

THE EFFECT OF COSTLY RISK BEARING
ON INSURERS' SUPPLY DECISIONS

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I. INTRODUCTION

Efficient contracts for sharing risk will allocate risk according to comparative advantage. For many insurance contracts, the comparative advantage is straightforward. The policyholder faces the prospect that she can lose a significant proportion of her wealth by single events such as car crashes, illnesses and home accidents. In contrast, the insurer spreads its risk over tens of thousands of such exposures and, with such numbers, can rely on a predictable proportion of policies producing a predictable average loss. In short, the policyholder is undiversified whereas the insurer is diversified.

But this comparative advantage is established only in the event insureds have a low correlation. Earthquakes do not fit this description. The high correlations between the claims on the insurer's policies will (in the limit) equalize the costs of risk bearing for the insurer and insured. But the insurer's comparative advantage is not necessarily entirely removed. Correlations are not perfect; while the same earthquake will cause damage to a large proportion of policies in any seismic zone, structures will have very different levels of damage. This feature alone offers some degree of diversification. Further opportunities for diversification of this risk are present when the insurer writes policies in different locations (earthquake risk near the San Andreas system in California may have zero correlation with earthquake risk on the New Madrid fault in the mid-west). Still further opportunities for diversification are available to the insurer that pools earthquake insurance with other lines of business such as fire, automobile and liability insurance.

Insurance markets for earthquake risk can, and do, exist. The players in this market, and the amount of business they write, may still be explained by comparative advantage. However, the respective abilities of insurers to write this risk depend, not simply on their ability to write large numbers of policies, but on the characteristics of their entire portfolio as well as on financial features that influence the costs of risk bearing. Several recent contributions have shown why risk is costly to corporations such as insurers. The costs of risk arise from tax convexity, principal agent relationships within the firm, and the

costs of financial distress. We will show how these types of features jointly determine the capacity of insurers to write earthquake insurance. We collect these arguments together in a simple equilibrium model of insurance. From this we derive and estimate a cross sectional model of earthquake insurance which emphasizes the differing capacity of insurers to write this line of business.

II. THE COST OF RISK TO INSURERS

One of the major effects of writing insurance for earthquake losses is the increase in the variance of insurers' cash flows due to correlated losses and uncertainty regarding the loss distribution. The extent to which such an increase in risk matters is a subject of debate. According to modern financial theory, in particular the Capital Asset Pricing Model (CAPM) and the Arbitrage Pricing Theory (APT), diversifiable risk is not priced in the capital market. The value of the firm is equal to its expected future cash flows discounted by an appropriate interest rate. Since only systematic or "market" risks are priced, stakeholders will receive a risk premium for bearing systematic risk but not unsystematic risk, because the latter is diversifiable. These theories imply that decreasing risks at the corporate level which are diversifiable at the portfolio level does not benefit stockholders because such company specific risks can be efficiently managed by diversifying their asset holdings.¹

The above reasoning can be contrasted to the more recent view that, in fact, large, unmanaged, unsystematic risks can decrease the value of the firm by lowering the level of expected cash flows.² Modigliani and Miller (1958) show that "If there are no taxes, no transactions costs, and if the firm's real investment activities are fixed, then the firm's financial decisions will not affect firm value." However, this proposition can be restated in order to understand how management of total risk can affect value: If financial decisions

¹The same argument can not be made for mutual insurers since the owners/policyholders are not able to diversify their risk through the capital market.

²See Mayers and Smith (1982), Smith and Stulz (1985), Shapiro and Titman (1987), and Cornell and Shapiro (1987).

affect value, they must do so by their impact on transaction costs, taxes, or investment decisions (Smith, 1991).

Total risk lowers expectations about future cash flows by increasing the probability of suffering financial distress. This can decrease value by increasing firms' contracting costs with customers, suppliers and employees. For example, it may diminish customer confidence, leading to reduced sales and a reduced level of operating cash flows. Also, employees will demand higher compensation in order to compensate for their ill diversified income stream.³ An increase in risk can also give rise to management incentives that conflict with interests of other stakeholders. For example, under pressure from stockholders, managers may choose high risk investment projects that redistribute wealth from policyholders to equityholders.⁴ Finally, the variance of corporate earnings can modify a firm's expected cash flows by affecting its ability to take full advantage of tax credits and write-offs⁵ and, given a convex tax function, the firm can decrease its expected tax cost by decreasing the variance of its income.⁶ The next section models these effects and shows how insurers' supply decisions will be determined by their comparative advantage in risk bearing.

III. VALUE MAXIMIZATION GIVEN COSTLY RISK BEARING

The literature on corporate hedging practices and the relevance of risk for the firm suggests a model of the insurer that takes into account the various costs of risk. Assume that the insurer maximizes its market value, which is described by a single period, multi-factor asset pricing model⁷ as follows:

³Reagan and Stulz, 1983; Shapiro and Titman, 1985; Cornell and Shapiro, 1987; Smith, Smithson, and 1990.

⁴Shapiro and Titman, 1985; Jensen and Meckling, 1976; Stewart Myers, 1977; and Galai and Masulis, 1976.

⁵This effect was first described by DeAngelo and Masulis, 1980.

⁶Smith and Stulz, 1985; Smith, et al., 1990.

⁷This derivation is adopted from Doherty, "The Design of Insurance Contracts When Liability Rules are Unstable," Journal of Risk and Insurance, 1991.

$$V = E(Y) - \delta \text{COV}(Y;M) \quad [1]$$

where

Y is the terminal value of the firm;
 E(.) is the expectations operator;
 COV(Y,M) is the vector of covariances between Y and the returns on priced factors, M; and
 δ is the vector of prices of these factors.

The terminal value, Y, will be allocated amongst claimholders, including stockholders, policyholders, and the government. Many of these claims are contingent claims, as discussed previously, which payoff in the event that Y_1 is greater than or less than some value.

Recognizing the existence of the variance related claims described, the terminal value of the insurer may be expressed as the sum of two components. The first, PRIM, represents a set of primary cash flows which are valued according to Equation 1. The second represents a claim written on these cash flows which is related to their variance. Using value additivity and denoting the value of the variance related claims by the function $f[.]$, the value of the firm is:

$$V = E(\text{PRIM}) - \delta \text{COV}(\text{PRIM};M) - f[\text{VAR}(\text{PRIM});A_f] \quad [2]$$

where A_f is the vector of other arguments of $f[.]$ and the last term is the present value of the variance related flows.

Equation 2 can now be used to construct the insurer's objective function. Let P = premium income received by the insurer and L = claims paid out. Assume that the insurer writes two lines of insurance. The subscript 1 will denote "other line" and the subscript 2 will denote earthquake. The insurer writes n "other" policies and m earthquake policies. It is assumed that for line 1 n is large and the risks are independent, implying a well diversified portfolio of these risks. Earthquake policies are assumed to be identically but not independently distributed. Each policy has an expected loss equal to $E(L_2)$. The premiums and losses are considered to be the primary cash flows of the insurer and variance related claims will be considered to be written on these flows. Using Equation 2, the value of the insurer is:

$$V(\text{INS}) = nE(P_1) - nE(L_1) + mE(P_2) - mE(L_2) - (\delta) \text{COV}\{[\text{PRIM}];M\} - f\{\text{VAR}[\text{PRIM}];A_f\} \quad [3]$$

where $\text{PRIM} = \{nP_1 - nL_1 + mP_2 - mL_2\}$ and the following assumptions are used:

- 1)⁸ $\text{COV}(L_{1i};L_{1j}) = 0$
- 2) $\text{COV}(L_{2i};L_{2j}) > 0$
- 3) $\text{COV}(L_{1i};L_{2i}) > 0$

Assumption 1 states that for the other line of business, risks are not correlated. Assumption 2 accounts for correlation between earthquake policies, and Assumption 3 accounts for correlation between earthquake policies and other policies. These assumptions permit the model to be simple and still capture the fundamental aspect of the earthquake insurance market: dependence across policies and across lines.

Equation 3 demonstrates that risk affects the insurer in two ways. As dictated by the CAPM, systematic risk is priced by the market, as shown by the covariances with the priced factors. The second risk cost relates to the variance of the firm's operating revenues and the particular variance related claims which the firm may have on its operating revenues. Such costs are denoted VARIANCE RELATED COSTS (VRC) and they are specific to the insurer.

The insurer maximizes $V(\text{INS})$ by its choice of m , the number of earthquake policies to write, given the price determined in the market and that it has already chosen to write n other policies. The first order condition is:

$$P_2 - E(L_2) + \delta \text{COV}(L_2;M) - \{\partial f / \partial \text{VAR}(I)\} \{\partial \text{VAR}(I) / \partial m\} = 0 \quad [4]$$

Assuming that the covariance of losses with the market is zero,⁹ the first order condition is:

⁸ In the event of an earthquake, this covariance may be positive as well. However, in the derivation used here the aim is to exploit the diversification possibilities that exist.

⁹ Empirical evidence suggests that such covariances are very low or zero. See Cummins and Harrington, 1985.

$$P_2 - E(L_2) = \{\partial f / \partial \text{VAR}(I)\} \{\partial \text{VAR}(I) / \partial m\} \quad [5]$$

Thus, an insurer will choose m such that the marginal underwriting profit, $P_2 - E(L_2)$, is equal to the marginal variance related costs, $\{\partial f / \partial \text{VAR}(I)\} \{\partial \text{VAR}(I) / \partial m\}$.

Increasing m will impact insurer value by increasing the variance of its cash flows. This increase in variance represents an increase in the value of all options written on these cash flows. Since the government and creditors essentially "own" these options,¹⁰ the insurer may wish to decrease the variance in order to reduce its costs and increase expected value.

Regarding the marginal VRC, the first term, $\{\partial f / \partial \text{VAR}(I)\}$ is clearly positive.¹¹ As the variance increases the risk cost increases. The second term, $\{\partial \text{VAR}(I) / \partial m\}$, will be positive assuming there are no negative covariances, as stated above. Consider the term $\text{VAR}(I)$:

$$\begin{aligned} \text{VAR}(I) = n \sigma^2(L_1) + m \sigma^2(L_2) + n(n-1)\text{COV}(L_{1i}; L_{1j}) + \\ m(m-1)\text{COV}(L_{2i}; L_{2j}) + 2mn\text{COV}(L_{1i}; L_{2i}) \end{aligned} \quad [6]$$

and

$$\begin{aligned} \{\partial \text{VAR}(I) / \partial m\} = \sigma^2(L_2) + (2m - 1)\text{COV}(L_{2i}; L_{2j}) + \\ 2n\text{COV}(L_{1i}; L_{2i}). \end{aligned} \quad [7]$$

As m increases the $\text{VAR}(I)$ increases, implying an increase in the value of all claims written on the firm.

Insurers will choose the amount of insurance to supply based on the market price and their marginal cost curve. Firms with higher Variance Related Costs, and hence a higher marginal cost curve, will supply less insurance for high risk lines than firms with a lower marginal cost curve. Thus, the model implies that firms with lower variance related costs will assume a higher exposure to risk.

¹⁰Although shareholders own a limited liability option which would also increase in value with increases in variance, they will be better off with lower risk if creditors anticipate the possibility of expropriative behavior by shareholders and incorporate such information in the price they pay for claims, as discussed below. See Doherty, 1989.

¹¹This assumes that creditors price the default option owned by shareholders.

Firm characteristics that are predicted to be associated with the magnitude of a firm's variance related costs are specified below.

IV. PROXIES FOR VARIANCE RELATED COSTS

In order to test whether or not the cost of risk affects insurers' supply decisions, proxies are needed for variance related costs. Although we cannot observe VRCs, characteristics of the firm which are observable and are expected to be related to the magnitude of these costs can be used. Firms which have lower variance related costs, as implied by these characteristics, are expected to assume a greater amount of undiversifiable risk. The proxies used for VRCs are marketing structure, organizational form, return on equity, leverage, diversification, tax shields, regulation and the percent of business in personal lines of insurance. The expected relationship between VRCs and these characteristics of the firm is described below.

We first address how the distribution system used by the insurer will affect its cost of risk. One of the principle assets of an insurer is its agents. Whether insurers use direct writers or independent agents will be important as the risk of the firm changes. Since independent agents own the renewal rights on policies they place, they are likely to transfer policies to a rival when an incumbent insurer becomes financially distressed. Such "runs" on insurers, combined with other costs of financial distress, imply that the independent agent insurer would have higher VRCs than direct writers. However, there is a counter argument. The choice of distribution system and the method of compensating agents offer opportunities for the insurer to "reinsure" risk with another risk bearer. One explanation that has been offered for institutional arrangements such as sharecropping (Cheung, 1969, and Stiglitz, 1974) and franchising (Martin, 1988) in which the principal subcontracts a productive function to an agent, and makes the agent a residual claimant on the output, as a means for the principal to insure her risk, is optimal risk sharing. Insofar as the agent receives performance related compensation, such risk sharing is achieved. We speculate that independent agent insurers are more likely to have access to such reinsurance since performance related compensation is widespread

amongst independent agents, but direct writers have fixed costs (salaries, severance pay, overhead employment costs, etc.) associated with their sales employees. This implies that VRCs are higher for direct writers than for independent agent insurers. *A priori* we cannot evaluate the relative magnitudes of these opposing effects, and we cannot sign the expected relationship between VRCs and distribution system.

Another issue for insurers as the variance of their cashflows increases is the ability to finance the recovery of a catastrophic loss of surplus. The expected costs of adjusting to such shocks is a primary cost of risk for insurers. One factor which influences financing costs is organizational form. On the one hand, mutual insurers are better able to absorb deviations to surplus caused by unexpected losses since they have greater ability to pass these effects on to policyholders by varying policyholder dividends (see Marshall 1976 and Doherty and Dionne 1993). While mutuals do, in fact replace a greater proportion of lost surplus from retained earnings than stocks, this advantage is more than offset by mutuals' inability to raise external capital (see Doherty, Kleffner and Posey 1993). This results in mutuals replacing a lower percentage of lost capital than stock insurers. Thus, on balance, mutuals face more severe deteriorations in leverage following loss of surplus than do stock insurers. This will translate into greater contraction in supply, or more acute reductions in product quality, than stock insurers following adverse draws on their total loss distribution. Accordingly, we suggest that the VRCs are lower for stock insurers than for mutuals since the former can more easily access external capital. Similarly, insurers that are owned by a holding company are expected to have lower VRCs than those that are not since such insurers may receive capital contributions from their parent, implying a lower cost of adjusting to surplus shocks than for insurers not held by a holding company.

Profitability is also expected to influence an insurer's VRCs by its effect on the expected cost of adjustment. More profitable insurers have lower expected

costs of adjusting to surplus shocks¹², and hence lower VRCs, since they have greater internal capital sources and it is easier for them to attract investors for a new equity issue. Consequently, we postulate that VRCs are negatively related to insurer profitability. Profitability is measured as Net Income After Tax in period t divided by Surplus at the beginning of period t .

The level of diversification establishes, *inter alia*, the degree of riskiness of insurer cash flows. Here we are interested in the differential abilities of insurers to write an earthquake exposure of given risk. The respective ability of insurers to do so will depend on their ability to spread this risk across a portfolio of other exposures with which it has low correlation. Exploiting such low correlations, diversification can take place across lines, and by establishing geographical spread within the earthquake (or indeed any other) line. Such diversification lowers the probability that the insurer will suffer large fluctuations in surplus and thus lowers the probability of financial distress. Thus, we postulate that the more diversified the insurer, the lower will be the cost of bearing a given earthquake insurance exposure. Diversification is measured using two herfindahl concentration indices. The index is calculated using the percentages of direct business written in each of the 50 states and the District of Columbia and in each of the 26 lines of insurance for each insurance company.¹³ These indicate the spread of an insurer's portfolio of business across states and across lines.

An insurer's leverage also will influence the magnitude of its VRCs. The lower an insurer's leverage, the lower its VRCs because such insurers have a greater capacity to absorb unexpected losses and greater flexibility in adjusting to negative surplus shocks. This rationale is based on the argument that one of the main costs of financial distress arises from distortions in project selection

¹²This is shown in "Catastrophic Risks and The Functioning of Insurance Markets," Dissertation by Anne E. Kleffner, (1993) University of Pennsylvania.

¹³The index is calculated for each company as $H = \sum I_s^2$, where $s = \text{state} = 1, \dots, 51$ and $I_s = PW_s/TPW$. PW_s is the dollar amount of premium written in a particular state and TPW is the dollar amount of total premiums written across all 50 states and the D.C. Similarly, the index is calculated using premiums written by lines of insurance.

associated with the interaction of risk and leverage (see Myers 1977). It follows that these costs can be mitigated either by reducing risk or reducing leverage. *Ceteris paribus*, the higher the leverage of the insurer, the higher will be the expected loss of value from dysfunctional project selection from any assumed level of risk. The interaction of risk and leverage is further compounded by regulatory attention. Insurers incur costs of dealing with regulation and, for any given level of liability risk, such costs are expected to be higher for the more highly levered insurer. Thus we postulate that VRCs for insurers will be positively related to leverage, which is measured as Liabilities/Assets.

Regarding the insurer's tax position, the tax benefit from reducing risk increases as a firm's tax code becomes more convex and as the size of its tax credits increases. The convexity of the tax function is determined by a number of factors, including the presence of tax loss carryforwards, the likelihood that such carryforwards will be used, and the discount rate. Since the convexity of a firm's tax function is likely to vary as the level of pretax income varies, convexity can only be determined for a given income level, and the income level is in turn determined by the probability distribution of different income levels. Hence, there does not exist a single, unique measure of convexity¹⁴ and therefore it is difficult to develop a proxy. However, insurers with large, excess tax deductions will have higher VRCs than firms without due to the possibility of losing them in the event of bankruptcy. Short of bankruptcy, underutilized tax shields represent a cost to the firm equal to the discount taken if they are sold. The excess of a firm's tax deductions is measured as the ratio of its tax deductions¹⁵ to taxable investment income. However, there are two problems with this measure. First, not all tax shields are reported by

¹⁴One indicator for the convexity of a firm's tax function is the size of its tax loss carry-forwards. However, corporations are not required to reveal the amount of losses carried forward from previous years, making this measure unavailable. See Lew (1991).

¹⁵Tax deductions include all items which should be deducted from total earnings to reach taxable earnings, such as claims costs and interest earned from tax-exempt bonds.

firms¹⁶ so the measure does not fully capture the size of a firm's tax shields. And second, this measure may pick up another effect of tax shields. Namely, that large tax shields act as hidden surplus and such tax shields are only valuable if the firm makes a profit. Hence, in order to make use of the tax shields, firms may take on **more** risk since a higher expected return will put the tax shields "in the money."¹⁷ It is unclear, then, whether firms will take on more or less risk as the size of their tax shields increase.

Another determinant of VRCs is the regulatory environment in which the insurer operates. We postulate that the expected cost of regulation to the insurer will increase with the variance of its cash flows. This bias is specifically built into some regulatory laws. For example, Florida has an excess profits tax in addition to prospective rate regulation. Thus, while insurers are allowed prices that ensure a fair rate of return, the excess profits tax promises to confiscate favorable profit realizations while leaving unfavorable realizations with insurers (see Doherty, 1987)¹⁸. But even more pervasive is an disposition on the part of regulators to operate on a "heads I win, tails you lose" strategy. Thus, regulators have an asymmetric tendency to seek rate reductions following favorable realizations, but not allow rate increases following unfavorable profit realizations (e.g., Lyon 1991). Thus we would expect that VRCs would be higher for those insurers whose portfolios comprise a large volume of business in highly regulated (prior approval) states. Our regulatory measure is the percentage of business in auto and workers' compensation in states that have a "prior approval" or administered rating system. (NOTE: This variable

¹⁶For example, corporations do not report losses carryforwards.

¹⁷It is possible, however, to lose more money, creating even large tax shields that may go unused.

¹⁸Another example is the Maine Fresh Start law for workers' compensation insurance. Insurers are supposedly only administrators of the residual market being guaranteed a break-even result. In the voluntary market, insurers are priced achieve a fair expected rate of return on equity. However, Fresh Start dictates that favorable realizations of profit (above the cost of capital) in the voluntary market can be confiscated to subsidize residual market losses. However, voluntary market return below the cost of capital cannot be subsidized from the residual market.

has not yet been incorporated).

Finally, the cost of risk to an insurer is a function of whether they write personal or commercial lines of insurance. Policyholders in personal lines have less power to negotiate the terms of the contract and are less likely to be well informed about the financial condition of the insurer. Further, they have less incentive than commercial buyers to become well informed since if the insurer did go bankrupt, their claims would fall within the limits of insurance guaranty fund coverage. In contrast, the commercial demand for insurance is much more elastic and is expected to respond more to a deterioration in an insurer's financial condition, making the cost of risk greater for insurers who primarily write commercial coverages. Hence, the amount of risk an insurer will assume should increase with the proportion of their business in personal lines of insurance. However, since insurers in California are required to offer earthquake insurance with each homeowner's policy they write, this cannot be tested. To control for this, the percentage of homeowners' multi-peril an insurer writes is included as a control variable in the empirical tests.

V. DATA, METHODOLOGY, AND RESULTS

As described above, variance related costs will differ for insurers depending on specific characteristics of the firm. Empirical tests are performed to examine whether or not the magnitude of an insurer's earthquake exposure can be explained by the size of its variance related costs. Firms' earthquake exposure is measured using probable maximum loss (PML) data¹⁹ from the California Department of Insurance (CDI). The amount of risk an insurer assumes is measured as the fraction of an insurer's surplus at risk from a catastrophic earthquake, PML/Surplus. The PML/Surplus ratio is used by the CDI as a measure of insurers' vulnerability to a catastrophic earthquake. This measure is better

¹⁹Each year all property/casualty insurance companies licensed to do business in California are required to report their earthquake exposures with respect to risks located in California. In this context, PML means the expected shake damage loss (after deductible) for a certain class of structure given the maximum size earthquake which is likely to occur. This definition assumes an earthquake of magnitude 8.25 on the Richter scale, which is about the size which occurred in San Francisco in 1906 and Alaska in 1964.

than premiums written because a portion of the earthquake insurance coverage that is provided is not explicitly reported in insurers' annual statements, usually because it is an endorsement on another policy, making premiums written an inferior measure of exposure.

The PML data is for reporting year 1987. Two sets of results are reported since each insurer reports two PML figures: one for Southern California (Zone B) and one for Northern California (Zone A). The data for the other variables is taken from the AM Best Property Casualty tapes.

The sample used for the test consists of 102 firms: 76 stock companies, 5 reciprocals, and 21 mutuals. Seventy companies use the independent agency marketing system and 32 use direct writers. Comparing the PML/Surplus ratios for Zones A and B we see that for Zone B, Los Angeles, the mean ratio is very close to .10. The California Department of Insurance uses as a conservative rule that the potential loss on one risk²⁰ should not exceed 10% of surplus. This suggests that the ratio for some companies exceeds this upper bound. According to the model, those companies assuming a greater amount of risk are those with the lowest variance related costs.

A multivariate regression equation is estimated using Ordinary Least Squares to test for differences across firms. The regression model can be expressed in the following manner:

$$(PML/K)_j = \beta_0 + \sum \beta_i X_{ij} + \sum \tau_j Y_{ij} + \epsilon_j \quad [9]$$

where

(PML/K)_j = probable maximum loss/surplus for firm j;
 β_0 = intercept;
 ϵ_j = error term.

CONTROL VARIABLES

X₁ = PERS = Personal PW in California/Total PW in California;

X₂ = SIZE = ASSETS;

X₃ = DIV = California DPW/U.S. DPW.

²⁰The PML exposure in a zone is considered as one risk.

EXPLANATORY VARIABLES		EXPECTED SIGN
Y1A = STOCK	= 1 if insurer is stock, 0 otherwise;	(+)
Y1B = HOCO	= 1 if insurer is owned by a holding company, 0 otherwise;	(+)
Y2 = IA	= 1 if insurer uses the independent agency marketing system, 0 otherwise;	(-/+)
Y3 = ROE	= Net income after tax _t /Surplus _{t-1} ;	(+)
Y4 = TAX	= $\frac{\text{Tax shields}}{\text{Taxable investment earnings}}$;	(-)
Y5 = HERFSTAT	= Herfindahl index by state;	(-)
Y6 = HERFLINE	= Herfindahl index by line;	(-)
Y6 = LEVG	= Liabilities/Assets;	(-)
Y7 = RECIPS	= 1 if the insurer is a reciprocal; 0 otherwise.	(+/-)

Two measures of access to capital markets are used. First, whether the insurer is a stock company, and second, whether the insurer is held by a holding company. The expected sign for both of these is positive. Regarding the tax variable, what we want to measure is a firm's excess tax deductions. However, given the data reported in Best's this is not possible. The best approximation given the data available is the ratio of tax deductions to taxable investment earnings. Given that firms may alter income figures to improve their tax situation, this variable is expected to have a large noise to signal ratio. Summary statistics are presented below.

SUMMARY STATISTICS

Variable	Mean	St. Dev.
PML/Surplus _A	.0671	.2542
PML/Surplus _B	.0945	.3591
Asset	2228415677	4158053289
PERS	.0667	.1058
LEVG	.7071	.1268
DIV	.2756	.3241
ROE	.1496	.2438

The results from estimating Equation 9 are presented in Tables 1 and 2. The first set of results in Tables 1 and 2 use insurers' PML from Zone A (San Francisco) and the second set of results use Zone B (Los Angeles). Tables 1A and 1B contain the results using Stock and Reciprocal dummy variables to measure access to capital markets and Tables 2A and 2B present the results using a holding company dummy variable.

Tables 1A and 1B show that the results support all of the testable hypotheses except for that relating to the firm's tax deductions and diversification by line. Specifically, the following observations can be made:

- The higher a firm's leverage, the less earthquake risk it assumes.
- Stock insurers assume a greater amount of risk than mutual insurers. There is no significant difference between reciprocals and mutuals.
- The more diversified is an insurer, as measured by how concentrated it is by state, the greater the risk it assumes. There is no significant difference between firms that are highly concentrated by line versus those that are not.
- Insurers that use the independent agency system assume less risk than those that use the direct writer marketing system.
- The more profitable is an insurer, the greater the risk it assumes.
- The greater a firm's tax shields relative to its taxable income, the more risk it assumes.

That more highly levered firms will assume less risk is implied by the notion that such firms have a higher expected cost of distorted investment policy and it is harder for such firms to adjust to surplus shocks.²¹ It is more difficult for them to raise external capital and they are more constrained regarding the adjustment in their price and quantity of insurance in response to

²¹See Kleffner, 1993.

a large loss. Furthermore, as firm leverage increases, so too does the expected cost of financial distress. Hence, more highly levered firms are predicted to have higher VRCs and assume a lower level of risk, and the results support this hypothesis.

The positive and significant coefficient on the stock variable suggests that the ability to raise external capital after a large loss is important in determining who supplies catastrophic insurance.²² If an insurer must wait for the slow build up of retained earnings after a depletion in surplus, it must also reduce the quantity of insurance provided in the short to medium term, if it desires to maintain the same level of safety. This represents a loss of profit and goodwill for the insurer, and a higher cost of assuming risk.

Insurers that are more diversified by state, as measured by the herfindahl index, have a lower probability of financial distress and hence lower expected costs of financial distress. Such insurers are able to take on a higher level of risk since the probability that they will incur a large surplus shock is lower than those who concentrate in only one or a few states. The herfindahl index by line was not significant. This may be due to the fact that almost all lines of insurance have a positive correlation with earthquake. For example, in the event of a catastrophic earthquake an insurer is likely to pay claims on fire, workers' compensation, and liability policies. Hence, writing more lines of insurance may actually increase the probability of financial distress.

Next the results indicate that independent agency firms assume less earthquake risk than direct writer firms.²³ This supports the notion that agency firms have a higher cost of financial distress due to the agents having ownership of expirations. As the risk of an insurer increases, so too does the probability that an agent will cease doing business with the firm, taking

²²This is also consistent with the hypothesis that stock insurers will concentrate in lines of insurance which require greater managerial discretion due to the lower cost of controlling agency conflicts. (Mayers and Smith, 1988).

²³Since 75% of PML exposure is due to commercial property, it is safe to conclude that this result cannot simply be explained by direct writers being more efficient, and hence dominating, in the homeowners market, where they are required to offer earthquake insurance on each policy sold or renewed.

policyholders with him/her. This is costly to the firm, and the rational response is to assume a lower level of risk.²⁴

The profitability of the insurer also appears to be important in determining how much risk it assumes. It is easier for more profitable insurers to raise external capital and they rely less on internal capital to replenish surplus. These all imply that the more profitable an insurer is, the more risk it can safely assume due to the lower expected cost of financing in the event of an unexpected reduction in surplus.

The result for the tax variable is not consistent with the hypothesis that firms assume **less** risk in order to protect their tax shields. One possible explanation for this is that insurers who assume a large earthquake risk also concentrate in other high variance lines and since these lines are more prone to large underwriting losses, there is a positive relationship between the tax variable and the risk variable. The correlation between PML/Surplus_A and PML/Surplus_B and TAX is .32 and .40, respectively. The positive and significant coefficient on the tax variable provides evidence that insurers with higher tax deductions assume a larger amount of risk. This suggests that the value in the hidden surplus of the tax shield dominates the expected cost of losing it in the event of bankruptcy.

The results in Table 2 are consistent with those in Table 1. The coefficient on HOCO is positive and significant, suggesting that firms held by a holding company assume a greater amount of risk than those that are not. The signs and significance of the other variables remain the same.

Although the evidence presented supports the hypotheses regarding how the cost of risk varies across insurers, the validity of the results is conditional on the validity of the proxies used to measure VRCs. The fact that similar results were obtained using two earthquake zones and two measures for access to capital markets provides additional support for the reliability of the results.

²⁴Recognizing that independent agency is positively correlated with the stock form of ownership, and noting that the two variables have opposite signs, we checked for multi-collinearity to make sure that it was not just an ownership effect being detected. The correlation between STOCK and IA is .38 and the tests demonstrated that multi-collinearity was not a problem.

VI. CONCLUSION

This research examines the relationship between the cost of bearing risk and the amount of risk insurers assume in their underwriting portfolio. If firm-specific risk does not affect the value of the firm it will not affect operating decisions. However, when risk bearing is costly, firms' optimal risk level will equate the marginal cost of risk with the marginal cost of reducing that risk. The evidence suggests that firms with a higher cost of bearing risk assume less risk, as measured by the percent of surplus at risk from a catastrophic earthquake.

The existence of costly risk bearing implies that not all insurers are equally equipped to insure high variance lines of insurance. Instead, an efficient market solution requires that those firms who have a comparative advantage in risk bearing, as determined by organizational form, leverage, profitability, diversification and marketing structure, should assume a greater share of the risk. This is borne out by the results.

TABLE 1A
Test of VRC Model: Zone A
Results Using Stock Dummy Variable

Variable	Coefficient	T	Prob >	T
Intercept	.198032	1.007	.3167	
SIZE	-6.88E-12	-1.135	.2594	
PERS	-.089322	-.370	.7119	
LEVG	-.384986	-1.836	.0697	
DIV	.450308	2.709	.0081	
STOCK	.096233	1.589	.1155	
RECIPS	-.020581	-.164	.8698	
HERFSTAT	-.537227	-2.986	.0036	
HERFLINE	.071408	.483	.6304	
IA	-.113639	-1.909	.0595	
ROE	.131133	1.311	.1933	
TAX	.020677	3.310	.0013	

TABLE 1B
Test of VRC Model: Zone B
Results Using Stock Dummy Variable

Variable	Coefficient	T	Prob >	T
Intercept	.264712	1.007	.3166	
SIZE	-8.80E-12	-1.086	.2803	
PERS	-.142842	-.443	.6586	
LEVG	-.623597	-2.225	.0286	
DIV	.605305	2.725	.0077	
STOCK	.145328	1.796	.0758	
RECIPS	-.049443	-.295	.7684	
HERFSTAT	-.744213	-3.095	.0026	
HERFLINE	.112028	.567	.5723	
IA	-.146693	-1.844	.0685	
ROE	.198323	1.483	.1415	
TAX	.036740	4.401	.0001	

TABLE 2A
Test of VRC Model: Zone A
Results Using HOCO Dummy Variable

Variable	Coefficient	T	Prob >	T
Intercept	.216831	1.136	.2588	
SIZE	-7.09E-12	-1.186	.2387	
PERS	-.128913	-.556	.5798	
LEVG	-.412593	-1.986	.0500	
DIV	.458457	2.858	.0053	
HOCO	.103749	2.132	.0357	
HERFSTAT	-.518399	-2.933	.0042	
HERFLINE	.045837	.313	.7552	
IA	-.101703	-1.847	.0680	
ROE	.148919	1.508	.1350	
TAX	.020614	3.352	.0012	

TABLE 2B
Test of VRC Model: Zone B
Results Using HOCO Dummy Variable

Variable	Coefficient	T	Prob >	T
Intercept	.289593	1.138	.2583	
SIZE	-9.13E-12	-1.144	.2556	
PERS	-.208999	-.675	.5012	
LEVG	-.663948	-2.396	.0186	
DIV	.612446	2.862	.0052	
HOCO	.158032	2.435	.0169	
HERFSTAT	-.713500	-3.026	.0032	
HERFLINE	.072851	.373	.7103	
IA	-.126173	-1.717	.0893	
ROE	.226644	1.720	.0888	
TAX	.036690	4.473	.0001	

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