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Capital, corporate income taxes, and catastrophe insurance

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Abstract

We provide estimates of the equity capital needed and the resulting tax costs incurred when supplying catastrophe insurance/reinsurance using a partial equilibrium model that incorporates a specific loss distribution for US catastrophe losses. After consideration of insurer investment in tax-exempt securities, tax loss carry-back/forward provisions, and personal taxes, our results imply that the tax costs of equity finance alone have a substantial effect on the cost of supplying catastrophe reinsurance. These results help explain a variety of industry developments that reduce tax costs. Also, when coupled with non-tax costs of capital, these results help explain the limited scope of catastrophe insurance/reinsurance.

JEL classification: H20; G22; G28; G32

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1. Introduction

The magnitude of the tax disadvantage of equity financing (or equivalently, the tax benefits of debt financing) is an important and sometimes controversial issue in the corporate finance literature (see Graham, 2000). This paper quantifies the tax disadvantage of equity financing for catastrophe insurance arrangements. The focus on this particular sector is interesting and important for several reasons. First, the tax costs have important public policy implications. For example, the desirability of government reinsurance or indemnity

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for large losses from natural catastrophes or terrorism depends on private market supply of catastrophe insurance, which in turn depends on the magnitude of the tax costs. Also, proposals to reduce the tax disadvantage by allowing insurers to establish tax-sheltered reserves for catastrophe coverage have been introduced in the US Congress. Second, as we discuss more fully in the paper, efforts by insurers/reinsurers to mitigate the tax costs help to explain a number of developments in catastrophe insurance/reinsurance markets during the past decade.

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). Typically, equity holders provide most of the capital backing policyholders' claims.[1] The tax, agency, and asymmetric information costs associated with equity finance therefore are part of an insurer's cost of capital and correspondingly an important determinant of the cost of supplying insurance in general and catastrophe insurance/reinsurance in particular. Without implying that agency and asymmetric information costs are unimportant, we focus on the tax costs associated with equity finance. This focus reflects that tax costs are more easily measured and, as mentioned above, taxes are central to public policy proposals related to catastrophe and terrorism insurance. The specific question that we confront is: how large is the tax disadvantage of equity financing in the context of catastrophe insurance? Surprisingly, there has been little research on this question.[2]

We provide "ballpark" estimates of the magnitude of the tax costs of equity financing using a partial equilibrium, single-period model of insurance pricing and capitalization that incorporates specific loss distributions for US catastrophe losses. After consideration of a number of issues, including insurer investment in tax-exempt securities, loss carry-forward and carry-back provisions, and personal taxes, our analysis implies that tax costs of equity capital have a substantial effect on the cost to US insurers of supplying catastrophe reinsurance for high layers of coverage. In many cases, estimates of the tax costs exceed 100% of the present value of expected claim costs. Thus, if the tax incidence falls on consumers, insurers purchasing reinsurance would need to pay more than twice what they expect to receive in claim payments for such coverage. [3] The high levels of capital needed to supply reinsurance translate into relatively high costs of supplying catastrophe coverage in the primary insurance market.

A natural question given our findings is why insurers do not issue 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

[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 roughly 70 percent in 1996. Our discussion, however, focuses on the source of funds used to bond promises to pay policyholder claims.

[2] A number of papers have highlighted the tax disadvantages associated with holding equity capital to bond promises to pay catastrophe claims (e.g., Harrington et al., 1995; Harrington, 1997; Jaffe and Russell, 1997; and Myers, 1999), but we are not aware of any studies that have quantified the magnitude of the tax costs on insurer equity.

[3] 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), Myers and Cohn (1987), and Doherty and Garven (1986).

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. Our analysis also helps to explain the recent growth in catastrophe reinsurance for US risks with offshore (foreign) reinsurers in tax-favored jurisdictions.

In contrast to the considerable research that has been conducted during the past decade on short run disruptions in insurance markets, our focus is on the long-run impact of taxes on insurance markets. We do not analyze the causes of short-run price increases and coverage decreases in catastrophe reinsurance following hurricane Andrew and the Northridge earthquake (see Froot, 2000), or the price increases and apparently acute reductions in private sector capacity to insure losses from terrorism following the destruction of the World Trade Center. 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, 1995; Cummins and Danzon, 1997; and Froot and O'Connell, 1999). Stein (1999) notes that the costs of holding capital are also important for these explanations, for if capital costs were low then insurers would simply hold sufficient capital to withstand shocks. Thus, the magnitude of tax costs on capital is important for the theories that have been used to explain short-run disruptions in insurance/reinsurance markets.

Our analysis also helps to shed light on a puzzle or anomaly in the insurance economics literature highlighted by Froot (2000). Theory suggests that natural catastrophe risk—and, more broadly, any risk that involves a remote possibility of enormous loss—should be shared across a broad base of risk bearers. But property owners often fail to insure catastrophe risk, and when it is insured, primary insurers retain much of the risk, instead of distributing it 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 (2000) estimates that only about 30 percent of US insurance industry catastrophe losses in excess of $8 billion were reinsured in 1998.[4]

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, 1992), incorrect risk assessment (Kleindorfer and Kunreuther, 1999), ex post disaster relief that reduces demand for coverage (Arvan and Nickerson, 1998), high insurer capital costs due to agency problems and/or corporate taxes (Jaffe and Russell, 1997; Harrington, 1997; Zanjani, 2002), and other barriers to capital entering reinsurance (Froot and O'Connell, 1999; Froot, 2000). Our analysis suggests that corporate tax costs may contribute materially to both the limited scope of catastrophe insurance and to a variety of responses to mitigate these costs. However, we do not analyze possible non-tax explanations of the limited sharing of catastrophe risk, and our analysis does not imply that those explanations are unimportant.

The paper proceeds as follows. In Section 2, we present a partial equilibrium model for insurer capital and pricing that incorporates the possibility of insurer insolvency, the

[4] For some reference points, Hurricane Andrew caused about $16 billion of insured losses and the Northridge earthquake caused about $20 billion in insured losses. The probability distribution for US catastrophe losses used later in the paper indicates that the probability that annual US catastrophe losses exceed $10 billion is 0.197 (see Table 3). Also see Swiss (1997)).

asymmetry in the tax treatment of profits and losses, as well as a specific loss distribution that approximates catastrophe losses in the US. The model is solved numerically for the tax costs associated with catastrophe coverage under various parameter values and the results are presented in Section 3. In Section 4, we use the model to assess the effects of global diversification and insurer investment in tax-exempt securities. Section 5 briefly discusses other mitigation efforts, such as offshore reinsurance, subordinated debt finance, catastrophe bonds, and insurer organizational form (mutual and reciprocal organization). Section 6 contains a brief summary.

2. The basic model

2.1. Assumptions

Our objective is to find the equilibrium price and supporting capital for an annual catastrophe reinsurance contract issued by a stock insurer.[5] Claim costs are assumed to be independent of any risk factor that is priced in the capital markets. Premiums, 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 end-of-year, claim costs are paid and the residual funds are distributed to equity holders.

The reinsurance contract is based on the annual aggregate losses from the primary insurer's entire portfolio of catastrophe losses. The primary insurer's annual aggregate loss is denoted by L, which has the probability density function, $f(L)$. The claim amount paid by the reinsurer is determined by two policy parameters: α equals the attachment point or deductible (the value of losses that must be exceeded before the reinsurer begins to pay claims) and λ equals the coverage limit. For example, if $\alpha = \$10$ million and $\lambda = \$20$ million, then the reinsurer pays up to \$20 million of the primary insurer's losses once losses exceed \$10 million.

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.[6] In practice, γ is endogenous; its level reflects the costs and benefits of lower insolvency risk. Given that our purpose is to measure one of the costs of lower insolvency risk—the tax costs associated with holding more capital—we do not model the benefits of lower insolvency risk.[7] Instead, we simply vary γ to assess the importance of insolvency risk on our results.

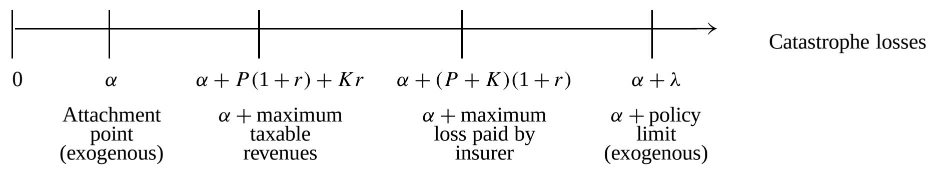
[5] We defer discussion of mutual insurers until Section 5.

[6] Cummins et al. (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.

[7] To incorporate the demand for lower insolvency risk, we would need to incorporate factors, such as franchise value, quality-sensitive demand (Cummins and Danzon, 1997), or foregone investment opportunities (Froot and Stein, 1998) that cause insurers to benefit from lower insolvency risk. Since our objective is to quantify the tax costs, incorporating these factors would present the problem of quantifying their importance, which research to date has not achieved.

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 $b \leqslant 1$. The parameter b represents the reduction in the 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 carry-forwards. These assumptions imply that the marginal tax rate as a function of claim costs equals τ up to the point where claim costs equal 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. [8]

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.[9]

The end of year payoff to the owners of the insurer depends on the range in which the value of catastrophe losses falls. Table 1 gives the possible payoffs.

Table 1

Range of losses	Owners' payoffs
$0 \leqslant L < \alpha$	$\Pi_1 = (K+P)(1+r) - \tau[P(1+r) + Kr]$
$\alpha \leqslant L < \alpha + P(1+r) + Kr$	$\Pi_2 = (K+P)(1+r) - (L-\alpha) - \tau[P(1+r) + Kr - (L-\alpha)]$
$\alpha + P(1+r) + rK \leqslant L < \alpha + (P+K)(1+r)$	$\Pi_3 = (K+P)(1+r) - (L-\alpha) + \tau b[(L-\alpha) - P(1+r) - Kr]0$
$\alpha + (P+K)(1+r) \leqslant L < \infty$	$\Pi_4 = 0$

[8] The parameters τ and b are taken as exogenous. As Graham et al. (1998) discuss, marginal tax rates actually depend on other firm decisions and the probability distribution of future earnings. For earlier discussion of these issues, see Altshuler and Auerbach (1990) and Shevlin (1990). Also see Garven and Louberge (1996). Developing a dynamic equilibrium model for premiums, capital and marginal tax rates schedules is intractable. As described further in Appendix A, we have solved the model with an exponential tax rate schedule, where the parameters for the tax rate schedule were set based on simulations of marginal tax rates as a function of claim costs in a manner similar to Graham (2000). The conclusions of our analysis are unchanged by this analysis.

[9] Whenever there is a positive probability of insolvency, the policy limit (λ) will exceed the value of funds available at the end of the period $(P + K)(1+r)$. If there is no risk of insolvency ($\gamma = 0$), then the insurer will choose $(P + K)(1+r) = \lambda$ and the fourth interval will not exist.

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

$$K(1+r) = \int_0^{\alpha} \Pi_1 f(L)\,\mathrm{d}L + \int_{\alpha}^{\alpha+P(1+r)+Kr} \Pi_2 f(L)\,\mathrm{d}L + \int_{\alpha+P(1+r)+Kr}^{\alpha+(P+K)(1+r)} \Pi_3 f(L)\,\mathrm{d}L. \tag{1}$$

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

The insolvency constraint described earlier can be written as follows:

$$\gamma = \frac{\int_{(K+P)(1+r)+\alpha}^{\alpha+\lambda}[L-(K+P)(1+r)-\alpha] f(L)\,\mathrm{d}L}{\int_{\alpha}^{\alpha+\lambda}(L-\alpha) f(L)\,\mathrm{d}L + \int_{\alpha+\lambda}^{\infty} \lambda f(L)\,\mathrm{d}L} + \frac{\int_{\alpha+\lambda}^{\infty}[\lambda-(K+P)(1+r)] f(L)\,\mathrm{d}L}{\int_{\alpha}^{\alpha+\lambda}(L-\alpha) f(L)\,\mathrm{d}L + \int_{\alpha+\lambda}^{\infty} \lambda f(L)\,\mathrm{d}L}. \tag{2}$$

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

The insolvency constraint, Eq. (2), and the capital market constraint, Eq. (1), provide two equations that can be solved for the two unknowns: capital (K) and premium (P). [10] Since the equations cannot be solved analytically (except for special cases), solutions are obtained numerically for a specific loss distribution described below.

Since the only market imperfection incorporated into the model is corporate taxes, the difference between the equilibrium premium and the present value of expected claim costs is a dollar measure of the tax costs. For comparison purposes, we scale expected tax costs by the discounted value of the expected claim costs. This scaling measures the tax costs in a form that is relevant to consumers. Expected utility theory and, assuming that capital market imperfections cause firm value to be concave in payoffs, the theory of the corporate demand for insurance predict 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.

[10] 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.

2.2. Special case of no-insolvency risk and symmetric taxes

When the insurer is constrained to hold enough capital to eliminate the risk of insolvency ($\gamma = 0$), the insolvency constraint (Eq. (2)) requires that premiums satisfy the following equation:

$$(P + K)(1 + r) = \lambda. \tag{2$'$}$$

In words, end of year funds must equal the policy limit. The model can be simplified further by assuming a symmetric tax structure by setting $b = 1$ so that profits and losses are taxed at the same constant rate τ. Under these assumptions, Eqs. (1) and (2) can be solved analytically and a simple intuitive expression for the equilibrium premium results:

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

where $E(X)$ is the expected value of claims. The first term is the present value of expected claim costs, and the second term is the present value of the tax costs on the investment income on capital grossed-up to reflect that premiums must cover tax costs and that premiums themselves are taxable. This is the same formula derived by Myers and Cohn (1987) assuming that capital is exogenous.

The net premium loading, defined as the difference between the premium and the present value of expected claim payments, is the second term in Eq. (3). Dividing the net premium loading by the present value of expected claim costs gives the tax costs per dollar of expected indemnity:

$$\text{Tax costs per dollar of expected indemnity} = \frac{Kr\tau}{E(X)(1 - \tau)}. \tag{4}$$

This expression highlights the basic intuition for the model's results.[11] Because of the nature of catastrophe risk—high potential severity with low frequency—insurers need to hold a large amount of capital relative to expected claim costs to make their promises to pay claims credible. Consequently, factors that increase the cost of holding capital, including taxes, agency conflicts, and asymmetric information, can have a substantial impact on the price of catastrophe insurance. These effects are especially important for high "layers" of coverage, where the capital needs are high relative to the expected claim costs.

2.3. Catastrophe loss distribution

To provide estimates of the tax costs associated with insuring US catastrophe exposures under the US tax system, we use a loss distribution that reflects total US catastrophe loss experience. We therefore are measuring the capital costs for an entity (or insurance/reinsurance pool) that insures a proportional share of all the catastrophe exposures in the US. By assuming that the entity has complete diversification within the set of US

[11] The amount of capital is endogenous in the model. Thus, expressions (2′) and (4) can be solved for P as a function of the exogenous variables.

catastrophe exposures, we overstate the extent to which some insurers/reinsurers are diversified with respect to catastrophe risk, and understate the diversification of others. Issues related to diversification with other loss exposures, within the US or with catastrophe losses from other countries, are discussed later in the paper. [12]

To identify a distribution for US catastrophe losses, we start with the results reported by Cummins et al. (1999a), who fit frequency and severity distributions to catastrophe loss data simulated by a major catastrophe-modeling firm, Risk Management Solutions (RMS). Their results suggest that a Poisson distribution with parameter 9.52 events per year fits the annual frequency data and that a lognormal distribution with mean of $736.53 million and standard deviation of $3,790.45 million fits the severity data. The severity parameters are denominated in 1994 dollars.

Recall that our model requires a distribution for total annual catastrophe losses. Unfortunately, an analytical solution does not exist for the distribution of total catastrophe losses when frequency is Poisson and severity is lognormal. We therefore 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. (1999a) for the Poisson and lognormal distributions to simulate 25,000 annual observations for total 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 can be described by a lognormal distribution with expected annual losses of $7.045 billion and standard deviation of annual losses equal to $9.382 billion in 1994 dollars. Figure 1 illustrates the density function for this lognormal distribution and compares it to the simulated data. Table 2 provides some descriptive characteristics for the distribution. For example,

Table 2
Characteristics of the fitted distribution for US catastrophe losses

Expected loss	$7.045 billion
Standard deviation	$9.382 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

Lognormal distribution with logarithmic mean = 8.35 and logarithmic standard deviation = 1.01 (reported numbers are in 1994 dollars).

[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 Murdock, 1996).

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

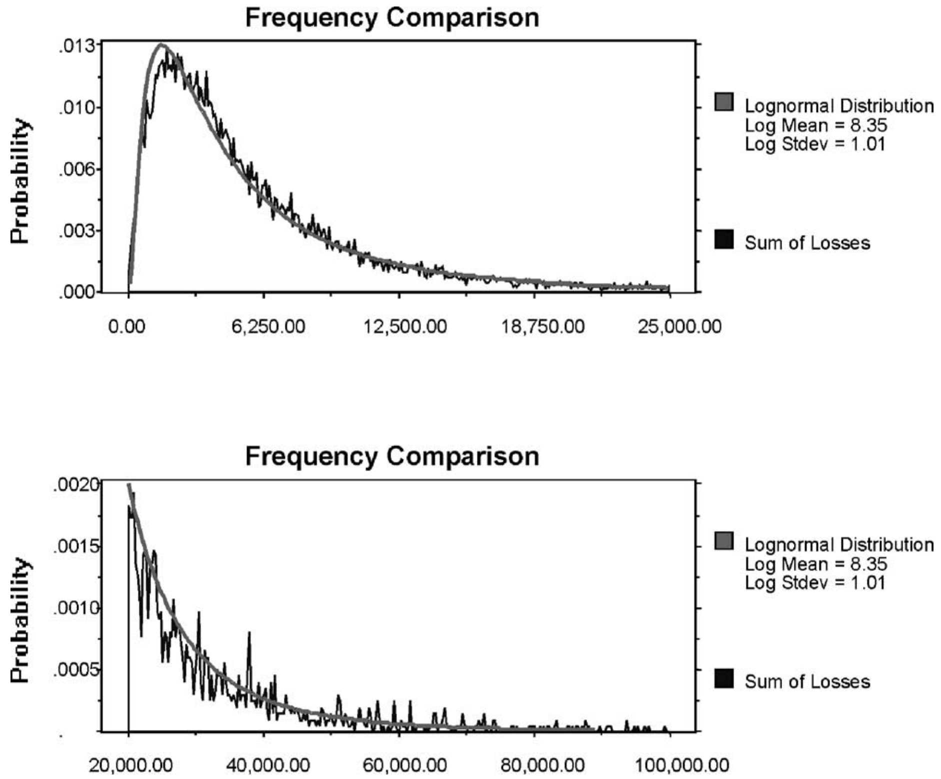


Fig. 1. Fitted lognormal distribution compared to simulated annual aggregate loss data where twenty-five thousand simulated annual aggregated losses are generated by assuming frequency of catastrophes has a Poisson distribution with parameter 9.52 events per year and severity of catastrophes has a lognormal distribution with logarithmic mean and standard deviation equal to 4.95 and 1.82, respectively (mean loss = \$736.53 million and standard deviation = \$3,790.45 million). The simulated data are illustrated by the jagged curves. The best fit of the simulated data (of the seven distributions examined) is the lognormal distribution with expected loss equal to \$7.045 billion and standard deviation equal to 9.382 billion. The fitted lognormal density is illustrated by the smooth curves.

the simulated probability that annual catastrophe losses exceed \$10 billion is 0.197, and the simulated probability that annual catastrophe losses exceed \$50 billion is about 0.007.

This fitted probability distribution could plausibly have a thinner tail than the true distribution of annual catastrophe losses. Under the fitted distribution, the probability that annual catastrophe losses exceeds \$50 billion is less than 1 percent. Insured damage from a single hurricane hitting a major east coast city, such as Miami, or from an earthquake hitting a metropolitan area of California could easily exceed \$50 billion. A thinner tail will result in lower amounts of capital needed to insure high levels of losses and therefore lower the estimated tax costs in our model. We have solved the model using alternative distributions and the general conclusions are robust.

3. Results

Using the fitted lognormal distribution for national catastrophe losses, we solve Eqs. (1) and (2) numerically for the present value of expected claim costs, capital (K), premiums (P), and the tax costs per dollar of expected claim costs. We first present basic results to illustrate the magnitude of the capital needed and the resulting tax costs for various layers of coverage. We then consider how the model's parameters and personal taxes influence the results. The subsequent sections incorporate additional elements into the model and examine the sensitivity of the basic results to these additional complications.

3.1. Base case

Table 3 provides illustrative results from solving the model 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 ($\gamma = 0.05$), 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.

First panel of Table 3 indicates that for the lowest layer of coverage (\$25 billion excess of \$0), the insurer would need to hold capital \$11.4 billion. The expected tax costs as a percentage of the present value of expected claim costs equal a modest 10.5%. For the next coverage layer (\$25 billion excess of \$25 billion), however, the capital needed almost doubles to \$20.0 billion and the expected tax costs increases to 115.0% of the expected claim costs. For each of the next two successive layers of \$25 billion of coverage, the

Table 3
Tax costs as a percentage of the present value (PV) of expected claim costs under policies with various attachment points

Exogenous parameters						Endogenous variables (in millions)			
Attachment point (α)	$\alpha +$ 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	\$5761	\$6364	\$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
0	100,000	0.05	0.25	0.5	0.06	6285	7106	24,119	13.1
0	100,000	0.01	0.25	0.5	0.06	6549	7812	51,608	19.3

Notes. These results are based on the model in Section 3 and the assumption that claim costs follow a lognormal distribution with expected value equal to \$7.045 billion and standard deviation equal to \$9.382 billion (in 1994 dollars), respectively. Dollar figures reported in the table are in millions of 1994 dollars.

capital needed is about $21 billion, but because the expected claim costs fall, the expected tax costs increase dramatically to 451.7% and 1,293.0%, respectively.[14]

The magnitude of the tax costs and their relationship with the coverage layers are broadly consistent with Froot's (2000) evidence on catastrophe reinsurance prices between 1980 and 1991. In particular, Froot documents that catastrophe reinsurance premiums relative to expected claim costs increase for higher layers of coverage and that premiums typically are between one and five times expected claim payments. Although we do not model the demand for coverage, the results in Table 3 suggest that capital costs in general and the tax costs in particular could contribute materially to the price for high layers of catastrophe reinsurance coverage and therefore help explain the limited quantity of high-layer catastrophe reinsurance purchased.

3.2. Primary market

High costs for catastrophe reinsurers will imply high marginal costs of supplying catastrophe coverage at the primary market level (see Zanjani, 2002). To provide some insight into the magnitude of the effect on the primary market, suppose that all property owners in the US purchase insurance policies that only cover catastrophe losses and that the primary insurers reinsure their entire catastrophe loss exposure with a single reinsurer that agrees to pay up to $100 billion in total annual catastrophe losses (in 1994 dollars) and expects to default on five percent of promised expected claims. As panel B of Table 3 indicates, the amount of capital needed to write this reinsurance is $24.1 billion and the tax costs equal 13.1 percent of expected claim costs. This estimate suggests that the price of catastrophe insurance in the primary market must include a loading of about 13 percent just to cover the tax costs that arise from the need to hold capital, ignoring any non-tax frictional costs of achieving widespread risk spreading in markets with dozens of primary insurers and reinsurance. This loading is of the same order of magnitude as the loading that is typically needed to cover loss adjustment expenses (A.M. Best Company, 2002).

If, in the previous illustration, we require the reinsurer to have expected unpaid claims of only one percent of promised expected claims (instead of five percent), then the amount of capital needed by the reinsurer increases dramatically. As reported in the second row of panel B, the reinsurer would need to more than double the amount of capital that it holds to $51.6 billion. The tax costs associated with this capital as a percentage of the present value of expected claim costs increase accordingly, equaling 19 percent of expected claim costs for $100 billion of coverage. Moreover, the large amounts of capital required to provide coverage credibly imply correspondingly large effects of any non-tax costs of equity. Thus, these results suggest that the capital needed to support primary market catastrophe

[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.

insurance is substantial and that the resulting tax costs associated with that capital can have a material effect on primary market prices.

3.3. *Effects of different parameter values*

Table 4 illustrates how the parameters of the model influence the capital needed and 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, insurers need less capital, which will lower the tax costs. 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 for this coverage layer is relatively small. For example, with zero default risk, expected tax costs equal 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.

The second panel indicates that assumed marginal tax rates have a large impact on tax costs. For example, an increase in the marginal tax rate 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. While the marginal tax rate when the insurer is profitable has a substantial effect on the tax costs, the third panel illustrates that the asymmetry in the tax structure has a relatively small impact on the tax costs. For example, when the tax rate is 25 percent when income is positive, the tax costs equal 108.2% with a symmetric tax structure ($b = 1$). Under a tax system with no value to

Table 4
Tax costs as a percentage of the present value (PV) of expected claim costs

Exogenous parameters						Endogenous variables (in millions)			
Attachment point (α)	$\alpha+$ 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

Notes. The data obtained under different assumptions about expected default costs (γ), marginal tax rates (τ and b), interest rates (r). Claim costs follow a lognormal distribution with expected value equal to \$7.045 billion and standard deviation equal to \$9.382 billion (in 1994 dollars), respectively. Dollar figures reported in the table are in millions of 1994 dollars.

loss carry-forwards ($b = 0$), the tax costs equal 121.8%. The asymmetry has a relatively small impact because the likelihood of negative profits is small (major catastrophes are rare events).[15]

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 outweighs the effect of the higher interest rate on the present value of expected claim costs. This result contrasts with the typical prediction that insurance premiums are inversely related to interest rates. 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).

3.4. Personal taxes

As discussed by Miller (1977), the corporate tax disadvantage of equity may be offset, at least in part, by the personal tax advantage of equity.[16] If so, equity investors would require a lower expected rate of return than we have been assuming in our model. The left-hand side of Eq. (1) sets the required expected rate of return on equity capital equal to the before-tax return on taxable bonds (r). When equity capital receives preferential personal tax treatment, the expected before-personal-tax return on equity capital will be less than the before-tax return on taxable bonds.

We illustrate the possible effect of personal taxes on our results assuming that the personal tax rate on interest income is 30% and that the effective personal tax rate on equity returns is 15%.[17] If taxable bonds yield 6%, then the required expected return on equivalently risky equity securities would be 4.94% (i.e., 4.94% $(1 - 0.15) = 6\%\,(1 - 0.30)$). The results of solving the model using a required return on equity of 4.94% are presented in Table 5. The tax costs for each layer of coverage are lower than those reported in Table 3, and the effect of personal taxes is pronounced for higher layers of coverage. For example, the illustrated tax costs for the $50–$75 billion layer drop from 451.70% to 151.0% of the present value of the expected indemnity. Nevertheless, the tax costs are still material. These findings are consistent with Graham's (1998, 2000) evidence that the personal taxes reduce, but do not eliminate the tax disadvantages of equity compared to debt.

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[15] As noted earlier, the sensitivity of the tax costs to the assumed marginal tax rate led us to simulate marginal tax rate schedules in a manner similar to Graham (2000). We then used the simulated marginal tax rates schedule in place of the step function used above (tax rate equals τ when income is positive and $b\tau$ when income is negative) and numerically solved for the equilibrium premium, capital, and tax costs. The results of this exercise, which are summarized in Appendix A, yielded estimates of tax costs similar to the simpler model.

[16] 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 generally are neutral with respect to taxes. Returns on personal life insurance and corporate insurance receive preferential tax treatment.

[17] This differential is consistent with Green and Hollifield's (1999) estimate that deferral of equity taxation reduces the effective equity tax rate by about 50 percent.

Table 5
Tax costs as a percentage of the present value (PV) of expected claim costs when personal taxes are considered

Exogenous parameters						Endogenous variables (in millions)			
Attachment point (α)	$\alpha +$ limit (λ)	Insolvency constraint (γ)	Corp. tax rate (τ)	Value of unused tax shields (b)	Before-tax 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	\$5761	\$6221	\$11,587	8.0
25,000	50,000	0.05	0.25	0.5	0.06	399	595	20,308	48.9
50,000	75,000	0.05	0.25	0.5	0.06	92	231	21,253	151.0
75,000	100,000	0.05	0.25	0.5	0.06	32	159	21,571	402.0
0	100,000	0.05	0.25	0.5	0.06	6285	6798	24,427	8.2
0	100,000	0.01	0.25	0.5	0.06	6549	7146	52,274	9.1

Notes. Personal tax rate on interest income equals 30% and on equity income equals 15%, implying an after-tax required return on equity to be 4.94%. Claim costs follow a lognormal distribution with expected value equal to \$7.045 billion and standard deviation equal to \$9.382 billion (in 1994 dollars), respectively. Dollar figures reported in the table are in millions of 1994 dollars.

4. Incorporating mitigation efforts in the model

4.1. Investment in tax-exempt securities

In the previous model, we implicitly allowed for investment strategies that reduce taxes (e.g., investing in tax-exempt bonds and equities) by assuming that insurers faced a marginal tax rate equal to 25% when taxable income is positive, instead of the higher statutory rate that typically applies. We now report the results of a more detailed analysis of insurer investment in tax-exempt securities, assuming a corporate income tax rate of 35%.

The desirability of investing in tax-exempt securities increases as the yield differential between taxable and tax-exempt securities decreases and as the likelihood of negative taxable income decreases. [18] For catastrophe reinsurers offering high coverage layers, the likelihood of negative taxable income is relatively low, which increases the benefits of investing in tax exempts compared to other insurers. When we incorporate the ability to invest in tax-exempt securities in our model and assume that the tax-exempt rate equals 4.5%, the taxable rate equals 6%, and the corporate tax rate equals 35%, we find that the optimal investment policy (the one that minimizes the tax costs) is to invest 100% of the assets in tax-exempt bonds.[19] One-hundred percent investment in tax-exempt bonds implies that the tax costs associated with catastrophe insurer equity capital are solely due to the implicit tax rate (which given the rates assumed equals 25%).[20] Table 6 reports the results of solving the model under the parameters given above. The percentage tax costs remain

[18] See PonArul and Viswanath (1995) for a formal analysis.

[19] For other parameter values, we find other optimal investment policies. Contrary to our assumptions, interest income on municipal bonds is not completely tax-exempt for insurers. See Cummins and Grace (1994) for a description of the actual tax treatment of tax-exempt interest and an analysis of insurer investments in tax-exempt securities.

[20] The implicit tax rate between AAA municipal yields and AAA corporate yields averaged about 31 percent between 1995 and 2002.

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 4.5% and taxable bonds yield 6%

Exogenous parameters						Endogenous variables (in millions)			
Attachment point (α)	$\alpha+$ limit (λ)	Insolvency constraint (γ)	Corp. tax rate (τ)	Value of unused tax shields (b)	Before-tax 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	0.35	0.5	0.06	$5761	$6495	$11,568	12.7
25,000	50,000	0.05	0.35	0.5	0.06	399	672	20,531	68.2
50,000	75,000	0.05	0.35	0.5	0.06	92	266	21,527	187.7
75,000	100,000	0.05	0.35	0.5	0.06	32	183	21,858	479.3
0	100,000	0.05	0.35	0.5	0.06	6285	7107	24,567	13.1
0	100,000	0.01	0.35	0.5	0.06	6549	7505	52,768	14.6

Notes. Personal tax rate on interest income equals 30% and on equity income equals 15%, implying an after-tax required return on equity to be 4.94%. Claim costs follow a lognormal distribution with expected value equal to $7.045 billion and standard deviation equal to $9.382 billion (in 1994 dollars), respectively. Dollar figures reported in the table are in millions of 1994 dollars.

substantial, especially for high layers of coverage. For example, the tax costs equal 68.2% of the present value of the expected indemnity for the $25 billion layer of coverage above $25 billion.

4.2. Product line and global diversification

The preceding analysis assumes the maximum possible diversification within the US market for catastrophe coverage, but it ignores the possible effects of product line and global diversification. Product line and global diversification opportunities alone, however, are unlikely to alter the basic implication that the US tax code can have a substantial effect on the cost of supplying catastrophe insurance/reinsurance. Even with product line diversification, catastrophe coverage will 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 US catastrophe risk is also constrained. The US catastrophe exposure represents a large share of potentially insurable global risk because of the high aggregate value of US 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 US share of this total was 61.4% (Hartwig, 1999; Swiss, 1997). Moreover, global risk pooling necessarily entails non-trivial transaction costs, including those associated with risk evaluation, contract design and enforcement. In addition, there are costs associated with meeting the regulatory requirements that would allow domestic insurers and reinsurers to receive balance sheet credit for shifting risk to foreign reinsurers.[21]

We conduct a simple analysis to provide some quantitative insight into the possible effects of international diversification on the amount of capital needed to supply catastrophe coverage and resulting tax costs. Because we do not have data to estimate a non-US loss distribution, we assume that non-US catastrophe exposures have the same distribution as US catastrophe exposures (the distribution used in the previous section), but that the two exposures are uncorrelated. We then examine how the capital and 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).[22]

To provide insight into whether diversification would substantially reduce the capital needed to insure infrequent, but potentially large losses and thereby reduce tax costs, we compare the capital needed to insure the global portfolio to the capital needed to insure the US and non-US exposures separately. For illustrative purposes, we consider a $25 billion layer of coverage above $25 billion for each of the individual exposures (US and non-US). Table 7 indicates that $20.3 billion of capital would be needed to insure each exposure (total capital of $40.6 billion). Incorporating the personal tax advantage of equity financing in the analysis, Table 7 indicates that the tax costs of insuring each exposure equals 48.9 percent of the present value of the expected indemnity (a total cost of 97.8%).

Because 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 $25 billion excess of $25 billion policies for the individual exposures, we solve the model for two different policies. Consider first a policy that provides $50 billion of coverage excess of $25 billion for the global portfolio. Any US or non-US loss that would have been covered if insured separately (using $25 billion excess of $25 billion policies) would also be covered under this global policy, but this global policy would cover many losses that separate policies would not cover. The capital needed for this policy is $33 billion, a 16.7 percent reduction relative to separately insuring both exposures, but still a substantial amount of capital. The tax cost for this policy as percentage of the present value of the expected indemnity is 28.4%.

[21] In order for a US insurer to receive balance sheet credit, the foreign reinsurers must be licensed in the US, deposit substantial funds in a trust, or post an irrevocable evergreen letter of credit from an approved financial institution. Also, insurers and reinsurers must pay a 1 percent excise tax on premiums paid to foreign reinsurers. The possible effects of more favorable income tax treatment of insurer catastrophe reserves in some other countries are briefly discussed in Section 5.

[22] 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 lognormal, our numerical approach should produce results that are qualitatively similar to using the empirical distribution from the simulation.

Table 7
Tax costs as a percentage of the present value (PV) of expected claim costs when US and assumed non-US exposures are aggregated

Exogenous parameters						Endogenous variables (in millions)			
α	$\alpha+\lambda$	Insolvency constraint (γ)	Corp. tax rate (τ)	Value of unused tax shields (b)	Before-tax interest rate (r)	Present value of expected claim costs	Premium (P)	Capital (K)	Tax costs as a percentage of PV of expected claim costs
US (or non-US) exposures alone									
25,000	50,000	0.05	0.25	0.5	0.06	\$399	\$595	\$20,308	48.9
Global exposure									
25,000	75,000	0.05	0.25	0.5	0.06	\$1437	\$1845	\$33,849	28.4
33,300	83,300	0.05	0.25	0.5	0.06	\$798	\$1130	\$35793	41.6

Notes. Each exposure has a lognormal loss distribution with expected value equal to \$7.045 billion and standard deviation equal to \$9.382 billion (in 1994 dollars), respectively. The loss distribution that bests fits simulated losses when exposures are aggregated is lognormal with expected value equal to \$13.888 billion and standard deviation equal to \$12.279 billion (in 1994 dollars), respectively. Personal tax rate on interest income equals 30% and on equity income equals 15%, implying an after-tax required return on equity to be 4.94%. Dollar figures reported in the table are in millions of 1994 dollars.

The second policy reported in Table 7 for the global portfolio also provides \$50 billion of coverage, but above an attachment point of \$33.3 billion, which was chosen to give the same present value of expected indemnity (\$798 million) as is provided by separate \$25 billion excess of \$25 billion policies on the US and non-US exposures (\$399 million times two). The capital needed for this policy is \$35.8 billion and the tax costs as a percentage of the present value of the expected indemnity is 41.6%. Thus, although global diversification has the effect of reducing the capital that is needed and cutting the tax costs roughly in half, this analysis suggests that the required capital and tax costs are still substantial. Also, it is important to keep in mind that global diversification involves material transaction and regulatory costs.

5. Other mitigation efforts

5.1. Offshore reinsurance

If, as our analysis suggests, the US tax code contributes significantly to the high costs of supplying catastrophe coverage, a natural response for insurers/reinsurers offering catastrophe coverage is to locate in jurisdictions that provide a more favorable tax environment. Bermuda, for example, imposes no tax on investment income. Our analysis also suggests that increases in the expected frequency and severity of catastrophe losses (as has occurred in the past decade), and the attendant increase in the amount of capital needed to bond insurers' promises credibly, would stimulate insurer and reinsurer growth in tax-favored jurisdictions, and other means of reducing tax costs.

Although material transaction costs (and, as noted, a federal excise tax) are incurred by US insurers and reinsurers that cede coverage abroad, there is considerable anecdotal evidence that insurers are responding as predicted. For example, losses in the late

1980s and early 1990s led to entry and significant growth of offshore reinsurers (primarily in Bermuda) providing coverage to domestic catastrophe insurers and reinsurers (Froot, 2000). Also, insurance industry capital expansion following the September 11, 2001 terrorist attacks was primarily located in Bermuda (Bradford, 2001).

Since 1999, several US insurers have either redomesticated to Bermuda or have established wholly-owned subsidiaries in Bermuda that offer reinsurance to the parent company and its other sister subsidiaries (McLeod, 2000). A controversial legislative proposal in the Congress would limit domestic insurers' ability to reduce taxes by reinsuring with offshore subsidiaries.

5.2. Conventional (non-contingent) subordinated debt

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 property-liability 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 (A.M. Best Company, 1998).[23]

As is true for non-financial corporations, a variety of factors impede greater reliance on debt finance by insurers. Using debt capital to bond promises to pay policyholder claims can lead to rating downgrades on the debt (e.g., following a catastrophe), which could lower future demand for the insurer's policies. Stated differently, substituting debt for equity financing increases the likelihood that the insurer's franchise value, which largely reflects quasi-rents from prior investment in building its book of business, will be eroded. Greater use of debt also can exacerbate conflicts between debtholders and equityholders regarding output decisions (Myers, 1977). Since policyholder claims are senior to debtholders' claims, debtholders might prefer that an insurer not expand supply at opportune times, e.g., following major industry capital shocks.[24]

[23] 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. These data exclude mutual and reciprocal insurers, which often make modest use of surplus notes, a regulated form of subordinated debt.

[24] Monitoring insurer risk levels, however, is a benefit of subordinated debt highlighted in the banking literature (see, e.g., the discussion by Flannery and Sorescu, 1996). Some of the benefits of debt discussed in the literature also are likely to be less important for catastrophe insurers. Harris and Raviv (1990), for example, highlight how debt provides information to investors about management performance and firm value. For catastrophe insurers, however, the potential informational role of debt is reduced because the occurrence of a catastrophe is readily observable and outside of the control of management. Thus, an insurer's default due to a catastrophe is less 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.

5.3. Catastrophe bonds

The past decade saw the emergence of catastrophe bonds as a new form of contingent, subordinated debt for financing catastrophe loss (see, e.g., Froot, 1999, 2000). 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 the insurer that establishes the SPV. 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.[25] The tax savings, however, presently can only be achieved by incurring significant costs to meet regulatory and tax rules relating to these instruments. Considerable care must be taken to ensure that the SPV is not subject to US corporate tax in order to make the transactions economically viable (Davidson, 1998). Among other issues, this objective generally requires the SPV to be incorporated and operated exclusively in a tax-advantaged jurisdiction. These frictions may help to explain the relatively slow development of the catastrophe bond market despite possibly large tax advantages. On the other hand, slow development of that market also raises the questions of whether there are non-tax factors that reduce investors' appetites for such instruments.

5.4. Organizational form

Mutual (and reciprocal) property-liability insurers are subject to a "prepayment" tax system. Although distributions to mutual "owners" are tax deductible to the mutual insurer, the corporate tax burden is not necessarily lower than for stocks because premiums collected by mutual insurers to generate capital through retained earnings are taxable when collected (Graetz, 1986; Myers and Kolbe, 1998). Given that distributions to mutual policyholders are not subject to personal taxation, the total corporate and personal tax cost of safety capital could be lower for mutuals than for stocks. The tax cost, however, will still be positive if the corporate tax rate (or implicit tax rate on tax exempts) exceeds the average personal tax rate on direct investments by mutual policyholders in equivalent securities. Moreover, at least two other costs are likely to offset, at least partially, any tax cost advantage of mutuals compared to stock firms.[26] First, mutuals plausibly face higher costs of

[25] 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 insurance/reinsurance (see Section 5.4).

[26] Mayers and Smith (1988) provide detailed discussion of agency costs associated with alternative organizational forms in property-liability insurance. Myers and Kolbe (1998) show that a prepayment tax system can cause the total net present value (NPV) of identical *positive* NPV investments to be greater for mutuals than for

raising funds after large losses, which would require them to hold more capital than stock insurers ex ante to have the same insolvency risk and would at least partially offset any lower tax cost per dollar of capital (Harrington and Niehaus, 2002). Second, mutual "ownership" provides policyholders with little or no liquidity because their implicit claims on the firm's value are inalienable unless the firm converts to stock ownership and distributes cash or stock to policyholders.

6. Conclusions

Credibly insuring large losses from catastrophes—whether natural or man-made—requires insurers/reinsurers to hold large amounts of equity capital in relation to expected claim costs, thus producing correspondingly large tax and non-tax costs of holding that capital. Our analysis suggests that the US corporate income tax can produce tax costs on this capital that exceed 100 percent of the present value of expected claims for high "layers" of coverage. Tax costs of this magnitude can produce large tax loadings in catastrophe reinsurance and primary insurance premiums, thus reducing the scope of private sector insurance against catastrophe losses. Insurer/reinsurers can engage in a number of strategies to reduce the tax costs associated with supplying US catastrophe insurance, including product line and global diversification, investment in tax-exempt securities, issuance of subordinated debt and catastrophe bonds, and the purchase of offshore reinsurance, but these efforts also are costly.

Our illustrations suggest that policy changes that would lower tax costs, such as allowing insurers/reinsurers to establish tax deferred reserves, changing tax and regulatory rules to facilitate onshore arrangements for catastrophe bonds, and/or integrating corporate and personal taxes could have a material impact on the price of catastrophe insurance coverage. On the other hand, uncertainty concerning the relative importance of tax costs and non-tax impediments to the sharing of catastrophe risk and the complexity of domestic and international taxation suggest caution in making policy inferences based solely on our analysis.[27]

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stocks. This potential advantage to mutuals should not be material in the context of our analysis (investments in securities with zero NPV before corporate tax).

[27] Froot (2000), for example, considers a variety of non-tax factors that may help explain the dearth and relatively high prices for coverage of large catastrophe losses, including capital market imperfections, possible market power by reinsurers, frictional costs, and the dampening effects on demand of ex post government financing of catastrophe losses.

versities of Alabama, South Carolina and Tennessee, the 2000 meeting of the Risk Theory Society, and the 2001 American Finance Association Meeting.

Appendix A. Marginal tax rates for a catastrophe insurer

The model in the text assumed that the marginal tax rate schedule facing a catastrophe insurer was a step function equal to τ when taxable income was positive, $b\tau$ when the insurer was solvent but taxable income was negative, and zero when the insurer was insolvent. 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. Consequently, a firm's effective marginal tax rate on an additional dollar of income depends on the realization of future cash flows (Graham, 1996). A firm's *expected* marginal tax rate for a given level of current income reflects an average rate over possible realizations of future cash flows.

The tax loss carry-back/forward provisions imply that the tax 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. As noted in the text, 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 carry-forward and carry-back provisions for determining the expected marginal tax rate schedule of catastrophe insurers. Using the results of the basic 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 using a procedure similar to the method used by Graham (2000) to simulate marginal tax rate schedules for a broad set of corporations.

The simulation assumes a statutory rate of 35% and the ability to carry losses back three years and forward 15 years, assuming that the insurer has no prior history. We first 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 the text. 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. (We do not allow insolvencies.) The third and fourth steps are repeated 1000 times, and we calculate the mean of the 1000-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.

The simulation yields an expected marginal tax rate for a given 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 A.1,

Table A.1
Simulated expected marginal tax rates schedules

	Assumptions			
Attachment pt.	\$0	\$25,000	\$50,000	\$75,000
Premium	6669	905	545	474
Capital	16,916	22,679	23,039	23,111
Current year claim cost	Average marginal tax rate from 1000 simulations, %			
\$0	30.0	33.1	34.4	35.0
2500	28.7	28.0	26.8	25.7
5000	27.7	22.1	19.5	19.1
7500	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

Notes. Simulated marginal tax rates equal the average marginal tax rate from 1000 simulations of catastrophe losses in years 2 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.

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, 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 carry-forwards once losses exceed a certain level.

To investigate the impact of the simulated expected marginal tax rates on our earlier results, we fitted an exponential model to the simulated expected marginal tax rate data in the first column of Table A.1. Specifically, we estimated $\mathrm{MTR} = \tau_0 \mathrm{e}^{-\delta X}$, 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 A.1), 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 1 of Table A.1) 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 solved 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 used

Table A.2
Tax costs as a percentage of the present value (PV) of expected claim costs under policies with various attachment points

Exogenous parameters						Endogenous variables (in millions)			
Attachment point (α)	$\alpha+$ limit (λ)	Insolvency constraint (γ)	Tax rate (τ)	Decay parameter (δ)	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	0.30	0.00005	0.06	$5761	$6396	$11,411	11.0
25,000	50,000	0.05	0.33	0.00010	0.06	399	1089	20,755	172.7
50,000	75,000	0.05	0.34	0.00010	0.06	92	709	21,095	667.9
75,000	100,000	0.05	0.35	0.00010	0.06	32	635	21,095	1905.0

Notes. The data are obtained using the marginal tax rate schedule: $t_0 \exp(-\delta X)$, where X is current year claim costs, t_0 is the marginal tax rate when current year claim costs equal zero (see Table A.1), and δ is the decay parameter. Claim costs follow a lognormal distribution with expected value equal to $7.045 billion and standard deviation equal to $9.382 billion (in 1994 dollars), respectively. Dollar figures reported in the table are in millions of 1994 dollars.

the estimated decay parameter. For the other coverage layers, we simply doubled the decay parameter to account for the faster rate of decline in the simulated marginal tax rates. The results are reported in Table A.2. Compared to the results reported in Table 3, 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.

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