct losses, thus using the model assumption there is some stability in

[18]This normalization controls for cross-sectional scale differences between primary insurers that is inherent in our data set but is not part of our model which focuses a single contractual relationship between a primary insurer and a reinsurer. It turns out, however, that the qualitative results reported below are not affected by this normalization.

[20]Thus, abnormal losses realization can cause mischief if the reinsurance is non proportional. If there is a deductible in the reinsurance then random realizations will automatically generate a negative coefficient for this variable whereas an upper limit would generate a spurious positive coefficient.

the reinsurance relationship.[21] Our model predicts a positive relationship between P_t^R / L_t^R and L_{t-1}^R / L_{t-1}^D when the primary insurer and reinsurer are affiliates (where monitoring costs, c_1 and c_2, are lower); less significant otherwise.[22]

Regression Equation

The predictions of the model can, therefore, be tested by the following regression equation,

(11)
$$\underbrace{\frac{P_t^R}{L_t^R}}_{\substack{\text{reinsurance}\\ \text{price}}} = a + b\cdot\underbrace{\frac{P_{t-1}^D}{L_{t-1}^D}\cdot\frac{L_{t-1}^R}{L_{t-1}^D}}_{\substack{\text{direct price}\\ \text{control}}} + c\cdot\underbrace{\frac{P_{t-1}^D}{L_{t-1}^D}}_{\substack{\text{experience}\\ \text{rating}}} + d\cdot\underbrace{\frac{L_{t-1}^R}{L_{t-1}^D}}_{\text{monitoring}} + \text{other controls}$$

"Other control variables" include an additional lag on the direct premium-to-loss ratio, P_{t-2}^D / L_{t-2}^D, the firms assets (*assets*), net premiums earned (*npe*), the interest rate (relevant for investment income), and a dummy variable indicating the organization type of the primary insurer (mutual and reciprocals = 1; stock = 0).

To summarize, we make the following *a priori* predictions on the signs of the coefficients. Barring perfect monitoring, the value of b should be negative for both non-affiliates and affiliates but a stronger relationship should exist for non-affiliates where monitoring costs are higher. The value of c is ambiguous due to competing longitudinal and cross-sectional effects. The value of d should be positive but a stronger relationship should exist for affiliates where the cost of monitoring is cheaper.

[21]Notice that we also used a lagged ratio of reinsurance coverage in the interactive direct price variable. In so doing ,we also avoided such problems of spurious correlation.

[22] The monitoring term could pick up another effect if the primary insurer and reinsurer aren't rational. In particular, if reinsurers do not anticipate that more reinsurance will lead to more losses, then we might find a negative relationship between the premium price and the monitoring term. Our empirical finding of a positive relationship among affiliates, therefore, is not caused by this bias.

Results

Tables 1 - 3 report regression results for three of the largest lines with reinsurance: homeowners, product and general liability, and total (all) lines of insurance. For each insurance line, separate regressions were run for reinsurance transactions between affiliates and between non-affiliates. Data restrictions prevented including those few insurers that reinsured their losses through *both* affiliates *and* non-affiliates.[23] Tables 1*a* and 1*b* reports regression results for the homeowners line of insurance for both affiliates and non-affiliates. As expected, in both regressions for affiliates and non affiliates, the cross sectional variation overwhelms any time series effects in the experience rating variable and we look to the direct price control variable to detect the presence of price incentives to offset moral hazard. For affiliates (Table 1*a*), the regression coefficient for the direct price control term, $\frac{P_{t-1}^{D}}{L_{t-1}^{D}} \cdot \frac{L_t^R}{L_t^D}$, is negative and significant, albeit small in absolute value. The regression coefficient for the monitoring term, L_t^R / L_t^D is positive, significant (at the 5 percent level) and quite large. These results indicate that moral hazard exists in the reinsurance market with affiliates and is controlled via price incentives and monitoring, but mostly by monitoring. For non-affiliates (Table 1*b*), the direct price control is negative and significant, and almost twice as large as for affiliates.[24] The monitoring term, though, is not significantly different from zero. These results indicate that moral hazard exists in the non-affiliated reinsurance market and is controlled mainly via price incentives with little or no use of monitoring.

Tables 2*a* and 2*b* report regression results for the liability line of insurance while Tables 3*a* and 3*b* report the results for total (all) lines of insurance. For each pair of tables, the same pattern shown in Tables 1*a* and 1*b* emerge: (1) moral hazard exists in the reinsurance market and (2) it is

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[23] Losses are aggregated and cannot be decomposed into losses reinsured by affiliates and non-affiliates.

[24] Moreover, the direct price control coefficient estimated for non-affiliates is statistically different than the direct price control coefficient estimated for non-affiliates. This relationship also holds for the other lines of insurance.

controlled between affiliates mainly with the use of monitoring whereas non-affiliates rely almost exclusively on price incentives.

In sum, the evidence is supportive of the moral hazard model outlined earlier. Since the cost of monitoring is lower within affiliates, affiliated reinsurers most rely on this incentive mechanism. Similarly, non-affiliated reinsurers rely almost exclusively on price incentives. It is interesting to note that not only is the regression coefficient for the monitoring term significant only for affiliates, the point estimate is much larger than for non-affiliates.

IV. Conclusion

In this paper, we present a multi-period principle agent model of the reinsurance transaction from which we derive predictions on the optimal contract design in the presence of moral hazard. The contractual features include insurer risk retention, direct monitoring and loss sensitive premiums. The model predicts that price controls would be particularly strong when contracting parties (principal and agent) are non-affiliated (i.e., not part of the same financial group) while monitoring would be relatively more observable among affiliates. We then use panel data on U.S. property liability reinsurance to test the model. The empirical results are consistent with the main predictions of the model. In particular, we find evidence for the use of loss sensitive premiums when the insurer and reinsurer are not affiliates, but little or no use of monitoring. In contrast, we find evidence for the use of monitoring when the insurer and reinsurer are affiliates, where monitoring costs are lower, but less use of price controls.

Table 1*a*. Test for Moral Hazard. Homeowners Reinsurance: Affiliates

Independent Variable, P_t^R / L_t^R .

Dependent Variable	Point Estimate	T Statistic
intercept	-15.63	-7.00*
(direct price control) $\frac{P_{t-1}^D}{L_{t-1}^D} \cdot \frac{L_{t-1}^R}{L_{t-1}^D}$	-2.34	-7.97*
(monitoring) L_{t-1}^R / L_{t-1}^D	13.76	7.10*
P_{t-1}^D / L_{t-1}^D	2.84	9.84*
P_{t-2}^D / L_{t-2}^D	0.14	3.25*
assets $_t$	0.00	0.89
npe $_t$	0.00	-0.78
interest rate $_t$	0.85	3.48*
organization type $_t$	-0.41	-0.56

* implies significance at the 5 percent level.

Table 1*b*. Test for Moral Hazard. Homeowners Reinsurance : Non-Affiliates

Independent Variable, P_t^R / L_t^R .

Dependent Variable	Point Estimate	T Statistic
intercept	1.65	0.82
(direct price control) $\frac{P_{t-1}^D}{L_{t-1}^D} \cdot \frac{L_{t-1}^R}{L_{t-1}^D}$	-1.73	-4.16*
(monitoring) L_{t-1}^R / L_{t-1}^D	2.00	1.02
P_{t-1}^D / L_{t-1}^D	1.78	6.78*
P_{t-2}^D / L_{t-2}^D	0.00	-0.15
assets $_t$	0.00	-0.19
npe $_t$	0.00	0.18
interest rate $_t$	-0.03	-0.07
organization type $_t$	-0.09	-0.08

* implies significance at the 5 percent level.

Table 2*a*. Test for Moral Hazard. Product and General Liability: Affiliates

Independent Variable, P_t^R / L_t^R .

Dependent Variable	Point Estimate	T Statistic
intercept	-12.18	-4.25*
(direct price control) $\frac{P_{t-1}^D}{L_{t-1}^D} \cdot \frac{L_{t-1}^R}{L_{t-1}^D}$	-2.95	-5.47*
(monitoring) L_{t-1}^R / L_{t-1}^D	13.98	5.27*
P_{t-1}^D / L_{t-1}^D	3.92	7.30*
P_{t-2}^D / L_{t-2}^D	-0.21	-3.47*
assets $_t$	0.00	-1.49
npe $_t$	0.00	0.91
interest rate $_t$	-0.15	-0.67
organization type $_t$	-0.60	-0.93

* implies significance at the 5 percent level.

Table 2*b*. Test for Moral Hazard. Product and General Liability: Non-Affiliates

Independent Variable, P_t^R / L_t^R.

Dependent Variable	Point Estimate	T Statistic
intercept	1.56	0.94*
(direct price control) $\frac{P_{t-1}^D}{L_{t-1}^D} \cdot \frac{L_{t-1}^R}{L_{t-1}^D}$	-0.66	-2.18*
(monitoring) L_{t-1}^R / L_{t-1}^D	0.48	1.76
P_{t-1}^D / L_{t-1}^D	1.22	6.24*
P_{t-2}^D / L_{t-2}^D	-0.01	-0.14*
assets $_t$	0.00	-1.00
npe $_t$	0.00	0.95
interest rate $_t$	0.36	1.05
organization type $_t$	-0.34	-0.33

* implies significance at the 5 percent level.

Table 3*a*. Test for Moral Hazard. Total Lines: Affiliates Independent Variable, P_t^R / L_t^R .		
Dependent Variable	Point Estimate	T Statistic
intercept	-2.10	-0.69
(direct price control) $\frac{P_{t-1}^D}{L_{t-1}^D} \cdot \frac{L_{t-1}^R}{L_{t-1}^D}$	-0.90	-2.40*
(monitoring) L_{t-1}^R / L_{t-1}^D	2.44	0.87
P_{t-1}^D / L_{t-1}^D	1.74	2.97*
P_{t-2}^D / L_{t-2}^D	-0.04	-0.11
$assets_t$	0.00	0.24
npe_t	0.00	-0.60
$interest\ rate_t$	0.15	0.82
$organization\ type_t$	-0.63	-1.14

* implies significance at the 5 percent level.

Table 3*b*. Test for Moral Hazard. Total Lines: Non-Affiliates

Independent Variable, P_t^R / L_t^R .

Dependent Variable	Point Estimate	T Statistic
intercept	-2.18	-2.90
(direct price control) $\frac{P_{t-1}^D}{L_{t-1}^D} \cdot \frac{L_{t-1}^R}{L_{t-1}^D}$	-2.26	-11.50*
(monitoring) L_{t-1}^R / L_{t-1}^D	1.25	1.28
P_{t-1}^D / L_{t-1}^D	1.97	14.41*
P_{t-2}^D / L_{t-2}^D	0.13	1.24*
assets $_t$	0.00	3.05*
npe $_t$	0.00	-0.69
interest rate $_t$	0.14	1.04
organization type $_t$	0.27	0.66

* implies significance at the 5 percent level.

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