On the Tax Costs of Equity Finance:

The Strange Case of Catastrophe Insurance

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1. Introduction

Catastrophe insurance arrangements provide an interesting venue to examine corporate capital structure issues. To bond promises to pay policyholder claims following major catastrophes, insurers need to hold large amounts of capital (assets in excess of the present value of expected claim payments). As a result, the cost of supplying catastrophe insurance is especially sensitive to insurers' cost of capital. Typically, the capital backing policyholders' claims is provided by equityholders. But, as is well known from the capital structure literature, equity is tax-disadvantaged relative to debt because of corporate income taxes.[1] Thus, the tax costs associated with equity finance are part of an insurer's cost of capital and correspondingly an important determinant of premiums paid for catastrophe insurance/reinsurance.[2] Despite the importance of equity tax costs, very little research has attempted to measure them systematically.[3] Thus, the main objective of this paper is to provide "ballpark" estimates of the tax costs of equity financing and the resulting effects on prices for catastrophe insurance arrangements.[4]

To measure the tax costs, we use a partial equilibrium, single-period model of insurance pricing and capitalization that incorporates specific loss distributions for nationwide catastrophe losses. After consideration of a number of issues, including insurer investment in tax-exempt

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[1] Compared to many corporations, property-liability insurers are highly levered when policyholder claims are considered liabilities. For example, the industry as a whole has a liability to asset ratio of 68% in 1996. Our discussion, however, focuses on the source of funds used to bond promises to pay policyholder claims.
[2] A consensus appears to exist in the insurance literature that the incidence of the taxes nominally paid by insurers falls on policyholders, at least in the long run. For example, most models used for insurance rate regulation explicitly assume that the policyholders bear the tax costs nominally paid by insurers. See e.g. Derrig (1994) and Myers and Cohn (1987).
[3] A number of papers have identified the tax disadvantages associated with holding equity capital to bond promises to pay catastrophe claims, including Harrington, Mann, and Niehaus (1995), Harrington (1997), Jaffee and Russell (1997), and Froot (1999), but surprisingly, we are not aware of any studies that have quantified the magnitude of the tax costs on insurer equity.
[4] Our focus on measuring the tax costs makes this research similar to that of Graham (1996, 1999), who estimates the tax benefits of debt financing for corporations in general. We, however, focus on an industry for

securities, loss carryforward and carryback provisions, and personal taxes, our analysis implies that the tax costs on equity capital have a substantial effect on catastrophe insurance/reinsurance prices, especially for high layers of coverage. In many cases, estimates of the tax costs exceed 100% of the present value of expected claim costs for catastrophe coverage, i.e., policyholders/insurers need to pay more than twice what they expect to receive in claim payments for catastrophe coverage. [5]

This result sheds light on a puzzle in the insurance economics literature. Even though theory suggests that natural catastrophe risk should be shared across a broad base of risk bearers, Froot (1999) presents evidence that catastrophe risk often is retained by property owners, and when it is insured, the majority of the risk is retained by the primary insurer, instead of being redistributed more broadly via the reinsurance market. Primary insurers' retention of catastrophe risk is especially pronounced for so-called "high layers" of catastrophe losses. For example, Froot (1999) estimates that only about 20 percent of U.S. insurance industry catastrophe losses in excess of $8 billion were reinsured in 1994.[6] A number of potential explanations have been put forth for the limited sharing of catastrophe risk, including adverse selection and moral hazard problems in the reinsurance market (Cutler and Zeckhauser, 1999, Niehaus and Mann, 1995), incorrect risk assessment (Kleindorfer and Kunreuther, 1999), ex post disaster relief (Arvan and Nicherson, 1998), and high insurer capital costs due to agency problems and/or corporate taxes (Jaffe and Russell, 1997, Harrington, 1997). This

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which the tax costs are likely to be especially burdensome to consumers and for which public policy proposals have surfaced to reduce tax costs.

[5] Actuaries often use models for determining insurance premiums in which they add an expense loading and a risk loading to the expected value of claim costs. The risk load is meant to capture the additional cost associated with insuring unpredictable losses. Actuarial models typically base the risk load on some measure of the predictability of claims, such as standard deviation or variance. Finance theory, however, suggests that insurers hold capital to bond promises to policyholders and consequently that the risk load should depend on the cost of holding capital and the amount of capital held. Although this conceptual point is well-accepted, little progress has been made in actually measuring the appropriate risk load (capital costs) that should be used for calculating insurance premiums. By calculating the tax costs associated with holding equity capital, this paper makes an initial step in that direction.

[6] For some reference points, Hurricane Andew caused about $16 billion of insured losses and the Northridge earthquake caused about $20 billion in insured losses. The probability distribution for U.S. catastrophe loses used later in the paper indicates that the probability that U.S. catastrophe losses exceed $10 billion is 0.197 (see Table 2).

paper suggests that the magnitude of the corporate tax costs have the potential to explain the limited scope of catastrophe insurance.

A natural question given our finding that the corporate tax costs associated with equity financing are high for catastrophe insurers is to ask: why don't insurers use more subordinated debt to bond their promises to policyholders? Our informal analysis of this issue emphasizes the adverse impact that debt renegotiation or bankruptcy would likely have on policyholder demand for coverage. The recent innovation of catastrophe bonds, however, can be interpreted, at least in part, as a means by which insurers can reduce tax costs associated with equity financing and simultaneously avoid the financial distress costs of subordinated debt financing.

In contrast to the considerable research that has been conducted during past decade on short run disruptions in insurance markets, our focus is on the long-run impact of taxes on insurance markets.[7] The research on short-run disruptions generally highlights the importance of capital adjustment costs following capital shocks (see e.g., Gron, 1994a, 1994b, Winter 1994, Harrington and Cagle, 199 , Cummins and Danzon, 1997). However, as Stein (1999) notes, the cost of holding capital are equally important, for if these capital costs were low then insurers would simply hold sufficient capital to withstand shocks. Thus, the magnitude of tax costs on equity capital is not only important for understanding insurer capital structure, but also for understanding short run disruptions in insurance markets.

The paper proceeds as follows. To highlight the intuition for how the tax treatment on insurer equity affects insurance premiums, we first present a simple model of insurer pricing and capitalization that abstracts from insolvency issues and the asymmetric tax treatment of profits and losses. The more elaborate model presented in Section 4 incorporates the possibility of insurer insolvency and a more realistic tax structure, as well as a specific loss distribution that approximates catastrophe losses in the U.S. The model is solved numerically for the tax costs associated with catastrophe coverage under various parameter values. The remainder of the paper then investigates the robustness of the results to various assumptions. In Section 5, we explain why product line and global diversification are unlikely to negate the implication that tax costs substantially increase the price of catastrophe coverage. Section 6 analyzes investment in tax-exempt bonds. Following recent work by Graham (1996, 1999), Section 7 examines the effects of actual rules for carrying losses backward and forward on expected marginal tax rates. Personal tax issues are discussed in Section 8. Section 9 contains a brief analysis of the costs associated with subordinated debt finance and how catastrophe bonds potentially reduce the net costs of bonding insurer promises. The paper ends with a summary and a discussion of the implications of our results for tax policy issues related to catastrophe insurance.

2. Perspective and Common Assumptions

At the primary insurance market level, catastrophe coverage often is bundled with non-catastrophe coverage. For example, homeowners insurance policies typically include coverage for wind damage from hurricanes, as well as coverage from many other perils.[8] In other cases, however, policyholders must purchase separate coverage for catastrophe losses (earthquake and flood coverage in many states are examples). Regardless of whether catastrophe coverage is bundled with other coverages at the primary market level, the price paid by policyholders to add catastrophe coverage will reflect primary insurers' marginal cost of bearing the catastrophe risk. This cost, in turn, depends on the cost of reinsuring catastrophe risk. Thus, our analysis focuses on the pricing of catastrophe reinsurance contracts. High prices for catastrophe reinsurance will imply high marginal prices for catastrophe coverage at the primary market level.

Common assumptions and notation used in each of the models are as follows. We consider an annual catastrophe reinsurance contract issued by a stock insurer.[9] Claim costs are assumed to be

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[7] Harrington and Niehaus (1999) provide a summary of this literature and an extensive reference list.
[8] Flood damage, however, is not typically included.
[9] Although mutual and stock companies have different tax treatment, as a first approximation, similar results will apply to mutual insurers. The distributions to the owners of mutual insurers (policyholders) are considered

independent of any risk factor that is priced in the capital markets (e.g., claim costs have a zero beta in the CAPM framework). Premiums net of expenses, P, and equity capital, K, are received at the beginning of the year and invested in risk-free securities that yield the before-tax return of r. At the end of the year, claim costs are paid and the residual funds are distributed to equityholders.

3. One-Period Model with No Insolvency Risk and Symmetric Taxes

This section presents a simple model that captures the intuition for how the tax costs associated with equity financing affect reinsurance prices. In this simple model, realized catastrophe claim costs are denoted by X with an expected value equal to E(X) and a maximum value of M. We assume that insurers hold enough equity capital to prevent insolvency and the tax system is symmetric, i.e., profits and losses are taxed at the same rate on an annual basis regardless of the level of claim costs. These assumptions imply that initial capital must be set so that funds available at the end of the year are sufficient to pay M, which means

$$(K+P)(1+r) = M. \quad \textbf{(1)}$$

The symmetric tax system implies that the insurer's end-of-year cash flow equals

$$r(P+K) + (P - X) - \tau\,[r(P+K) + (P - X)]. \quad \textbf{(2)}$$

The first term is investment income, the second term is underwriting profit, and the last term equals tax payments. The symmetry of the tax system assumed here implies that if claim costs exceed taxable revenue, $X > r(P+K)+P$, the insurer receives an immediate tax refund equal to τ times the loss.

The equilibrium premium in this simple model equates the expected after-tax rate of return earned on insurer capital to the expected return owners could obtain by investing their capital in a mutual fund that holds the same assets as the insurer. Since the insurer is assumed to hold risk-free assets and claim costs are uncorrelated with priced risk factors, the required return on insurer capital is simply the risk-free return, r. Thus, equilibrium requires that the expected end-of-year cash flow

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a return of premium and therefore are tax-deductible expenses at the corporate level. However, mutual insurers' capital is taxable when it is initially contributed in the form of insurance premiums. See Graetz (1986) and equals Kr (or that expected gross value equals (1+r)K). Equating the expected value of expression (2) to Kr and solving for P yields the equilibrium insurance premium:

$$P = \frac{E(X)}{1+r} + \frac{Kr\tau}{(1+r)}\frac{1}{(1-\tau)} \quad . \tag{3}$$

The first term is the present value of expected claim costs, and the second term is the present value of the tax costs on capital grossed-up to reflect that premiums must cover tax costs and that premiums themselves are taxable.

The net premium loading, defined as the difference between the premium and the present value of expected claim payments, is the second term in equation (3). Since corporate taxes are the only market imperfection in this model, the net premium loading is also a measure of the tax costs on capital. Dividing the net premium loading by the present value of expected claim costs gives the tax costs per dollar of expected indemnity:

$$\text{Tax cost per dollar of expected indemnity} = \frac{K\tau r}{E(X)(1-\tau)} \quad . \tag{4}$$

This scaling measures the tax costs in a form that is relevant to consumers. Expected utility theory predicts that demand for coverage falls with the policy's proportional loading - the difference between the premium and expected claim costs divided by expected claim costs (see e.g., Ehrlich and Becker, 1972). The proportional loading or a similar variable often is used to measure the price of insurance.

Equations (3) and (4) are functions of the level of capital. The no insolvency constraint, equation (1), can be used to solve for P, K, and the tax costs as a function of the exogenous parameters: τ, r, E(X), and M. The resulting solutions are:

$$P = \frac{E(X)}{1+r} + \frac{[M - E(X)]\, r\tau}{(1+r)(1+r-\tau)} \quad ,$$

Myers and Kolb (1998).

$$K = \frac{[M - E(X)](1 - \tau)}{(1 + r - \tau)}$$, and

$$\text{Tax cost per dollar of expected indemnity} = \frac{[M - E(X)] r\tau}{E(X)(1 + r - \tau)} .$$

An important parameter in these expressions is the difference between the maximum loss and the expected loss. This difference is the primary determinant of the amount of capital, which in turn affects the tax costs and the premium. Holding other factors constant, the tax costs per dollar of expected indemnity increase with the maximum claim cost, the tax rate, and the interest rate. The tax costs decrease as expected claim costs increase, all else equal.

Table 1 illustrates the magnitude of the tax costs per dollar of premium under various sets of parameter values. In the first four scenarios, the tax rate is 25%, the interest rate is 6%, and the expected loss equals $2 billion. The first four rows therefore differ only in the maximum possible claim cost. When the maximum possible loss is $4 billion, the tax costs equal 1.8% of the present value of the expected indemnity. When the maximum possible loss is $50 billion, the tax costs equal 44.4% of the expected indemnity, and when the maximum possible loss is $100 billion, the tax costs equals 90.7% of the expected indemnity.

This model suggests that the tax costs can be significant when insurers need to hold large amounts of capital in relation to expected indemnities. Tax costs will often be high for catastrophe insurance/reinsurance because the amount of capital needed is large in relation to the expected indemnity. This result is especially likely for high "layers" of coverage that involve low probability outcomes. There are several shortcomings of the model, however, including (1) assuming zero default risk, (2) assuming a symmetric tax structure, (3) not incorporating a realistic probability distribution for catastrophe losses, and (4) not incorporating specific insurance contract features, such as attachment points and limits. The more general model developed in the following section addresses these points.

4. Model with Non-Zero Insolvency Risk and Asymmetric Taxes

4.1 Basic Approach

Again we consider an annual reinsurance contract, but in this model α equals the attachment point (the value of losses that must be exceeded before the insurer begins to pay claims) and λ equals the coverage limit. For example, if α = \$10,000 and λ = \$20,000, then the policy provides coverage of \$20,000 above \$10,000. Catastrophe losses, L, are described by the probability density function, f(L). Catastrophe claims (as opposed to losses) depend on the policy's attachment point (α) and limit (λ).

Instead requiring no insolvency, we impose the constraint that the ratio of expected unpaid claim costs to total expected promised claim costs equals an exogenous parameter γ. This constraint is similar to fixing the value of an insurer's insolvency put option (per dollar of expected claim costs).[10] With this constraint, the amount of insurer capital depends on the exogenous parameter γ, the terms of the insurance contract (α and λ), and the specific loss distribution assumed. In addition, the amount of capital depends on the endogenous equilibrium premium, which in turn depends on the tax costs of holding capital. In practice, γ is endogenous; its level reflects the costs and benefits of holding capital. Given our purpose, however, we do not model capital choice.[11] Instead, we simply vary γ to assess the importance of insolvency risk on our results.

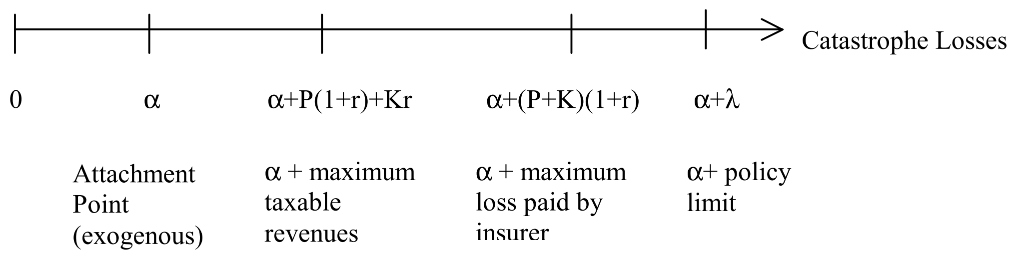
Unlike the model in Section 2, the tax treatment of income depends on the value of losses experienced during the year. Underwriting profits and investment income are taxed at the rate τ if taxable earnings are positive. If taxable earnings are negative but the insurer is still solvent, then the insurer receives a tax shield equal to $b\tau$, where $b \leq 1$. The parameter b represents the reduction in the

[10] Cummins, Harrington, and Niehaus (1993) discuss how risk-based capital requirements can be viewed as imposing a constraint on the value of an insurer's insolvency put option. We obtain similar results if we assume that the probability of insolvency must equal an exogenous constraint.

[11] To incorporate insurers choice of capital would require us to incorporate factors, such as franchise value or quality-sensitive demand, that cause insurers to benefit from lower insolvency risk. Since our objective is to quantify the tax costs, incorporating factors such as franchise value and quality-sensitive demand would present the problem of quantifying their importance, which research to date has not been able to do.

value of an insurer's tax shields as a result of having to carry them forward to offset future income. If the insurer is insolvent, then the tax shield on losses is zero, i.e., there is no value to loss carryforwards. These assumptions imply that the marginal tax rate as a function of claim costs equals τ up to the point where claim costs equals premiums and investment income. The marginal tax rate then drops to $b\tau$ until the point is reached where claim costs cause insolvency; then the marginal tax rate equals zero.

With this model, it is useful to divide possible catastrophe losses into four ranges as illustrated in the following diagram:



The first range consists of losses below the attachment point, α. The second range contains losses from the attachment point up to the point where claims exhaust taxable revenues, $\alpha+P(1+r)+Kr$. The third range of losses goes to the point where claim costs cause insolvency, which equals $\alpha+(P+K)(1+r)$. In the fourth range, the insurer is insolvent.

The end of year payoff to the owners of the insurer depends on the range in which the value of catastrophe losses fall. The following table gives the possible payoffs.

Range of Losses	Owners' Payoffs
$0 \le L < \alpha$	$\Pi_1 = (K+P)(1+r) - \tau\,[P(1+r) + Kr]$
$\alpha \le L < \alpha+P(1+r)+rK$	$\Pi_2 = (K+P)(1+r) - (L - \alpha) - \tau[P(1+r) + Kr - (L - \alpha)]$
$\alpha+P(1+r)+rK \le L < \alpha+(P+K)(1+r)$	$\Pi_3 = (K+P)(1+r) - (L - \alpha) + \tau b[(L - \alpha) - P(1+r) - Kr]$
$\alpha+(P+K)(1+r) \le L < \infty$	0

The expected payoff to owners must equal what they could obtain in the capital market; therefore, the following equation must be satisfied:

$$K(1+r) = \int_{0}^{\alpha} \Pi_1 f(L)dL + \int_{\alpha}^{\alpha+P(1+r)+Kr} \Pi_2 f(L)dL + \int_{\alpha+P(1+r)+Kr}^{\alpha+(P+K)(1+r)} \Pi_3 f(L)dL. \quad \textbf{(5)}$$

We refer to this equation as the capital market equilibrium constraint.

The insolvency constraint described earlier can be written as follows:

$$\gamma = \frac{\int_{(K+P)(1+r)+\alpha}^{\alpha+\lambda} [L - (K+P)(1+r) - \alpha] f(L)\, dL + \int_{\alpha+\lambda}^{\infty} [\lambda - (K+P)(1+r)] f(L)dL}{\int_{\alpha}^{\alpha+\lambda} (L - \alpha) f(L)\, dL + \int_{\alpha+\lambda}^{\infty} \lambda f(L)dL}. \quad \textbf{(6)}$$

The numerator is the expected value of unpaid claims and the denominator is the expected value of promised claim payments.

The insolvency constraint, equation (6), and the capital market constraint, equation (5), provide two equations that can be solved for the two unknowns: capital (K) and premium (P). The solutions are obtained numerically for a specific loss distribution to be described below. Expected tax costs equal the difference between the premium and the present value of expected claim costs. For comparison purposes, we again scale expected tax costs by the discounted value of the expected indemnity.

4.2 Catastrophe Loss Distribution

We use a loss distribution that reflects total U.S. catastrophe loss experience. We therefore are measuring the capital costs for an entity (or insurance/reinsurance pool) that insures all the catastrophe exposures in the U.S. By assuming that the entity has complete diversification within the set of U.S. catastrophe exposures, we overstate the extent to which some insurers/reinsurers are diversified with respect to catastrophe risk, and understate the extent of diversification of others.

Issues related to diversification with other loss exposures, within the U.S. or with catastrophe losses from other countries, are discussed later in the paper.[12]

To identify a distribution for U.S. catastrophe losses, we start with the results reported in Cummins, Lewis, and Phillips (1999), who fit loss distributions to actual catastrophe losses and to catastrophe losses simulated by a major catastrophe modeling firm, Risk Management Solutions (RMS). Their analysis suggests that the frequency of catastrophe losses has a Poisson distribution and the severity of catastrophe losses is lognormal. We use these distributions to numerically estimate the distribution for total annual catastrophe losses. In particular, we use the parameter estimates provided in Cummins, et al., for the Poisson and lognormal distributions describing the RMS data to simulate 25,000 annual observations for catastrophe losses. We then identify the probability distribution that best fits the simulated data, where the distribution with the best fit is defined as the distribution with the lowest chi-squared statistic.[13] The result of this process indicates that annual national catastrophe losses (in $ millions) can be described by a lognormal distribution with a mean equal to $7.045 billion and standard deviation equal to $9.382 billion. Figure 1a illustrates the density function for this lognormal distribution, and Table 2 provides some descriptiove characteristics of the distribution. For example, the probability that catastrophe losses exceed $10 billion is 0.197, and the probability that catastrophe losses exceed $50 billion is about 0.007.

4.3 Illustrative Results

Table 3 provides some illustrative results from solving the model in the previous section using the fitted lognormal distribution for national catastrophe losses. We solve numerically for the present value of expected claim costs, capital (K), premiums (P), and the tax costs per dollar of

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[12] The analysis also provides an estimate of the tax costs that would be avoided if a particular layer of coverage were provided by a government reinsurance program that was exempt from taxes. Catastrophe reinsurance programs of this type have been introduced in Congress and advocated by some analysts (see e.g., Lewis and Murdoch, 1996).

[13] We compared using Crystal Ball the following distributions: lognormal, extreme value, Weibull, gamma, beta, logistic, Pareto, and exponential.

expected claim costs for successive layers of $25 billion of catastrophe insurance coverage. Initially, each coverage layer is evaluated assuming that the expected value of unpaid claims due to insurer default equals 5 percent of promised claim payments (γ=0.05), an interest rate of 6%, a marginal tax rate of 25% when taxable income is positive, and a marginal tax rate of 12.5% (b=0.5) when taxable income is negative.

Panel A of Table 3 indicates that for the lowest layer of coverage ($25 billion excess of $0), the expected tax costs as a percentage of the present value of expected claim costs equal 10.5%. For the next coverage layer ($25 billion excess of $25 billion), the expected tax costs equal 115.0%. For the next two successive layers of $25 billion of coverage, the expected tax costs equal 451.7% and 1,293.0%, respectively. Thus, for the high coverage layers the tax costs are a substantial fraction of the present value of expected claim costs. It is not too surprising that the demand for coverage by policyholders or insurers would be relatively low at prices that are double or triple expected indemnity payments.[14]

Table 4 illustrates how the parameters of the model influence the tax costs for the $25 billion layer of coverage above $25 billion. The first panel illustrates the effect of insolvency risk. As the expected default cost parameter (γ) increases, tax costs on insurer capital decline because insurers can hold less capital. On the other hand, the tax costs due to the asymmetry in the tax code increase with the expected value of unpaid claims, because of the assumption that insurers lose the value of tax shields if they default. Overall, the magnitude of the effect of insolvency risk on total tax costs is relatively small. For example, with zero default risk, expected tax costs equal to 115.3%. Allowing the insurer to default on 10% of its promised claim payments results in expected tax costs equal to 109.8% of the expected indemnity.

[14] The results in Table 3 indicate the tax costs of providing insurance for a particular coverage layer in isolation. Another perspective is to ask what are the additional tax costs of insuring an additional layer of coverage? The implications of the "marginal" analysis are similar to those presented in Table 3. For example, to add the $25 billion excess of $25 billion layer to the $25 billion excess of $0 layer would require additional premium equal to 115.4% of the additional expected claim costs, which is similar to the tax cost reported in Table 3 for insuring this layer in isolation.

The second panel indicates that assumed marginal tax rates have a large impact on tax costs. For example, an increase in the marginal tax rates from 15% to 25% when income is positive and from 7.5% to 12.5% when income is negative increases the tax costs from 61.6% to 115.0% of the present value of expected claim costs. Given the large impact of the assumed tax rates, we further discuss and analyze marginal tax rates later in the paper. The third panel illustrates that the asymmetry in the tax structure has a relatively small impact on the tax costs. With a symmetric tax structure (b=1), the tax costs equal 108.2%. Under a tax system with no value to loss carryforwards (b=0), the tax costs equal 121.8%.

The fourth panel of Table 4 illustrates that higher interest rates increase the tax costs. For example, an increase from 6% to 8% causes the tax costs to increase from 115.0% to 142.8%. The higher tax costs associated with higher interest rates for this layer of coverage cause the premium to increase with interest rates, even though the present value of expected claim costs declines. That is, the increase in total tax costs at a given tax rate outweighs the effect of the higher interest rate on the present value of expected claim costs. This effect contrasts sharply with the analysis of the effect of interest rates on equilibrium premiums found in the existing literature (see e.g., Myers and Cohn, 1987). The more typical negative relationship between interest rates and insurance premiums does hold for low layers of coverage. For example, for the first $10 billion layer of coverage (attachment point equals zero), the tax costs increase modestly with interest rates but the premium decreases with interest rates (not reported).

5. Product and Global Diversification

The preceding results assume the maximum possible diversification within the U.S. market for catastrophe coverage, but they ignore the possible effects of product line and global diversification. Product line and global diversification opportunities alone, however, are unlikely to alter the basic conclusion that the U.S. tax code has a substantial effect on the price of catastrophe insurance. Regardless of the amount of product line diversification, catastrophe coverage will still have a disproportionate effect on the tail of an insurer's total loss distribution and on the required amount of capital to achieve a given level of insolvency risk. Absent large scope economies in administrative/transaction costs across coverages and regions, the incidence of high capital costs for catastrophe risk will be on catastrophe coverage in high-risk regions.

Reducing capital and the attendant tax costs through global diversification of U.S. catastrophe risk is similarly constrained. The U.S. catastrophe exposure represents a large share of potentially insurable global risk because of the high aggregate value of U.S. property exposed to catastrophe loss compared to other countries with less economic development and/or broader government mechanisms for funding catastrophe losses. The 40 largest catastrophes from 1970-1998 cost insurers $107.9 billion in 1998 dollars, and the U.S. share of this total was 61.4% (Hartwig, 1999). Moreover, global risk pooling necessarily entails non-trivial transaction costs with possible diseconomies of scope.[15]

In order to provide some quantitative insight into the possible effects of international diversification on the tax costs of catastrophe coverage, we conducted a simple analysis. Because we do not have data to estimate a non-U.S. loss distribution, we assume that non-U.S. catastrophe exposures have the same distribution as U.S. catastrophe exposures (the distribution used in the previous section), but that the two exposures are uncorrelated. We then examine how the tax costs would be affected if the two uncorrelated exposures were aggregated into a "global portfolio." To aggregate the two distributions, we simulate 20,000 observations on losses for each of the two uncorrelated exposures and sum the results of each draw to obtain 20,000 observations for losses from the global portfolio. Following our earlier procedure, we then fit a variety of distributions to the global loss observations. The lognormal distribution with mean equal to $13.888 billion and standard deviation equal to $12.279 billion has the best fit (minimizes the chi-squared statistic).[16]

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[15] U.S. insurers and reinsurers also must pay an excise tax on premiums ceded to foreign reinsurers. The effects of more favorable income tax treatment of insurer catastrophe reserves in some other countries are briefly discussed in Section 8.

[16] Fitting the aggregate loss distribution allowed us to readily solve our non-linear equation system, which depends on the probability density of aggregate losses. Although the sum of lognormal variates is not

The key issue we wish to address is whether a global portfolio of catastrophe exposures would greatly reduce the tax costs under U.S. tax rules of insuring infrequent, but potentially large losses. We therefore wish to compare the tax costs associated with insuring the global portfolio to the tax costs associated with insuring the U.S. and non-U.S. exposures separately. For illustrative purposes, we consider a $50 billion layer of coverage above $50 billion for each of the individual exposures (U.S. and non-U.S.). The first row of Table 5 indicates that the tax costs of insuring this layer equals 662.4% of the present value of the expected indemnity for each of the exposures, implying a total cost of 1,324.8% of the present value of the expected indemnity if insured separately.

It is impossible to set an attachment point and limit for a policy covering the global portfolio that will cover the same losses that would be covered under separate $50 billion excess of $50 billion policies for the individual exposures. We therefore solve the model for several policies. Consider first a policy that provides $100 billion of coverage excess of $50 billion for the global portfolio. Any U.S. or non-U.S. loss that would have been covered if insured separately would also be covered under this global policy, but this global policy would cover many losses that the individual policies would not cover. The tax costs for this policy as percentage of the present value of the expected indemnity is 476.5%. The remaining policies reported in Table 6 for the global portfolio have higher attachment points, and therefore lower overall coverage. For example, when the attachment point equals $60 billion, the tax costs as a percentage of the present value of the expected indemnity increases is 625.9%. This analysis illustrates that while global diversification will reduce the tax costs, the tax costs remain substantial.

5. Investments in Tax-Exempt Securities

Insurers can reduce tax costs by investing part of their assets in tax-exempt bonds and in equity securities. In the previous model, we implicitly allowed for investment strategies that reduce

lognormal, our numerical approach should produce results that are qualitatively similar to using the empirical distribution.

taxes by assuming that insurers face a marginal tax rate equal to 25% when taxable income is positive, instead of the higher statutory rate that typically applies. In this section, we examine the issue of investment in tax-exempt bonds in more detail.

With non-taxable investment income, an insurer faces two marginal tax rate schedules: one for underwriting income and one for investment income. Let τ_U equal the marginal tax rate on underwriting income, which for now we treat as exogenous. Then the marginal tax rate on investment income, τ_I, depends on the percentage of assets invested in tax-exempt securities, η, and the rates of return on taxable securities, r_T, and tax-exempt securities, r_E. Specifically,

$$\tau_I = \left[\frac{(1-\eta) r_T}{(1-\eta) r_T + \eta r_E} \right] \tau_U . \qquad \textbf{(7)}$$

Equation (7) states that the marginal tax rate on investment income is proportional to the marginal tax rate on underwriting income, where the proportionality factor equals the proportion of investment income that is derived from taxable securities.[17] For example, if 50% of assets are invested in taxable securities and the rates of return on taxable and tax-exempt securities are 6% and 5%, respectively, then the marginal tax rate on investment income is 54.5% of the marginal tax rate on underwriting income. Of course, there is also an implicit tax from investing in tax-exempt securities due to the difference in rates of return. With returns of 6% and 5%, respectively, on taxable and tax-exempt securities, the implicit tax rate is 16.7%.

Under certainty, Hendershott and Koch (1980) show that if the after-tax return on taxable bonds exceeds the tax-exempt rate, then all of an insurer's assets should be invested in taxable securities. If the after-tax return on taxable bonds is less than the tax-exempt rate, then the optimal

[17] The ability to invest in tax-exempt securities also influences the expected marginal tax rate on underwriting income. As discussed in the next subsection, marginal tax rates depend on the probability distribution of future taxable earnings, which are affected by investment policy. As the proportion of assets invested in tax-exempt securities increases, expected future taxable earnings decline. When current taxable income is positive, lower expected future earnings implies that there is a higher likelihood of loss in the future, which can be carried back to offset the taxes paid on current income. As a result, the expected marginal tax rate on current taxable income falls. In addition, when current taxable income is negative, lower expected future earnings imply that there is a lower likelihood of positive income in the future, which reduces the value of the loss carryforward associated

policy is to invest just enough in taxable securities so that taxable investment income offsets underwriting losses. The remainder of the assets are invested in tax-exempt bonds. Cummins and Grace (1994) and PonArul and Viswanath (1995) show that uncertainty can lead to different asset allocation rules.[18] Using a model that incorporates similar tradeoffs as our model, PonArul and Viswanath show that the optimal fraction of assets to invest in tax-exempt bonds varies continuously between zero and one. If the tax-exempt rate is sufficiently lower than the taxable rate, then it is optimal to invest zero percent in tax-exempts. Holding the taxable rate constant, the percentage invested in tax-exempt bonds gradually increases as the tax-exempt rate increases, and the percentage invested in tax-exempts reaches 100 percent before the tax-exempt rate reaches the insurer's after-tax return on taxable bonds.

The important insight of PonArul and Viswanath (1995), for our purposes is that the percentage invested in tax-exempt bonds depends on the probability distribution of taxable income.[19] All else equal, the proportion of assets invested in tax-exempt bonds increases as the likelihood of positive taxable income increases. For catastrophe insurance coverage, the likelihood of negative taxable income is relatively low (high catastrophe losses are rare). Consequently, the disadvantage of investing in tax-exempt bonds is relatively low for catastrophe insurers, especially those insuring high layers of coverage. This intuition is supported by our model. When we incorporate the ability to invest in tax-exempt securities and assume that the tax-exempt rate equals 5%, the taxable rate equals 6%, and the tax rate equals 25%, we find that the optimal investment policy (the one that minimizes

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with the current year's loss. Thus, investment in tax-exempt securities implies that the marginal tax rate schedule on underwriting income will be lower.

[18] Cummins and Grace (1994) focus on the effects of the Tax Reform Act of 1986 on insurer investment behavior.

[19] To see the tradeoffs, consider the decision to invest an additional dollar in tax-exempt securities. The potential benefit is the additional after-tax income, equal to $r_E - r_T(1-\tau)$ when taxable income is positive and the marginal tax rate equals τ. The potential cost is the lost investment income, equal to $r_T(1-b\tau) - r_E$, when taxable income is negative and the marginal tax rate equals $b\tau$. Thus, the optimal investment in tax-exempt bonds depends on the firm's marginal tax rates (the terms τ and $b\tau$) as well as the likelihood of taxable income being positive or negative.

the price of insurance) is to invest 100% of the assets in tax-exempt bonds.[20] One-hundred percent investment in tax-exempt bonds implies that the tax costs associated with catastrophe insurer equity capital is largely due to the implicit tax rate, which is determined by the difference in the yields between taxable and tax-exempt securities, which given the rates assumed equals 16.7%.

The results of solving the model assuming that 100% of the insurer's assets are invested in tax-exempt bonds are reported in Table 6. Although the tax costs are lower when insurers invest in tax-exempt securities, the results reported in Table 6 indicate that the tax costs as a percentage of the present value of expected indemnity remain substantial, especially for high layers of coverage. For example, the $25 billion layer of coverage above $25 billion, the tax costs equal 85.6% of the present value of the expected indemnity.

6. Implications of Loss Carryforwards and Carrybacks for Expected Marginal Tax Rates

We previously assumed that insurers are taxed at a rate of τ (e.g., 25%) when income is positive and that they receive a tax refund equal $b\tau$ (e.g., 12.5%) on each dollar of losses that exceeds taxable revenue up to the point of insolvency. The parameter b captured the reduction in value of tax shields as a result of having to carry them forward to offset future income. The parameters τ and b were taken as exogenous. However, as Graham, Lemmon, and Schallheim (1998) discuss, marginal tax rates depend on other firm decisions and the probability distribution of future earnings.[21]

In practice, insurers (and other corporations) can carry losses back to receive refunds on taxes previously paid and forward to reduce taxes on future profits. As discussed by Graham (1996), these provisions can affect a firm's marginal tax rate in unexpected ways. For example, if the statutory tax rate equals 35%, then a firm with losses in a given year can face a marginal tax rate equal to 35% if those losses can be carried back to offset tax payments on profits earned during the previous years. If carrying losses back is not possible, the marginal tax rate could turn out to be close to 35% if the firm

[20] For the layer of coverage with a zero attachment point and $10 billion limit, we find that interior investment policies are optimal for some parameter values.

has high profits during the next year that permit the loss in the current year to be carried forward to offset taxes on next year's profits. For example, if the appropriate discount rate is 10%, the marginal tax rate on the current year's loss would be 0.35/1.1 = 31.8% if the loss is used to offset profits in the subsequent year. On the other hand, a firm with positive profits in a given year can end up having a marginal tax rate significantly less than 35%. For example, if the firm experiences a loss in the subsequent year that permits a full refund on the taxes paid during the current year, then the marginal tax rate will be 0.35 – 0.35/1.1 = 3.2% (assuming a discount rate of 10%). These examples illustrate that a firm's effective marginal tax rate on an additional dollar of income depends on the realization of future cash flows. Therefore, a firm's expected marginal tax rate reflects an average rate over possible realizations of future cash flows.

The tax loss carryback and carryforward provisions imply that the taxes paid by an insurer on current year's profits (or the refund actually received from current year's losses) depends on the future realization of claims costs and on future premiums and capital.[22] Developing a dynamic equilibrium model for premiums, capital, and marginal tax rate schedules is intractable. We follow a less ambitious approach, but one that is likely to provide insights into the importance of loss carryforward and carryback provisions for determining the expected marginal tax rate schedule of catastrophe insurers. Using the results of the previous model as a guide, we first set premiums and capital for each year, and simulate an expected marginal tax rate schedule as a function of current year claim costs.[23] The appendix describes the simulation procedure, which is similar to the method used by Graham (1999) to simulate marginal tax rate schedules for a broad set of corporations.

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[21] For earlier discussion of these issues, see Altshuler and Auerbach (1990) and Shevlin (1990).

[22] If, as we assume, losses can be carried back three years and forward 15 years, then the next 18 years are potentially relevant to calculating the actual tax paid on the current income, because the current year's losses can be carried forward 15 years and the effective tax on profits 15 years from the current year can be influenced by losses in years 16 through 18. The past three years of earnings also can influence an insurer's marginal tax rate. However, we take a long-run equilibrium perspective and analyze the effects of loss carryforward and carryback provisions assuming that an insurer has no history.

[23] The simulation assumes a statutory rate of 35% and the ability to carry losses back three years and forward 15 years.

The simulation yields an expected marginal tax rate for each level of current year claim costs. Consider, for example, an insurer that is providing $25 billion of coverage in excess of zero. If current year claim costs equal $2.5 billion, then, as reported in Table 7, the expected marginal tax rate equals 28.7%. If current year claim costs equal $5 billion, then the expected marginal tax rate equals 27.7%. Not surprisingly, the expected marginal tax rate declines as current year claim costs increase. In contrast to our earlier assumption that the marginal tax rate was a step function (25% until claim costs equal taxable revenue, 12.5% until claim costs cause insolvency, and zero thereafter), the simulation results indicate that the expected marginal tax rate declines gradually as current year claim costs increase for the lower coverage layers. For the higher layers, however, the marginal tax rate quickly drops to zero after current year losses exceed a minimal level. The reason is that premiums are so low that the insurer will not be able to utilize all loss carryforwards once losses exceed a certain level.

To investigate the impact of the simulated expected marginal tax rates on our earlier results, we fit an exponential model to the simulated expected marginal tax rate data in the first column of Table 7. In particlar, we estimate MTR = $\tau_0 e^{-\delta X}$, where MTR is the expected marginal tax rate, X is the value of current year claim costs, τ_0 equals the expected marginal tax rate when current year claim costs are zero (given in the first row of Table 7), and δ is the rate of decay for the marginal tax rate as current year claim costs increase. Using the marginal tax rates for the lowest layer of coverage (column two of Table 7) to estimate the decay parameter, we find that $\delta = 0.00005$. Since the marginal tax rates for the higher coverage layers abruptly drop to zero, we do not estimate a separate exponential model for these layers.

We then solve our model using an exponential marginal tax rate schedule instead of the step function used earlier. For the first coverage layer ($25 billion excess of zero), we use the estimated decay parameter. For the other coverage layers, we simply double the decay parameter to account for the faster rate of decline in the simulated marginal tax rates. We continue to assume that all of the insurer's assets are invested in tax-exempt bonds and that the yield on taxable bonds equals 6% and the tax-exempt yield equals 5%. The results are reported in Table 8. Comparing these results with those reported in Table 6, we see that the estimated exponential marginal tax rate schedule leads to higher tax costs. The results therefore do not alter the main conclusion that the tax costs associated with insuring catastrophes are substantial, especially for high layers of coverage.

7. Personal Taxes

As discussed in Miller (1977), equity securities have a personal tax advantage relative to debt securities, because the capital gains on equity are taxed at a lower rate than interest income and because the capital gains tax can be deferred. This differential tax treatment can cause expected returns that corporations must pay on debt to be higher than the expected returns they must pay on equity, holding other factors (e.g., risk and liquidity) constant. Consequently, the corporate tax disadvantage of equity may be offset, at least in part, by the personal tax advantage of equity.[24]

Green and Hollifield (1999) estimate that investors can reduce taxes by about 50% if they receive cash distributions through share repurchases as opposed to dividends or interest payments. This evidence suggests that the personal tax advantage of equity cannot be dismissed, implying that investors will require a lower expected rate of return than we have been assuming in our model. The left-hand side of equation (5) sets the required expected rate of return on equity capital equal to r, which is the before-tax return on taxable bonds (recall that risk is diversifiable by investors). When equity capital receives preferential personal tax treatment, the expected before-personal-tax return on capital will be less than the before-tax return on bonds, holding risk constant.

To examine the possible effect of personal taxes on our results, we assume that the personal tax rate on interest income is 33.3%, and based on the results of Green and Hollifield (1999) that the

[24] Note that these arguments do not apply to the main type of debt financing used by insurers – i.e., policyholder liabilities. Personal property insurance premiums and claim payments are neutral with respect to taxes. Returns on personal life insurance and corporate insurance receive preferential tax treatment.

effective personal tax rate on equity returns is 16.7%.[25] If taxable bonds yield 6%, then the required expected return on equivalently risky equity securities would be 4.8% (i.e., 4.8%(1-0.167) = 6%(1-0.333)). The results of solving the model using a required return on equity of 4.8% are presented in Table 9. The tax costs for each layer of coverage are lower than those reported in Table 3, which shows comparable results without the personal tax advantage of equity. The effect of personal taxes is especially pronounced for the higher layers of coverage. For example, for the layer of coverage from $50 to $75 billion, the tax costs drop from 451.70% to 110.7% of the present value of the expected indemnity. Nevertheless, the tax costs are still material. Premium loadings of 110.7% due solely to taxes are likely to have a material impact on the quantity of coverage purchased.

7. Other Factors Mitigating the Tax Costs

7.1 Offshore Reinsurance

Large catastrophe losses in the late 1980s and early 1990s led to entry and significant growth of offshore reinsurers providing coverage to domestic catastrophe insurers and reinsurers. The additional capacity was created in tax-advantaged jurisdictions, such as Bermuda, that impose little or no corporate income tax. More generally, international reinsurers operate under more favorable tax rules than U.S. insurers and reinsurers. Although material transaction costs (and, as noted, a federal excise tax) are incurred by U.S. insurers and reinsurers that cede coverage abroad, lower tax costs provide a significant motivation for the use of offshore reinsurance. The growth during the 1990s of catastrophe reinsurance in offshore tax-advantaged jurisdictions, such as Bermuda, is consistent with our finding that the tax costs on U.S. catastrophe insurer equity are substantial.

7.2 Subordinated Debt

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[25] Similar estimates for the effective tax on equity returns are obtained using reasonable parameter values for holding periods, tax rates, and rates of return. For example, assuming a statutory capital gains rate of 20%, a 10 year holding period, and a 6% annual capital gains return, the effective tax rate on the capital gains equals 16.8%.

Stockholder-owned insurers issue traditional debt instruments at the holding company level that are subordinated to policyholder claims against subsidiary insurers. Thus, part of the consolidated equity for the holding company's subsidiary insurers is backed by debt at the holding company level. Subordinated debt reduces the tax costs of bonding the insurer's promise to pay claims, but such debt represents a relatively small proportion of long-term capitalization in the industry. At year-end 1997, long-term debt represented 15% of total capital for the 85 largest stock insurer holding companies specializing in commercial lines coverage. The corresponding ratios for the 26 largest stock personal lines companies and 17 largest reinsurers were 19% and 10%, respectively.[26] These data exclude mutual and reciprocal insurers, which often make modest use of surplus notes, a regulated form of subordinated debt.

As is true for non-financial corporations, a variety of factors impede greater reliance on debt finance by insurers. One cost arises because accessing debt capital to pay policyholder claims (e.g., following a catastrophe) can cause default on the debt, which, when publicly revealed, will likely lower future demand for the insurer's policies. Stated differently, greater use of debt financing (in place of equity capital) increases the likelihood that the insurer's franchise value will be eroded, which largely reflects quasi-rents from prior investment in building its book of business. Greater use of debt also can contribute to an underinvestment problem (Myers, 1977, Cummins and Danzon, 1997). Specifically, following a capital shock that produces a significant backward shift in industry supply (e.g., due to a large catastrophe), debtholders will resist allowing an insurer to expand supply and earn short-run profits.[27]

Some of the benefits of debt discussed in the literature also are likely to be of reduced importance for catastrophe insurers. For example, Harris and Raviv (1990) highlight how debt

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[26] Data reported in *Best's Holding Company Guide*, 1998 edition. Total capital excludes unrealized gains and losses on fixed maturity instruments. Property-Liability insurers also have issued modest amounts of trust preferred stock and related instruments, representing 4.5%, 5.9%, 3% of total capital for the commercial lines, personal lines, and reinsurance groups, respectively, at year-end 1997.

[27] Monitoring insurer risk levels, however, is a benefit of subordinated debt highlighted in the banking literature (see e.g., the discussion in Flannery and Sorescu (1996).

provides information to investors about management performance. More specifically, information is provided by (1) the firm's ability to make debt payments and (2) in the event of default, investors receive additional information, albeit at a cost, that can be used to alter the firm's policies or liquidate. For catastrophe insurers, however, this informational role of debt is not likely to be of significant value, because the occurrence of a catastrophe is readily observable and outside of the control of management. Thus, a catastrophe insurer's default, due to a catastrophe, is not likely to reveal valuable information, but the default would cause significant costs (either through insolvency proceedings or a private workout) under a traditional debt structure.

7.3 Catastrophe Bonds

The 1990s have seen the emergence of catastrophe bonds as a new form of contingent, subordinated debt for financing catastrophe loss. For regulatory and tax purposes, these bonds generally have been issued through an offshore special purpose vehicle (SPV). The funds raised from catastrophe bonds provide capital to support a catastrophe reinsurance contract sold by the SPV to an insurer or reinsurer. The bonds make payment of interest and, in many cases, principal contingent on the insurer's (or industry) catastrophe loss experience. In the event of a specified catastrophe loss, the interest and possibly some, or all, of the principal will not be paid to investors, without triggering default and the associated costs. In exchange for bearing catastrophe risk, the securities promise investors a yield that substantially exceeds the risk-free return.

In the context of this paper, the salient aspect of catastrophe bonds is that they fund catastrophe insurance/reinsurance in a way that reduces or eliminates the tax costs of equity, and simultaneously avoids the problems with using subordinated debt.[28] The tax savings, however, presently can only be achieved by incurring significant costs to meet regulatory and tax rules relating to these instruments. In particular, considerable care must be taken to ensure that the SPV is not subject to U.S. corporate tax in order to make the transactions economically viable (Davidson, 1998). Among other issues, this objective generally requires the SPC to be incorporated and operated exclusively in a tax-advantaged jurisdiction.

8. Conclusions

Credibly insuring large catastrophe losses requires insurers/reinsurers to hold large amounts of equity capital in relation to expected claim costs. The U.S. corporate income tax produces large tax costs on this capital and correspondingly large tax loadings in catastrophe insurance premiums, thus reducing the scope of private sector insurance against catastrophe losses. By substituting for insurer equity, a variety of insurer strategies reduce the tax costs of U.S. catastrophe insurance, including product line and global diversification, investment in tax exempt securities, subordinated debt, catastrophe bonds, and offshore reinsurance. However, these strategies also entail costs, and, more important, our analysis suggests that sizable tax costs remain after their use.

Our results have obvious implications for the on-going policy debate over catastrophe insurance. To date, the primary governmental response to perceived problems in catastrophe insurance markets has been to establish or propose establishing government insurance programs. Federal insurance programs for weather-related (and other) losses to agricultural production and for flood losses to residential property have been in effect for decades. In November 1999, the U.S. House Committee on Banking and Financial Services approved a bill that would create a federal catastrophe reinsurance program and thereby significantly expand the federal government's role in other forms of catastrophe insurance. State-run catastrophe insurance/reinsurance mechanisms were created in three states (California, Florida, and Hawaii) following large catastrophe losses in the 1990s. These mechanisms are exempt from federal income tax, an advantage that private insurers and reinsurers do not enjoy.

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[28] In addition, funds raised from issuing catastrophe bonds are placed in a trust that cannot be accessed for other purposes, which might reduce potential agency costs of holding capital to back catastrophe

Rather than expanded government insurance, our analysis suggests the strategy of modifying U.S. tax law to reduce the costs of providing catastrophe insurance in the private sector. Possible approaches that are specific to the insurance/financial sector include (1) allowing U.S. insurers/reinsurers to establish tax-deferred reserves, as has been proposed in the U.S. House, and (2) changing tax and regulatory rules to facilitate onshore arrangements for catastrophe bonds and reduce associated transaction costs. These policies would help create a level playing field with respect to tax costs for domestic insurance/reinsurance, offshore reinsurance, and catastrophe bonds. More generally, our analysis suggests a specific advantage – cheaper and more abundant catastrophe insurance – of some form of integration in U.S. corporate and personal income taxes.

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insurance/reinsurance.

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Table 1

Tax costs of equity capital using a model with no insolvency and symmetric taxes; values in millions

Exogenous Parameters						
Tax rate (τ)	Interest rate (r)	Expected claim costs [E(X)]	Maximum Claim Cost (M)	Capital (K)	Premium (P)	Tax costs per $ of expected indemnity
0.25	0.06	$2,000	$4,000	$1,852	$1,922	1.9%
0.25	0.06	$2,000	$10,000	$7,407	$2,027	7.4%
0.25	0.06	$2,000	$25,000	$21,296	$2,289	21.3%
0.25	0.06	$2,000	$50,000	$44,444	$2,725	44.4%
0.25	0.06	$2,000	$100,000	$90,741	$3,599	90.7%

Table 2

Characteristics of the Fitted Distribution for U.S. Catastrophe Losses

	Lognormal distribution with logarithmic mean = 8.35 and logarithmic standard deviation = 1.01
Expected Loss	$7.045 billion
Probability Loss > 10 billion	0.197
Probability Loss > 20 billion	0.062
Probability Loss > 30 billion	0.026
Probability Loss > 40 billion	0.013
Probability Loss > 50 billion	0.007
Probability Loss > 70 billion	0.003
Probability Loss > 90 billion	0.001

Table 3

Tax costs as a percentage of the present value (PV) of expected claim costs under policies with various attachment points using the model in section 3 and the assumption that claim costs follow a lognormal distribution with logarithmic mean and standard deviation equal to 8.35 and 1.01, respectively.

Exogenous Parameters						Endogenous Variables (in millions)			
Attachment Point (α)	α + Limit (λ)	Insolvency constraint (γ)	Tax rate (τ)	Value of unused tax shields (b)	Interest rate (r)	Present value of expected claim costs	Premium (P)	Capital (K)	Tax costs as a percentage of PV of Expected claim costs
0	25,000	0.05	0.25	0.5	0.06	$5,761	$6,364	$11,443	10.5%
25,000	50,000	0.05	0.25	0.5	0.06	399	859	20,044	115.0%
50,000	75,000	0.05	0.25	0.5	0.06	92	510	20,975	451.7%
75,000	100,000	0.05	0.25	0.5	0.06	32	441	21,289	1293.0%

Table 4

Tax costs as a percentage of the present value (PV) of expected claim costs under different assumptions about expected default costs (γ), marginal tax rates (τ and b), interest rates (r)

Exogenous Parameters						Endogenous Variables (in millions)			
Attachment Point (α)	α + Limit (λ)	Insolvency constraint (γ)	Tax rate (τ)	Value of unused tax shields (b)	Interest rate (r)	Present value of expected claim costs	Premium (P)	Capital (K)	Tax costs as a percentage of PV of Expected claim costs
25,000	50,000	0.00	0.25	0.5	0.06	420	905	22,679	115.3%
25,000	50,000	0.05	0.25	0.5	0.06	399	859	20,044	115.0%
25,000	50,000	0.10	0.25	0.5	0.06	378	794	17,803	109.8%
25,000	50,000	0.05	0.15	0.5	0.06	399	646	20,258	61.6%
25,000	50,000	0.05	0.25	0.5	0.06	399	859	20,044	115.0%
25,000	50,000	0.05	0.35	0.5	0.06	399	1131	19,773	183.1%
25,000	50,000	0.05	0.25	0.0	0.06	399	886	20,017	121.8%
25,000	50,000	0.05	0.25	0.5	0.06	399	859	20,044	115.0%
25,000	50,000	0.05	0.25	1.0	0.06	399	832	20,072	108.2%
25,000	50,000	0.05	0.25	0.5	0.04	407	757	20,548	85.9%
25,000	50,000	0.05	0.25	0.5	0.06	399	859	20,044	115.0%
25,000	50,000	0.05	0.25	0.5	0.08	392	952	19,564	142.8%

Table 5

Tax costs as a percentage of the present value (PV) of expected claim costs when multiple exposures are aggregated. Each exposure has a lognormal loss distribution with logarithmic mean of 8.35 and logarithmic standard deviation of 1.01. The loss distribution that bests fits simulated losses when two (three) exposures are aggregated is lognormal with logarithmic mean of 9.25 (9.75) and logarithmic standard deviation of 0.76 (0.64).

Exogenous Parameters						Endogenous Variables (in millions)			
α	$\alpha+\lambda$	Insolvency constraint (γ)	Tax rate (τ)	Value of unused tax shields (b)	Interest Rate (r)	Present value of expected claim costs	Premium (P)	Capital (K)	Tax costs as a percentage of PV of Expected claim costs
U.S.Exposure									
50,000	100,000	0.05	0.25	0.5	0.06	$124	$896	$39,635	662.4%
Global Exposure									
50,000	150,000	0.05	0.25	0.5	0.06	$315	$1,444	$57,339	358.3%
55,000	155,000	0.05	0.25	0.5	0.06	$241	$1,391	$59,004	476.5%
60,000	160,000	0.05	0.25	0.5	0.06	$187	$1,358	$60,521	625.9%

Table 6

Tax costs as a percentage of the present value (PV) of expected claim costs when 100% of assets are invested in tax-exempt securities yielding 5% and taxable bonds yield 6%

Exogenous Parameters						Endogenous Variables (in millions)			
Attachment Point (α)	α + Limit (λ)	Insolvency constraint (γ)	Tax rate (τ)	Value of unused tax shields (b)	Interest Rate (r)	Present value of expected claim costs	Premium (P)	Capital (K)	Tax costs as a percentage of PV of Expected claim costs
0	25,000	0.05	0.25	0.5	0.06	$5,761	$6,323	$11,655	9.7%
25,000	50,000	0.05	0.25	0.5	0.06	399	742	20,361	85.6%
50,000	75,000	0.05	0.25	0.5	0.06	92	381	21,308	313.1%
75,000	100,000	0.05	0.25	0.5	0.06	32	310	21,627	879.6%

Table 7

Simulated Expected Marginal Tax Rates Schedules

Simulated marginal tax rates equal the average marginal tax rate from 1,000 simulations of catastrophe losses in years two through 18. The simulation holds premiums, capital, asset allocation, interest rates, statutory tax rates, and policy coverage constant over time. Premiums and capital are set based on solving the equilibrium model with zero insolvency risk. One-hundred percent of the insurer's assets are invested in tax-exempt securities, the return on taxable securities equals 6%, the tax-exempt return equals 5%, the statutory tax rate equals 35%, and the coverage limit is $25,000.

	Assumptions			
Attachment Pt.	$0	$25,000	$50,000	$75,000
Premium	6,669	905	545	474
Capital	16,916	22,679	23,039	23,111
Current Year Claim Cost	**Average Marginal Tax Rate from 1,000 Simulations**			
$0	30.0%	33.1%	34.4%	35.0%
2,500	28.7	28.0	26.8	25.7
5,000	27.7	22.1	19.5	19.1
7,500	23.3	17.4	14.7	14.1
10,000	20.4	12.9	0.0	0.0
12,500	17.4	10.0	0.0	0.0
15,000	14.7	0.0	0.0	0.0
17,500	12.6	0.0	0.0	0.0
20,000	10.5	0.0	0.0	0.0
22,500	9.2	0.0	0.0	0.0
25,000	7.5	0.0	0.0	0.0

	Parameter estimates for the model: MTR = τ_0 exp($-\delta X$), where X = current year claim costs, MTR = average marginal tax rate, τ_0 = the marginal tax rate when current year claim costs = $0, and δ is the parameter to be estimated			
Estimate of δ X 1,000	0.05	na	na	na

[*]The decay parameter, δ, is not estimated when the marginal tax rates abruptly drop to zero, because an exponential function does not fit the data.

Table 8

Tax costs as a percentage of the present value (PV) of expected claim costs using the marginal tax rate schedule estimated in Table 7. 100% of assets are invested in tax-exempt securities yielding 5% and taxable bonds yield 6%

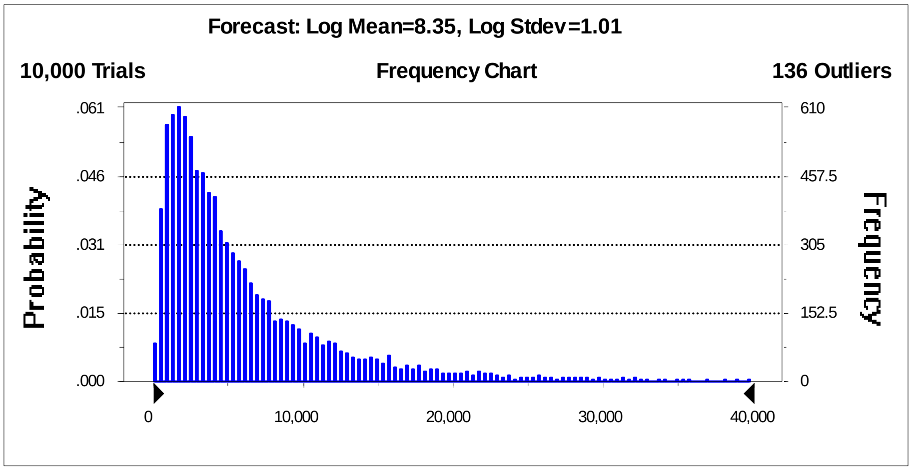
Exogenous Parameters					Endogenous Variables (in millions)			
Attachment Point (α)	α + Limit (λ)	Insolvency constraint (γ)	Tax rate when claim costs equal zero (τ_0)	Exponential decay parameter (δ)	Present value of expected claim costs	Premium (P)	Capital (K)	Tax costs as a percentage of PV of Expected claim costs
0	25,000	0.05	0.30	0.05	$5,761	$6,330	$11,646	9.9%
25,000	50,000	0.05	0.33	0.10	399	796	20,307	99.2%
50,000	75,000	0.05	0.33	0.10	92	408	21,281	341.9%
75,000	100,000	0.05	0.33	0.10	32	331	21,606	945.8%

Table 9

Tax costs as a percentage of the present value (PV) of expected claim costs when personal taxes are considered. Personal tax rate on interest income = 33.3% and on equity income = 16.7%

Exogenous Parameters						Endogenous Variables (in millions)			
Attachment Point (α)	α + Limit (λ)	Insolvency constraint (γ)	Tax rate (τ)	Value of unused tax shields (b)	Interest Rate (r)	Present value of expected claim costs	Premium (P)	Capital (K)	Tax costs as a percentage of PV of Expected claim costs
0	25,000	0.05	0.25	0.5	0.06	$5,761	$6,202	$11,606	7.6%
25,000	50,000	0.05	0.25	0.5	0.06	399	560	20,344	40.1%
50,000	75,000	0.05	0.25	0.5	0.06	92	195	21,290	110.7%
75,000	100,000	0.05	0.25	0.5	0.06	32	121	21,609	282.6%

Figure 1



Forecast: Log Mean=8.35, Log Stdev=1.01
10,000 Trials
Frequency Chart
136 Outliers
Probability
Frequency
.061
.046
.031
.015
.000
610
457.5
305
152.5
0
0
10,000
20,000
30,000
40,000

Appendix

Simulating an Expected Marginal Tax Rate Schedule

Figure A1 outlines the procedure for finding the expected marginal tax rate schedule. First, we fix the policy characteristics, i.e., the attachment point and limit, along with the level of premiums, P, and capital that will be maintained over time. The values for premiums and capital are found by solving the model in Section 3 assuming zero insolvency risk. Second, we fix the value for current year (year 0) claim cost at X. Third, we simulate claim costs for years one through 18 using the lognormal loss distribution described in Section 3. The value for tax payments each year are calculated taking into account the rules for carrying losses forward and backward. Fourth, the present value of tax payments is calculated using an interest rate of 6 percent, and then calculated again assuming that current year claim costs equal $(X-1) instead of $X. The difference in the present value of taxes paid in the two scenarios is the tax paid on an additional dollar of current year income -- the marginal tax rate – under one possible set of outcomes for claim costs during the subsequent 18 years.[29] The third and fourth steps are repeated 999 times, and we calculate the mean of the 1,000 observation sample of marginal tax rates. We then return to the second step, and repeat the simulation for other values of current year claim costs.

[29] We do not allow insolvencies during the course of the simulation.

Figure 2

Description of Marginal Tax Rate Simulation

1. Fix policy characteristics (α, λ), the interest rate (r), premium (P), and capital (K) for years 0 – 18.

2. Fix claim costs for year zero equal to X (e.g., $0).

3. Simulate claim costs for years 1– 18.

4. Perform two calculations using simulated claim costs:

A. PV of tax payments when current year claim costs equal X
B. PV of tax payments when current year claim costs equal X-1

The difference in the PV of tax payments in scenarios A and B is one realization of the marginal tax rate when current year claim costs equal X. Denote this marginal tax rate by τ_1 (X).

Redo steps 3 and 4 999 times to get 1,000 realizations of the marginal tax rate (e.g., τ_2(X), τ_3(X), …τ_{1000}(X))

D. Calculate sample mean of the τ_i(x)'s

Redo step B for different values of claim costs in year 0. For example, for claim costs equal to $2,500 in year 0 obtain 1,000 realizations of τ_i(2,500); calculate mean of these realizations.

Change policy characteristics, premium, and capital