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U.S. Reinsurance Prices, Financial Quality, and Global Capacity

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Abstract

The puzzle of underwriting cycles and insurance crises in property-liability insurance has led to numerous economic hypotheses and analyses, yet no single theory seems capable of explaining all of its aspects. Reinsurance is hypothesized to be a potential factor in observed cycles in the primary market; despite this, few underwriting cycle studies focus on reinsurance. The purpose of this research is to investigate determinants of reinsurance prices in the U.S. Nonproportional reinsurance is highlighted, since it is designed to cover the tail of the loss distribution and is considered to be relatively riskier than proportional reinsurance as a result. Separate samples of professional U.S. reinsurers for property and for casualty are studied, based upon the reinsurers' writings of property versus casualty nonproportional reinsurance. The sample period is 1991–1995. The results support both the capacity constraint hypothesis and the risky debt hypothesis, and this is the first research to support both. A major innovation in this study is the use of capacity variables that are broken down by major region of the world.

Introduction

The worldwide property-liability insurance industry has been rocked by the increasing catastrophes in recent years. For example, Hurricanes Andrew and Iniki and the Northridge earthquake increased demand for catastrophe cover (e.g., per occurrence excess of loss reinsurance), leading to a capacity shortage in property catastrophe reinsurance. Turmoil at Lloyd's of London in the early 1990s nearly brought that organization to its knees due to continuing reserving problems for certain liability coverages, especially asbestos and environmental impairment. More recently, the September 11 attacks are associated with increases in premiums for some lines of business, when coverage is available at all. These market developments are particularly important for nonproportional reinsurance because this coverage is designed to cover the tail of the loss distribution and is triggered only when losses are unexpectedly high. Further, a significant portion of U.S. nonproportional reinsurance is placed with non-U.S.

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insurers. In 1997, for example, insurers in North America ceded $40 billion in premiums to non-U.S. insurers (Swiss Re, 1998).

Theoretically, price and capacity (availability of insurance coverage) are related in the insurance literature. This research focuses on pricing of nonproportional property and casualty reinsurance in the U.S. market. The analysis focuses on reinsurers licensed in the United States, but the analysis allows for a linkage between reinsurance prices for the sample reinsurers and *global* capacity. As intimated above, the reinsurance market is global in scope, hence capacity in the international reinsurance markets may very well affect pricing in the United States. The premise of this research is that reinsurance pricing (in the United States and elsewhere) reflects conditions in the worldwide reinsurance market such as global capacity. Indeed, the analysis allows for the possibility that pricing is affected differently by the source of foreign capacity (e.g., continental Europe vs. Lloyd's of London).

An extensive literature on insurance pricing exists already—demand theory and underwriting cycle theory—and this study draws upon these theories to provide a framework for the statistical analysis. In particular, studies related to probability updating, loss shocks, and capacity are especially useful for this research (Winter, 1994; Gron, 1994; Cummins and Danzon, 1997; Froot and O'Connell, 1997, 1999; Lai et al., 2000). Under the capacity constraint hypothesis, prices and profitability are hypothesized to be inversely related to the supply of capital such that insurance prices are bid-up when capital is scarce and fall when capital is plentiful (Winter, 1994; Gron, 1994). These theories may prove especially useful in studying the effect of capacity shortages in nonproportional property insurance after Hurricanes Andrew and Iniki. Equilibrium price also might be affected if policyholders and/or (re)insurers change their loss expectations after events such as catastrophes (probability updating), leading to increased prices (Lai et al., 2000; Froot and O'Connell, 1997, 1999). Thus, the price increases follow the loss shocks because of constriction in supply *and* increased demand. The risky debt hypothesis predicts that policyholders are willing to pay higher premiums for greater financial quality; loss shocks that deplete the capital (surplus) of the firm are hypothesized to affect prices by driving insurers away from their optimal capital structures (Cummins and Danzon, 1997). The empirical analysis in this research sheds some light on all of these theories.

The purpose of this research is to isolate factors affecting price in U.S. nonproportional property and casualty reinsurance.[1] Nonproportional property reinsurance pricing is studied separately from nonproportional casualty. That is, four samples are analyzed, two consisting of U.S. nonproportional property reinsurers and the other two of U.S. nonproportional casualty reinsurers. For each coverage, one sample considers all firms with meaningful participation in the market, while the other considers firms with a larger market presence (at least 0.5% of the market) in terms of premium writings. The sample period is 1991–1995. This period encompasses the occurrence of three major catastrophes (i.e., Hurricanes Andrew and Iniki and the Northridge earthquake) that affected property catastrophe coverage in the United States. This period also includes the crisis period at Lloyd's of London, the subsequent introduction of corporate capital

[1] In the process of doing so, further tests of the capacity constraint and risky debt hypotheses using data from the reinsurance market are conducted.

at Lloyd's, and the formation of new reinsurers in Bermuda. It is beneficial to observe the market reaction to these past events in order to more fully understand the impact of more recent events such as the terrorist attack of September 11, 2001.[2] The latter affected both property and liability insurance, and the final tab for these losses will be unknown until losses fully develop. Loss shocks from these are likely to occur in the future along with new catastrophes. This research can provide insight on how events such as these affect pricing.

The remainder of this article is organized as follows. In the next section, an overview of the international reinsurance market is provided. Then previous literature concerning the relationship between insurance pricing and loss shocks is briefly reviewed. The next section contains the model. This is followed by sections detailing sample selection procedures and variable specifications. Then data sources are described. Finally, the results are reviewed, followed by the conclusion.

REINSURANCE MARKET DEVELOPMENTS

This article focuses on the pricing of nonproportional reinsurance in the United States. However, because reinsurance is provided in a global market, with much of the world reinsurance capacity originating in other countries, it is important to take into account the non-U.S. sources of reinsurance supply. In this section, trends in the principal reinsurance markets are discussed. The purpose is to provide market information on the sample period concerning (1) the trend in reinsurance capacity; (2) why it may be important to treat capacity differently by the geographic source of the capacity; and (3) to show why non-U.S. reinsurer capacity is important to U.S. reinsurers.

U.S. Reinsurance Market

The U.S. reinsurance market has grown rapidly in the last two decades.[3] *Nonproportional* reinsurance premiums, as a percentage of total net premiums written for the U.S. insurance industry, jumped from 1.8 percent in 1975 to 4.8 percent in 1995, reflecting an average 4.9 percent annual increase. The majority of U.S. nonproportional reinsurance premiums not ceded internationally are underwritten by the U.S. professional reinsurers. For example, in 1995, 83 professional reinsurers wrote 81.5 percent of these nonproportional net premiums written, while 436 primary insurers wrote the rest (Best's Aggregates and Averages, 1996). For this reason, the discussion focuses on professional reinsurers.

World Reinsurance Capacity

The volatility of world reinsurance markets during the period 1990–1995 affected both the demand for and supply of reinsurance. The costs of insured property catastrophes

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[2] For analysis of the immediate reaction to this event on insurers' stocks, see Doherty, Lamm-Tennant, and Starks (2002). Standard & Poor's (2003) presents evidence that insurance market tightening similar to that studied in this article was underway at the time of 9/11 and was exacerbated by the event. Cummins and Lewis (2003) show that there was a "flight to quality" in the insurance market following 9/11.

[3] For an overview of the reinsurance market, see Brockett et al. (1991) and Cummins and Weiss (2000).

rose to unprecedented magnitudes during this period (Insurance Information Institute, 1999), resulting in fluctuations in the prices and supply of property catastrophe reinsurance, especially after Hurricanes Andrew and Iniki (1992) and the Northridge earthquake (1994). As a result, the world reinsurance market was subject to significant price and supply shocks during the 1990s and a "flight to quality" led to increasing dependence on well-capitalized reinsurers, many of them "alien" (i.e., non-U.S.) (Schachner, 1995; Walsh and Elkind, 1995; Atkins, 1995).[4]

Although 43 percent of the world demand for property-casualty reinsurance comes from the United States (Carpenter, 2003), a substantial component of reinsurance supply originates from non-U.S. (alien) reinsurers. Globally, 63 percent of property-casualty reinsurance is provided by non-U.S. sources (Carpenter, 2003), and over the period 1991–1995, approximately 42 percent of all the U.S. reinsurance premiums ceded were placed with alien reinsurers (Reinsurance Association of America, 1997). Hence, it is important to take into account the supply of reinsurance from non-U.S. firms in analyzing nonproportional reinsurance pricing. The primary sources of supply of non-U.S. reinsurance are from the U.K. (both Lloyds and the London "company market"), continental Europe, and "offshore" jurisdictions such as Bermuda.[5] The Bermuda market emerged after Hurricane Andrew, when billions of dollars in new capacity flowed into the market to satisfy demand for U.S. catastrophe reinsurance. However, the London and European markets have remained substantial suppliers of reinsurance capacity. In 2002, for example, estimated world capacity was split among the major geographical markets as follows—Europe, 54 percent; U.S., 27 percent; Japan, 5 percent; and other jurisdications (including Bermuda, 14 percent) (Carpenter, 2003). The primary sources of the supply of nonproportional reinsurance are taken into account in the empirical analysis conducted below.

PRICE AND QUANTITY OF REINSURANCE

The starting point in an economic analysis of pricing is supply and demand theory. In long-run equilibrium (and perfect capital markets), the supply of reinsurance capital should be completely elastic (i.e., horizontal supply curve). Thus loss shocks that deplete reinsurer capital should have no impact on the supply of reinsurance—reinsurers would just raise additional capital, for example, in the equity market. In the short run, however, financial market imperfections may make it costly to issue capital after a catastrophe or loss shock, meaning that the short-run supply curve is upward sloping (Winter, 1994; Gron, 1994; Froot and O'Connell, 1997). As a result, prices would increase and quantities decline after a loss shock that reduces reinsurer capital below the long-run equilibrium level. Changes in demand after a loss shock such as a catastrophe may affect pricing if policyholders' expectations about future losses are

[4] In the late 1970s and early 1980s, insurers frequently ceded small amounts of business to many reinsurers to reduce credit risk (Kellogg and Watson, 1996). This practice changed in the 1980s, and primary companies began buying reinsurance from fewer, better-capitalized reinsurers with long-term commitments to the insurance industry. The NAIC also has tightened regulatory control over reinsurance recoverables through a series of reporting rule changes since.

[5] For an analysis of the London market, see Swiss Re (2002). Some reinsurance supply also comes from Asia, mainly Japan, although the statistics are difficult to interpret because Japanese insurers do not separately report primary insurance and reinsurance.

changed by the catastrophe as well. For example, Hurricane Andrew in 1992 may have caused insurers, reinsurers, and homeowners to reassess the likelihood of losses from hurricanes hitting Florida, causing prices to increase. The latter phenomenon is referred to as probability updating (Lai et al, 2000; Froot and O'Connell, 1997, 1999).

In the remainder of this section, theories concerning pricing and loss shocks are reviewed briefly. The theoretical foundation for why the price might change as capital levels change draws upon demand theory and underwriting cycle theory, especially the capacity constraint and risky debt hypotheses. Of interest in this discussion is how reinsurance margins are affected by retroactive loss shocks versus other types of capital shocks.[6] Finally, predictions of the theories for nonproportional property and casualty reinsurance margins are proposed.

Probability Updating and Price Elasticity

After a capital shock, demand for insurance may increase due to probability updating. Lai et al. (2000) show that the supply curve becomes more inelastic when a crisis occurs and that it shifts inwards. Similarly, demand changes (increases) as the expectations of future losses change (increase), and the policyholders' demand curve becomes more inelastic. The changes in demand and price elasticities after a capital shock then both lead to premium increases. One obvious explanation for the change in premiums is the change in expected losses. If perceived expected losses increase then so do premiums because they incorporate expected losses.

But the remaining part of the premium (underwriting expenses and the risk charge) might be affected too after a capital shock. Lai et al. (2000) and Froot and O'Connell (1997) indicate that the effects of changes in the variance of losses and covariance of losses are reflected in reinsurers' premiums. Hence, a perceived increase in the variance (volatility) of catastrophic property losses should increase the markup over expected catastrophe-related losses everything else held equal; the latter most likely occurred as a result of recent catastrophic losses (e.g., Hurricanes Andrew and Iniki). The covariance of losses is stressed more in liability insurance (especially commercial general liability insurance). As the covariance among losses increase, so does risk and, logically, the risk premium (i.e., markup over losses).

The decrease in demand price elasticity means that policyholders are willing to pay more for coverage.[7] In fact, policyholders have no choice but to pay higher premiums. Note that the perceived change in expected losses and their risk need not be symmetric for policyholders and reinsurers, and this will affect the extent of the shift in the

[6] For more comprehensive reviews of the literature, see Lai et al. (2000), Harrington and Niehaus (2000), and Froot and O'Connell (1997, 1999).

[7] Price increases for existing policyholders might be possible too because higher prices increase the financial strength of the reinsurer (and the reinsurer's ability to pay any losses incurred by the existing, old policyholder). Also, if loss shocks are correlated across reinsurers then the price elasticity of firm-specific demand is expected to decrease. The latter is made possible because existing policyholders face switching costs in changing their reinsurer and new entrants are hindered because they do not have access to all of the information known by existing reinsurers. However, in the long run, the advantage to existing reinsurers should be temporary only, as new entrants build up their stores of information.

policyholder's demand curve and change in elasticity. If the increase in premiums is considered to be too large by some policyholders, they will reduce coverage or fail to buy any coverage at all.

The impact of probability updating is likely to be line-specific. That is, prices would be expected to rise only in the line with the shift in losses. Froot and O'Connell (1997, 1999) recognize that probability updating occurs after catastrophic events in their catastrophe reinsurance pricing study.

Loss Shocks and Industry Capital

Firms may obtain capital from a number of different sources after a surplus-depleting shock. In general, externally raised capital is more costly than internally generated capital. For example, external capital is more costly than internal capital due to taxes on stock dividends and the costs of repurchasing stock. Further, informational asymmetries between capital providers and managers of a firm make external capital more costly than internal capital. For example, according to the pecking order theory, firms will first look to internal sources of capital and debt before raising external equity. One important source of internal capital is retained earnings (profits). Hence, after a loss shock, insurers *may* first rely on increasing profitability to restore capital; price increases would lead to higher profits and increase internal capital. In the discussion below, theories that explain the effect of capital shocks on price levels (i.e., capacity constraint and risky debt theories) are reviewed.

Capacity Constraint Hypothesis. The capacity constraint hypothesis postulates that capital does not flow freely into and out of the insurance industry due to market imperfections. As a result, insurers will be inclined to hold on to seemingly excess capital in profitable years, so as to have capital available to pursue opportunities in lean years. The capacity constraint hypothesis assumes also that claims are uncertain and correlated across policies, and insurers' (combined) equity determines industry supply. Because losses are correlated, all insurers will be affected similarly by a loss shock (e.g., adverse interpretation of tort law for general liability insurers in the 1980s leading to a general liability crisis). Thus industry-wide soft and hard markets will occur. In soft markets capital is plentiful, while in hard markets it is relatively scarce. As a result, in periods of excess capacity, insurance price is relatively low, and it is relatively high in periods with relatively low capitalization. Therefore prices are hypothesized to be sensitive to industry-wide capital. The main implication of the capacity constraint hypothesis in this research is that prices in the industry may be inversely related to *industry-wide* relative capital levels.

Winter (1994) and Gron (1994) test the capacity constraint theory using time series data aggregated across all lines. Gron (1994) also uses aggregate time series data for several lines (homeowners, general liability, automobile liability, and workers compensation) to test the theory. Both found general support for the capacity constraint hypothesis, although neither study could show that the capacity constraint hypothesis explained the liability crisis in the mid-1980s.

Risky Debt Hypothesis. While the capacity constraint hypothesis focuses on industry-wide relative capital levels, Cummins and Danzon (1997) use an option pricing model that focuses on the effects of loss shocks on individual firms. In the risky debt model, Cummins and Danzon (1997) assume that buyers are concerned with financial quality (i.e., financial strength) such that "safer" insurers command high prices. Further, their theory suggests that each insurer has its own optimal capital structure.

Loss shocks disturb the optimal capital structure. In particular, loss shocks cause capital to fall below the optimal level.[8] The risky debt hypothesis suggests that price is affected by a loss shock, although whether prices will fall or rise is ambiguous. Prices may decrease due to the increased insolvency risk associated with a lower capital level. In addition, prices may decrease (and capital costs increase) after a loss shock relating to reserving errors in particular because such errors introduce more uncertainty about the adequacy of the insurer's reserves.

On the other hand, Cummins and Danzon's model indicates that prices may increase after a loss shock if demand becomes less price elastic after a shock and/or the loss shock causes the firm's external cost of capital to increase sharply.[9] However, if the old policyholders are substantially the same as the new policyholders, the price increase may be more palatable because it strengthens the claims for the firm's old policyholders. Also, if the (policyholders) demand curve shifts outwards, then the insurer may be able to increase prices after a shock. Finally, if loss shocks are correlated across insurers then an industry-wide shock might make demand less elastic for individual firms in the industry. If a positive markup over cost is charged by the insurers, the positive markup might be used to restore safety levels from their post-shock level. They also posit that prices must increase before new external capital can be raised.

Cummins and Danzon (1997) use the following regression model to test their hypotheses:

$$P_t = \alpha + \beta_1 K_{t-1} + \beta_2 X_t + \beta_3 X_{t-1} + \varepsilon_t, \tag{1}$$

where p_t is price. K_{t-1} represents the difference between assets and liabilities for firm i at $t-1$ (i.e., policyholders' surplus), and X_t (X_{t-1}) are vectors of predetermined variables.[10] The variable designed to test the risky debt hypothesis is K_{t-1}, which is broken down into separate components. The components are new internal capital at $t-1$, new external capital in $t-1$, retroactive loss shock in $t-1$, and policyholders' surplus at $t-2$. This decomposition is used because the risky debt theory suggests that price responds differently to different types of capital shocks (especially retroactive loss shocks). The empirical analysis in Cummins and Danzon (1997) supports the risky debt hypothesis in the U.S. general liability insurance market.

[8] Under the risky debt hypothesis, insurers would be unable to immediately raise new external capital after a loss shock because it would dilute old equity and increase the claim of old policyholders free of charge.

[9] A sharp increase in the firm's cost of external capital might occur if any new equity capital increases the value of old liabilities enough to result in a capital loss (Cummins and Danzon, 1997, p. 20).

[10] The X_{t-1} includes firm-specific and industry-wide capacity constraint variables, a Best rating variable, and a specialization (in general liability) variable. The X_t consist of a stock dummy variable and a dummy variable indicating whether the insurer is publicly traded.

The main implications of the risky debt hypothesis for this research are that the price might respond differently to a retroactive loss shock versus other forms of capital shocks because retroactive loss shocks may call into question the adequacy of the individual insurer's reserves for prior claims. The impact on price may be positive or negative. Also, it is important to distinguish between new external and internal capital.

Implications for Empirical Analysis

The arguments relating to price and capital changes are varied. Some arguments differentiate between company-wide loss shocks (risky debt theory) versus line-specific loss shocks (probability updating). Capital costs are expected to vary by source of funding (internal funding cheaper than external funding). Furthermore, informational asymmetries between capital markets and managers may exist about the level of reserving adequacy in general when retroactive loss adjustments are announced. Thus prices may respond differently to retroactive loss shocks (i.e., reports of underreserving) versus loss shocks from other sources. Therefore, it is important to distinguish between company-wide and line-specific retroactive loss shocks and the source of new capital (internal versus external).

In addition to sources of capital, some theories discussed in the previous section distinguish between firm-specific capital shocks (risky debt hypothesis) versus relative industry-wide capital levels (capacity constraint hypothesis). On the surface, the capacity constraint and risky debt hypotheses seemingly give opposite predictions about the relationship between prices and capital levels. But both theories together are consistent with the notion that overall supply does affect the pricing, but these effects vary by firm such that relatively better capitalized insurers (i.e., having higher relative surplus) benefit from their position by garnering higher prices. Not only are the theories consistent, but both theories can be tested simultaneously using cross-section, time series data. That is, industry-wide capital levels that change over time are useful to test the capacity-constraint hypothesis, while cross-section data are needed to test the risky debt hypothesis. What is really puzzling is why the capacity constraint theory cannot be used to explain the general liability crisis. Winter (1994) suggests that one reason for this anomaly is that worldwide reinsurance capital supply (as a substitute for or addition to primary market capital) is ignored in capacity constraint studies. If Winter (1994) is right, then we should find evidence that reinsurance prices are affected by worldwide capacity also.

The effects of probability updating and supply contraction after a loss shock are impossible to separate using time series data from the financial statements because the two effects occur simultaneously. With the cross-section data, however, it may be possible to glean some impact from probability updating on pricing.[11] If probability updating is occurring, then the price of coverage (say for nonproportional reinsurance) should be significantly related to a (retroactive) loss shock for *nonproportional* reinsurance. On the other hand, if price is significantly related to a company-wide loss shock, but not

[11] Detailed data from actual policies or policy cohorts are also needed to disentangle probability updating from capacity shocks, as in Froot and O'Connell (1997, 1999). For example, policy limits may change when new policies are written or old policies renewed.

a loss shock for nonproportional reinsurance only, then probability updating due to reserving errors is probably not responsible for price changes.

Predictions for Nonproportional Reinsurance

The capacity constraint and risky debt models predict the same results for both property and casualty reinsurance. However, the magnitude of the reaction to a loss shock or other change in financial quality might vary between the property and casualty lines. Presumably, it is more difficult to estimate losses for casualty reinsurance than for property, since claims may not be filed for several years after the accident year. In fact, a long history of reserving errors has been documented in several long tail lines of coverage. Further, due to positive correlation among casualty losses (e.g., from trial verdicts) large blocks of past business may be affected. The latter is not as much of a concern in nonproportional property reinsurance due to its shorter payout period. Then it would be more difficult to assess the financial quality of casualty reinsurers because of the uncertainty. Hence in terms of the risky debt model, casualty reinsurers may have to rely relatively more on price mark-ups and internal capital than on external capital compared to nonproportional property reinsurers. Also, nonproportional property catastrophe reinsurers may need to hold more (normalized) capital relative to nonproportional casualty reinsurers. These reinsurers must be able to pay a large amount of funds relatively quickly at some unpredictable time in the future.[12] Conceivably, some property catastrophe losses may be so large that they are difficult to fully diversify on a global basis (e.g., a major earthquake centered in Tokyo or New York City). Then policyholders are likely to gravitate to especially large *and* well-capitalized nonproportional property reinsurers, and these reinsurers likely would charge a higher price.[13]

We expect capacity to be an issue for both nonproportional property and casualty reinsurers. Probability updating is hypothesized by some to be at least partly responsible for the dramatic increase in prices for catastrophe reinsurance during the sample period. One might expect more sensitivity to capacity in the property nonproportional reinsurance market due to depletions of capital attributable to the Northridge earthquake and Hurricanes Andrew and Iniki. That is, the property catastrophe insurance market was already hit hard by these events and adverse loss shocks would only make the situation worse. Even though no major disruption in the supply of casualty reinsurance occurred over the period (as it did for property catastrophe reinsurance), it is still relevant to look at the relationship between capacity and price in nonproportional casualty reinsurance due to the turmoil at Lloyd's.

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[12] (Re)insurers' liabilities are reported in nominal dollars (vs. present values). The payout proportions in the early development periods are higher for nonproportional property reinsurance than for nonproportional casualty reinsurance. Thus, assuming equal reported liabilities, the present value of liabilities for property nonproportional reinsurance is larger than for casualty nonproportional reinsurance. So, even though nominal losses and surplus may be the same for two property and casualty nonproportional reinsurers, in real terms the property nonproportional reinsurer would be relatively less well capitalized. As a result, we may observe higher *reported* surplus to liabilities ratios for property nonproportional reinsurers.

[13] An example of such a reinsurer is National Indemnity Insurance Company, a member of the Berkshire-Hathaway Group. It is known as a super-CAT reinsurer due to its large size and extraordinary capitalization.

METHODOLOGY

The model used is designed to find the important determinants of nonproportional reinsurance prices charged by U.S. reinsurers. The empirical model draws upon the regression model used by Cummins and Danzon (1997) to test the risky debt hypothesis (see Equation (1)). However, we categorize our variables a little differently by associating them with financial quality and capacity constraints.

The model can be stated in its simplest form as

$$p = f(q, c, z),$$

where p is price of property (casualty) nonproportional reinsurance, q is a vector of firm-specific financial quality-related variables, c is a vector of industry capacity-related variables, and z is a vector of other independent variables. Given that reinsurance transactions are international in nature, the capacity-related variables take into account the capacity of the major international reinsurance markets as well as the capacity of the U.S. reinsurance industry. The latter makes this study different from existing capacity constraint studies and from Cummins and Danzon (1997). Another distinguishing characteristic of this study, compared to Cummins and Danzon (1997), is inclusion of a size variable.[14] This section describes the model variables and hypotheses tested.

Dependent Variable

The dependent variable in each regression is price in property (casualty) nonproportional reinsurance for each U.S. reinsurer in the sample. Price is defined as premiums earned divided by the present value of accident year losses incurred (e.g., Winter, 1994; Cummins and Danzon, 1997).

Independent Variables

This section provides a conceptual discussion of the independent variables. Precise definitions of the variables are provided in the following section.

Financial Quality Variables. An insurer's financial quality is measured using the relationship between policyholders' surplus and liabilities. This is an inverse leverage ratio, which is relevant because insurers hold surplus primarily to cushion adverse fluctuations in loss liabilities. Following Cummins and Danzon (1997), we hypothesize that the price reaction to changes in surplus may vary depending upon the source of the change. The principal sources of surplus change are measured by decomposing policyholders surplus at time $t-1$ as follows:

$$\begin{aligned} PHS_{t-1} = PHS_{t-2} &+ (\text{New Internal Capital})_{t-1} + (\text{New External Capital})_{t-1} \\ &- (\text{Retroactive Loss Shock})_{t-1} \end{aligned} \tag{2}$$

[14] Models without a size variable were estimated as well.

Capital (surplus) is broken down into several parts because prices may respond differently to a retroactive loss shock, which may convey adverse information about the firm's management quality or financial strength, as opposed to some other sources of leverage changes such as inflows of new capital (per the risky debt theory).

A retroactive loss shock consists of past reserving errors or unexpected surges in claims frequency or severity for coverage provided in the *past*. Cummins and Danzon (1997) hypothesized that company-wide retroactive loss shocks may lead to more uncertainty to the investor and policyholder concerning adequacy of loss reserves.[15] Use of the company-wide retroactive loss shock can be justified on the grounds that it affects the overall risk of the reinsurer by reducing surplus (in the case of an adverse deviation). If a retroactive loss shock in a line of business causes reinsurers and cedents to reevaluate risk in that line and adjust price accordingly (probability updating), the line-specific retroactive loss shock may be important also. Use of the line-specific retroactive loss shock provides an indication of how price responds as reinsurers update loss reserve estimates for the particular line.[16] For example, in the case of the Northridge earthquake, several reinsurers dramatically revised reserves upward as worse than expected property losses began pouring in.[17] If prices increase as these updates occur, this would provide some evidence of probability updating.

The right-hand side variables in Equation (2) are included as independent variables in the model after normalization. (The variables are normalized by dividing by liabilities in the prior period.)[18] Added together, the components of Equation (2) portray the financial leverage of the firm (i.e., policyholders surplus/liabilities).[19] Price is assumed to be positively related to financial quality, so that increases in the ratio of policyholders surplus to liabilities are associated with greater financial quality and higher prices. So, the expected sign of the normalized variables are hypothesized to be positive according to the risky debt theory, except for the company-wide retroactive loss shock. (As explained earlier, the sign of the company-wide retroactive loss shock variable is ambiguous in the risky debt theory.) With probability updating, the expected relationship between the line-specific retroactive loss shock and price is expected to be positive if retroactive shocks cause insurers to revise upward their estimate of future claims costs.

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[15] In Cummins and Danzon (1997), the total company-wide retroactive loss shock was used since the dependent variable was company-wide price.

[16] That is, probability updating related to reserve revisions is isolated. The occurrence of the catastrophe itself, irregardless of reserve accuracy most likely leads to probability updating also. As indicated earlier, to determine the full impact of probability updating, detailed information on actual policies is needed as in Froot and O'Connell (1997, 1999).

[17] For further discussion of loss reserving errors made by reinsurers and how they impact pricing, see Sclafane (2000).

[18] The surplus variables are normalized by liabilities because the denominator of the price variable, i.e., present value of losses incurred, is most closely related to liabilities and because retroactive loss shocks represent a revision of prior estimates of liability. Also, the primary purpose of surplus is to absorb unexpectedly high losses. Thus, it makes sense to relate financial quality to the amount of surplus the insurer has relative to liabilities.

[19] In all models tested, the company-wide retroactive loss shock is used, just as in Cummins and Danzon (1997). In some models the line-specific retroactive loss shock is added along with the company-wide retroactive loss shock.

Two additional financial quality variables are included in the models. The Best's rating for each reinsurer is used as another indicator of financial quality. Price is assumed to be positively related to the Best's rating such that insurers with higher Best's ratings (everything else held constant) charge higher prices. In nonproportional reinsurance, especially property catastrophe reinsurance, the size of a reinsurer may be an important criterion for a cedent in selecting reinsurers. Insurers with larger assets (holding normalized liabilities constant) are capable of paying higher losses, possibly signaling greater financial strength to cedents (e.g., Schachner, 1995). If size is important, then a positive relationship between price and size is expected. On the other hand, better diversification of risk may accrue to larger reinsurers, affecting price for their business. The latter effect might result in lower reinsurance prices in a *competitive* market due to better loss predictability. However, the lower price may be offset somewhat by the increase in financial quality resulting from better diversification.[20]

Industry Capacity Variables. The capacity of the insurance industry is typically measured in terms of relative surplus, with higher relative surplus associated with greater capacity, everything else held equal. Thus a measure of relative surplus is included in the model. In the present article a "worldwide" relative capacity variable is included in the models to test the hypothesis that insurance prices are related to the relative supply of worldwide insurance capital, rather than just U.S. capital as in previous studies. A negative coefficient for a capacity-related variable signifies that price is inversely related to the relative supply of reinsurer capital (surplus). Under the capacity constraint hypothesis, the coefficients for the capacity-related variables are expected to be negative.

In a perfect world, the geographic origin of reinsurance capacity would be moot. However, regulation may play a role in reinsurer selection. Many reinsurers are treated as nonadmitted insurers in the United States, and ceding companies incur substantial accounting penalties when ceding business to such a reinsurer.[21] That is, the ceding company cannot take credit for the reinsurance in their financial statements. These factors may dampen demand for foreign reinsurance. Cost differences also exist for foreign versus domestic reinsurers, although whether such cost differences flow through to a markup over expected losses depends on market conditions such as price elasticity.[22] Alternatively, the effect of regional capacity levels may differ if reported capacity is

[20] In a noncompetitive market, larger insurers might garner higher profitability by maintaining higher prices. In this case, there would be no significant relationship between size and prices.

[21] That is, the liability for these reinsured losses continue to be reported as a liability in the ceding company's financial statements, making the insurer appear to be more highly leveraged.

[22] For example, when assuming U.S. business, a 1 percent excise tax on premiums is imposed on the alien reinsurer; and the alien reinsurer should post a letter of credit for the sum of unearned premiums and outstanding losses, including incurred but not reported (IBNR) losses to avoid the accounting penalty for alien reinsurers. On the other hand, investment income on loss reserves from U.S. business is not taxed if the business is reinsured by a Bermuda-based reinsurer, see "ACE hammers tax proposal" (*National Underwriter*, April 3, 2000, pp. 3 and 31). The latter considerations must be gauged relative to the tax and regulatory cost of maintaining a license as an U.S. reinsurer. Thus the location of a reinsurer can affect costs (e.g., taxes), and these cost differences *may* lead to price differences for reinsurance depending on the competitive environment.

not consistent with perceived capacity (e.g., due to under-reserving of liability losses). Therefore, the models tested in the article include models with worldwide capacity and Lloyd's capacity as control variables and models with a finer geographic breakdown (i.e., a separate relative U.S. capacity variable).

Other Independent Variables. Finally, three company-specific dummy variables are used to control for foreign-owned insurers, group membership, and distribution system. It is possible that U.S. owned reinsurers have an advantage over foreign owned reinsurers in the U.S. market because they are domestic. A dummy variable equal to one if the reinsurer is U.S. owned, and zero otherwise is included in the models. Barrese and Nelson (1997) found that direct reinsurers operate with higher costs than nondirect reinsurers, and therefore might charge higher prices, depending on the competitive environment. A dummy variable assigned the value one is used to identify direct reinsurers; this dummy variable is equal to zero otherwise. Insurers that are members of a group are identified by a dummy variable equal to one for group members and zero otherwise. Group members may be considered more financially viable if policyholders believe that the parent company would contribute additional resources if the reinsurer developed financial problems or if other differences are perceived for insurers that are members of a group (e.g., more or less X-efficiency). Arguably, the group variable may reflect some financial quality considerations (e.g., if policyholders believe the parent will bail out troubled member companies). However, the catch-all nature of this variable warrants its inclusion as a control variable in this study rather than as a financial quality variable.

Regression Model

The following pooled, cross-sectional, time series model is estimated:

$$P_{it} = \alpha + \beta_1 \frac{s_{i,t-2}}{l_{t-3}} + \beta_2 \frac{y_{i,t-1}}{l_{t-2}} + \beta_3 \frac{c_{i,t-1}}{l_{t-2}} - \beta_4 \frac{r_{i,t-1}}{l_{t-2}} + \beta_5 \log(a_{i,t-1}) + \sum_{m=6}^{M} \beta_m x_{m,t-1} + \sum_{k=1}^{K} \delta_k z_{kit} + \varepsilon_{it}, \tag{3}$$

where P_{it} is the price of property nonproportional reinsurance, defined as premiums earned divided by the present value of accident year losses, $s_{i,t-2}$ = policyholders surplus for firm i lagged two periods, $y_{i,t-1}$ = new internal equity for firm i, $c_{i,t-1}$ = net new external equity capital for firm i, $r_{i,t-1}$ = loss reserve adjustment (the increase (decrease) in the current period's loss reserves for claims from prior periods, and $a_{i,t-1}$ = total assets of firm i.[23] The $x_{m,t-1}$ are market-wide (not company-specific) variables, the z_{kit} are other independent variables, ε_{it} is the error term, and the subscripts i and $t-j$ represent reinsurer i and year $t-j$, respectively.[24] The subscript m denotes the capacity-related variables in the regression. The model was estimated again with

[23] The retroactive loss shock is not included in net income in Equation (3).

[24] This specification is the same as Cummins and Danzon's model (see Equation (1)), except that different capacity variables are used and a size variable is included. A few independent variables are different too.

casualty nonproportional reinsurance price as the dependent variable. Use of a pooled model allows for time effects posited by the capacity constraint hypothesis and cross sectional differences expected under the risky debt hypothesis.

Analysis of the OLS residuals from both price regressions indicated that heteroscedasticity was present.[25] Therefore, weighted least squares estimation was used.[26]

Sample Selection

The empirical analysis focuses on the U.S. reinsurance market over the period 1991–1995. The samples consist of large, U.S. professional reinsurers writing nonproportional property and casualty reinsurance. The sample period encompasses turmoil and rejuvenation at Lloyd's of London, several insured catastrophes, the birth of the Bermuda CAT reinsurance market, and a so-called "flight to quality" in reinsurance. Thus, it is important to include capacity-related and financial quality-related variables in finding the determinants of nonproportional reinsurance prices.

Separate samples of the U.S. nonproportional property and nonproportional casualty reinsurers are constructed so as to allow for possibly different price determinants for the two lines. In order to identify insurers playing more than a nominal role in nonproportional reinsurance in the U.S., the following criteria are used to select the reinsurers in each sample: (1) The reinsurer must be operating in the U.S. and file an Annual Statement with the NAIC.[27] (2) The market share of the property (casualty) reinsurer must exceed 0.1 percent of the total property (casualty) nonproportional reinsurance premiums in the United States.[28] The latter ensures that the sample reinsurers write a noticeable amount of property (casualty) nonproportional reinsurance. (3) At least 5 percent of total premiums written by the reinsurer must be property (casualty) nonproportional reinsurance. (4) The proportion of property (casualty) nonproportional reinsurance premiums assumed from nonaffiliates must exceed 70 percent. This criterion is used to exclude reinsurers that rely extensively on intra-group transactions.

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[25] The test for heteroscedasticity used is described in Breusch and Pagan (1979). The results are significant at better than the 1 percent level.

[26] A two-step estimation procedure described in Greene (2000, pp. 514-515) was used to adjust for heteroscedasticity. The test results for both property and casualty samples indicated that heteroscedasticity was related to the relative amounts of nonproportional premiums assumed and nonproportional premiums ceded. In the case of nonproportional property reinsurance price, ownership (U.S. vs. foreign owned) and the interaction between ownership and the relative amounts of nonproportional premiums assumed and ceded were significantly related to heteroscedasticity as well. Therefore, the weight in the casualty price equation uses the relative amount of nonproportional casualty premiums assumed and ceded. The weight in the property equation uses the predicted values from the regression of the normalized error term on ownership, relative amount of nonproportional property premiums assumed and ceded, and the interaction among the latter two variables. Studentized residuals were analyzed to determine if outliers were present. Observations with studentized residuals in excess of four were deleted. The limited time series prevented any adjustment for autocorrelation.

[27] Data for alien reinsurers were used to construct some relative world capacity variables; that is, data on alien reinsurers were used to specify some *independent* variables.

[28] The average cutoff levels of premiums are \$2.5 and \$6.8 million, respectively, for the property and casualty 0.1 percent samples.

As a robustness check, two additional samples were constructed, one each for property and casualty. Reinsurers in these samples meet all of the requirements above except for criterion 2. Instead of a 0.1 percent market share, the criterion was changed to 0.5 percent. Thus reinsurers in the two new samples each wrote at least a 0.5 percent market share in property (casualty) nonproportional reinsurance.[29] Using two samples balances the desirability of having a large number of observations for statistical testing purposes with the desire to focus the analysis on important market players in the nonproportional reinsurance market. In particular, it addresses the concern that some reinsurers in the 0.1 percent sample are only a very small part of the market. The 0.5 percent criterion was used also by Cummins and Danzon (1997), and so the results of this study are more readily comparable with theirs.

DATA

Data for the sample reinsurers were obtained primarily from the individual reinsurers' Annual Statements that are filed with the NAIC. Data for 1990–1995 were used (as these data were available to the authors).[30] To calculate price, Schedule P industry-wide payout tails for property and for casualty nonproportional reinsurance are used to determine payout proportions in each line. The U.S. Treasury yields over the payout period were then applied to discount losses (see, e.g., Winter, 1994; Cummins and Danzon, 1997).[31]

The change in accident year losses (reserving errors) from time $t-2$ to $t-1$ is used to measure the retroactive loss shock. Both company-wide and line-specific retroactive loss shock variables are calculated. To compute the loss shocks, reserving errors between time $t-1$ to $t-2$ are calculated for (1) nonproportional property reinsurance only (from Schedule P, Part 2N, Reinsurance A); (2) nonproportional liability reinsurance only (from Schedule P, Part 2O, Reinsurance B); and (3) company-wide losses (Schedule P, Part 2, Summary).

New internal capital in year $t-1$ is the sum of underwriting income (net of the retroactive loss shock), investment income, other income, and other changes in surplus in

[29] The average cutoff levels of premiums in these samples are \$12.5 and \$33.8 million, respectively, for the property and casualty 0.5 percent market share samples. Property and casualty nonproportional reinsurance premiums are obtained from Schedule P, Parts 1N and 1O.

[30] Six years of data are required to estimate some of the variables described earlier.

[31] Specifically, net premiums earned data for property and casualty nonproportional reinsurance are obtained for each reinsurer from Schedule P, Parts 1N and 1O, respectively. In determining the present value of losses, the first step is to obtain the estimated loss cash flow proportions associated with any given year's incurred losses. This was done using data from Schedule P, Parts 1N and 1O, respectively. The loss cash flow patterns are estimated using the chain ladder method (see Hossack, Pollard, and Zehnwirth, 2001). The cash flow patterns are the same for all years because prior work showed that these patterns are quite stable over periods of time of 5–10 years. The loss cash flow proportions (adding to 1.0) are multiplied by a given year's incurred losses to obtain the anticipated loss payment in each future year of the loss payoff period. The estimated loss payments are then discounted back to the accident year using U.S. Treasury yield curves, interpolated from bond yield rates obtained from the Federal Reserve Bank of St. Louis (FRED) database. Thus, the incurred losses and the U.S. Treasury yield curves vary by year but the same estimated cash flow runoff pattern is used for each year.

year $t-1$. New external capital in year $t-1$ is capital paid in minus dividends in year $t-1$. Each component of policyholders surplus in Equation (3) is normalized by dividing it by total liabilities at the end of $t-2$ except for $S_{i,t-2}$ which is normalized to total liabilities at the end of year $t-3$.[32]

Additional information such as the A. M. Best rating was gathered from *Best's Insurance Reports Property/Casualty Edition* (various years). Two specifications are tested. One specification is that used in Cummins and Danzon (1997): reinsurers with an A or better Best's rating are assigned a value of one, while all other reinsurers are assigned a value of zero. The alternative specification assigns a value of one if the reinsurer has an A+ or better rating, and zero otherwise. The alternative specification is more relevant if most of the reinsurers in the study have a high Best's rating already, or if Best's ratings fail to discriminate accurately among A or better rated reinsurers.

To measure worldwide relative capacity, total surplus of the world's top 100 reinsurance companies and Bermuda CAT reinsurers in each year are divided by the 5 year prior average value of surplus.[33] Winter (1994) and Cummins and Danzon (1997) also use the ratio of surplus to its prior 5-year historical average to test the capacity constraint hypothesis. Regional relative capacity variables are constructed as well. That is, separate relative capacity variables are estimated for the U.S. using surplus data for U.S. reinsurers.

The worldwide capacity variable is constructed using data from reinsurers on Standard & Poor's (S&P's) top 100 world reinsurers list and the property CAT reinsurers in Bermuda (discussed earlier).[34] The data on Bermuda-based property catastrophe reinsurers were obtained from *Standard & Poor's Classic Database*. The data on other alien reinsurers worldwide were obtained from *reactions*, published by Reactions Publishing Group, Ltd. Each year a listing of the world's 100 largest reinsurers is published in this journal.

Capacity of Lloyd's is stated in terms of the maximum premium (i.e., the premium income limit) the underwriters at Lloyd's can write.[35] Relative capacity at Lloyd's

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[32] Cummins and Danzon (1997) normalized their variables in the same way.

[33] Surplus is reported in U.S. dollars and deflated in each year by the CPI to produce comparable values.

[34] Bermuda capacity is estimated using surplus for the Bermuda CAT reinsurance companies that do not appear on S&P's top 100 reinsurance company list. In the casualty models, surplus of the Bermuda property CAT reinsurers that are not included in S&P's top 100 reinsurer list are not included, as they provide no capacity for casualty nonproportional reinsurance. S&P's top 100 reinsurance company list is used to identify alien reinsurers. The Japanese reinsurers on the list (except for Toa Re) can better be described as some of the world's largest primary insurers rather than reinsurers. It is unlikely that they actually write U.S. property or casualty nonproportional reinsurance. Further, they did not report the policyholders' surplus data needed for this study, and hence they are excluded. Winterthur Group is excluded also because of missing data. After these deletions, approximately sixty alien reinsurers are used to determine relative world capacity each year.

[35] Data for Lloyd's of London are not included in the capacity variables just discussed because a measure of surplus is not available. One reason is that some members have unlimited liability, and their net worth is not disclosed. (Neither are they included in S&P's top 100 reinsurers list during the sample period for the same reason.) Policyholders surplus estimates simply do not exist for the time period covered in this study. One potential capacity measure is

then is measured in this study based on the relative values of premium income limits over time. More specifically, the premium income limit for year $t-1$ is divided by the average premium income limit for the years $t-6$ to $t-2$. This ratio is included as an independent variable. *Statistics Relating to Lloyd's 1997* was used to obtain information about Lloyd's of London.

RESULTS

Summary statistics for the two property samples (0.1 and 0.5 percent) and two casualty samples (0.1 and 0.5 percent) are presented in Table 1.[36] Regression results are reported in Tables 2–4. The results are discussed below.

Differences between means tests were conducted for the variables in Table 1 between property and casualty reinsurers with at least a 0.1 percent market share and with at least a 0.5 percent market share. In the 0.1 percent market share samples, price is significantly higher for the casualty reinsurers while normalized Policyholders Surplus_{t-2} and the Best's rating are significantly greater in the property reinsurer sample. For the 0.5 percent property and casualty samples, the only significant difference is the size of total assets, with casualty reinsurers having a larger mean value. Thus the differences between the two samples lie in the financial quality variables.

Before discussing in detail the regression results by line in Tables 2 and 3, similarities and differences in the property versus casualty results are considered. Three of the financial quality variables (Policyholders Surplus_{t-2}, New Internal Capital_{t-1}, and New External Capital_{t-1}) are significant and positive in all models as predicted by the risky debt hypothesis. Also consistent with the risky debt hypothesis, the retroactive loss shocks are significant in the 0.5 percent casualty model and the 0.1 percent property sample in Tables 2 and 3. However, the signs of the loss shock coefficients vary in the property versus casualty models. (This is discussed in greater detail later.)

Consistent with the capacity constraint hypothesis, relative world capacity is negatively related to prices in all models, and significant in five of the models. Recall that under the capacity constraint hypothesis, price is inversely related to relative capacity so that high capacity is associated with relatively lower prices, everything else held constant. Thus, the results imply that both financial quality and market capacity play a role in explaining reinsurance prices.

In Appendix B, elasticities corresponding to the financial quality and capacity variables are reported. The elasticity of price with respect to Policyholders Surplus_{t-2} is higher in the property reinsurer sample than for casualty. That is, the elasticity is approximately 0.058 for casualty versus 0.071 for property in the 0.1 percent samples and 0.125 for property versus 0.052 approximately for the 0.5 percent samples.

the ratio of premiums written divided by the maximum premiums allowed. But the latter variable does not provide any information about whether capacity utilization is larger or smaller compared to other years. That is, it does not provide a measure of *relative* capacity utilization as do the other measures of relative regional capacity used in this study.

[36] The two samples of property and casualty nonproportional reinsurers differ significantly. For example, only 83 of the observations in the property sample are also in the casualty sample. Thus estimation by SUR or other system methods on the overlapping observations in the samples are not used because more information would be lost by restricting the sample than likely would be gained in terms of efficiency of the estimates.

TABLE 1
Summary Statistics

Variable	Property 0.1% Mean	Property 0.1% Standard Deviation	Property 0.5% Mean	Property 0.5% Standard Deviation	Casualty 0.1% Mean	Casualty 0.1% Standard Deviation	Casualty 0.5% Mean	Casualty 0.5% Standard Deviation	Property vs. Casualty Means Tests 0.1%	Property vs. Casualty Means Tests 0.5%
Price	\$1.44	\$0.67	\$1.58	\$0.68	\$1.72	\$0.64	\$1.57	\$0.70	***	
Financial Quality Related										
Policyholders surplus$_{t-2}$	0.974	0.980	0.653	0.772	0.757	0.779	0.609	0.853	*	
New internal capital$_{t-1}$	−0.014	0.617	0.023	0.115	0.026	0.126	0.020	0.087		
New external capital$_{t-1}$	0.118	0.650	0.100	0.659	0.082	0.510	0.072	0.634		
Company retroactive loss shock$_{t-1}$	0.015	0.099	0.022	0.074	0.015	0.064	0.011	0.056		
Line retroactive loss shock$_{t-1}$	−0.004	0.075	0.001	0.016	−0.005	0.053	−0.002	0.058		
Log(total assets)$_{t-1}$$^{\#}$	\$1.13	\$2.12	\$1.84	\$2.53	\$0.83	\$1.07	\$2.57	\$3.14	***	**
Best's rating (equals 1 if A+)$_{t-1}$	0.890	0.314	0.352	0.480	0.267	0.445	0.446	0.500	***	
Capacity-Related Variables										
U.S. relative capacity$_{t-1}$	1.150	0.040	1.153	0.040	1.146	0.045	1.145	0.046		
Lloyd's relative capacity$_{t-1}$	0.945	0.151	0.950	0.153	0.937	0.154	0.939	0.188		
Relative world capacity$_{t-1}$	1.391	0.090	1.393	0.088	1.393	0.092	1.405	0.093		
Other Variables										
U.S. (vs. foreign) owned	0.520	0.502	0.648	0.480	0.513	0.501	0.707	0.458		
Direct writer dummy	0.220	0.416	0.440	0.500	0.179	0.385	0.380	0.489		
Group membership dummy	0.772	0.420	0.824	0.383	0.756	0.431	0.870	0.338		
Number of observations	127		91		156		92			

Notes: New internal capital is the sum of underwriting income (net of retroactive loss shock), investment, income, other income, and other gains in surplus; New external capital is the new capital paid in minus dividends. Retroactive loss shock is the change in prior years' incurred losses; U.S. and World relative capacity is the average surplus divided by its prior five year average value; Lloyd's relative capacity is the premium income limit divided by its prior 5 year average value; U.S. owned is equal to one if U.S.-owned insurer and zero otherwise; Direct writer equals one if direct writer and zero otherwise; Group membership is equal to one if member of a group and zero otherwise. Financial quality variables normalized by dividing by the liabilities at $t-2$ except for surplus at $t-2$, which is divided by liabilities at time $t-3$ and except for log(total assets) at time $t-1$. Best's rating is equal to one if rating is A+ or above and zero otherwise. Price is defined as premiums earned divided by the present value of accident year losses. The measure of relative world capacity differs between the property and casualty samples because Bermuda's CAT reinsurers' capacity is included for the property sample. Otherwise, differences in the capacity measures across samples are attributable to differences in the numbers of sample reinsurers by year. Means tests conducted on all variables.

***Significant at 1% level; **Significant at 5% level; *Significant at 10% level; #in billions.

TABLE 2
Nonproportional Casualty Reinsurance

Dependent Variable: Price of Casualty Nonproportional Reinsurance

	Reinsurers With at Least 0.1% Market Share				Reinsurers With at Least 0.5% Market Share			
	Model 1 World Capacity		Model 2 Regional Capacity		Model 3 World Capacity		Model 4 Regional Capacity	
Independent Variables	Coeff.	*t*-ratio	Coeff.	*t*-ratio	Coeff.	*t*-ratio	Coeff.	*t*-ratio
Intercept	2.1718	5.35***	2.1097	4.91***	1.767	2.55**	1.7914	2.51**
Financial Quality Related								
Policyholders surplus$_{t-2}$	0.0662	8.58***	0.0649	7.89***	0.083	4.8***	0.0862	3.24***
New internal capital$_{t-1}$	1.5741	11.65***	1.5650	11.43***	1.168	2.36**	1.2155	2.08**
New external capital$_{t-1}$	0.1815	8.89***	0.1813	8.85***	0.1542	3.23***	0.1586	2.85***
Co. retroactive loss shock$_{t-1}$	−0.2267	−0.99	−0.2222	−0.97	−0.6603	−2.39**	−0.6519	−2.30**
Best's rating$_{t-1}$	0.0245	0.44	0.0215	0.38	−0.0572	−1.01	−0.0581	−1.02
Log(total assets)$_{t-1}$	0.0128	0.62	0.0140	0.67	−0.0537	−2.08**	−0.0532	−2.03**
Capacity-Related Variables								
U.S. relative capacity$_{t-1}$			0.1541	0.46			−0.0792	−0.16
Lloyd's relative capacity$_{t-1}$	0.1563	1.00	0.1265	0.74	0.0016	0.01	0.0145	0.08
Relative world capacity$_{t-1}$	−0.4939	−2.42**	−0.5538	−2.28**	−0.2251	−0.56	−0.1898	−0.41
Other Variables								
U.S. (vs. foreign) owned	−0.0519	−1.19	−0.0521	−1.19	0.1147	1.85*	0.1168	1.83*
Direct writer dummy	0.1690	3.74***	0.1764	3.66***	0.1653	3.53***	0.1639	3.41***
Group membership dummy	−0.0943	−2.82***	−0.0986	−2.83***	−0.0529	−0.95	−0.0528	−0.94
Adjusted R^2		0.88		0.88		0.43	0.42	

Note: New internal capital is the sum of underwriting income (net of retroactive loss shock), investment income, other income, and other gains in surplus; New external capital is the new capital paid in minus dividends. Retroactive loss shock is the change in prior year's incurred losses; U.S. and World relative capacity is the average surplus for the year divided by its prior five year average value; Lloyd's relative capacity is the premium income limit divided by its prior five year average value; U.S. owned is equal to one if U.S. owned insurer and zero otherwise; Direct writer equals one if direct writer and zero otherwise; Group membership is equal to one if member of a group and zero otherwise. Financial quality variables are normalized by dividing by liabilities at time $t-2$ except for surplus at $t-2$ which is divided by liabilities at time $t-3$ and except for log(total assets) at time $t-1$. Best's rating is equal to one if rating is A+ or above and zero otherwise. Price is defined as premiums earned divided by the present value of accident year losses.
***Significant at 1% level; **significant at 5% level; *significant at 10% level.

TABLE 3
Nonproportional Property Reinsurance

Dependent Variable: Price of Property Nonproportional Reinsurance								
	Reinsurers With at Least 0.1% Market Share				Reinsurers With at Least 0.5% Market Share			
	Model 1 World Capacity		Model 2 Regional Capacity		Model 3 World Capacity		Model 4 Regional Capacity	
Independent Variables	Coeff.	*t*-ratio	Coeff.	*t*-ratio	Coeff.	*t*-ratio	Coeff.	*t*-ratio
Intercept	3.8540	4.90***	5.7371	5.19***	5.6398	3.75***	8.1153	4.74***
Financial Quality Related								
Policyholders surplus$_{t-2}$	0.0690	3.34***	0.0774	3.76***	0.1715	1.84*	0.2095	2.31**
New internal capital$_{t-1}$	0.5187	2.38**	0.4140	1.90*	1.7989	2.40**	2.1604	2.94***
New external capital$_{t-1}$	0.5409	3.16***	0.3655	2.00**	0.3222	3.03***	0.3428	3.34***
Co. retroactive loss shock$_{t-1}$	0.9113	3.35***	0.8559	3.20***	1.0344	1.26	1.0312	1.30
Best's rating$_{t-1}$	0.3110	1.70*	0.3131	1.75*	−0.0594	−0.35	−0.0610	−0.38
Log(total assets)$_{t-1}$	−0.0948	−2.16**	−0.1112	−2.55**	−0.1793	−2.19**	−0.1665	−2.11**
Capacity-Related Variables								
U.S. relative capacity$_{t-1}$			−3.0609	−2.37**			−4.5134	−2.70***
Lloyd's relative capacity$_{t-1}$	−0.7616	−2.73***	−0.3791	−1.19	−1.0651	−2.28**	−0.2978	−0.56
Relative world capacity$_{t-1}$	−1.8475	−4.31***	−0.9733	−1.74*	−2.7708	−3.32***	−1.3880	−1.46
Other Variables								
U.S. (vs. foreign) owned	0.1728	2.17**	0.1521	1.94*	0.1499	1.14	0.1193	0.94
Direct writer dummy	0.3038	2.01**	0.3253	2.19**	0.7416	3.76***	0.7282	3.84***
Group membership dummy	0.2658	2.42**	0.3565	3.12***	0.1812	0.89	0.2479	1.26
Adjusted R^2		0.34		0.36		0.27		0.32

Note: New internal capital is the sum of underwriting income (net of retroactive loss shock), investment income, other income, and other gains in surplus; New external capital is the new capital paid in minus dividends. Retroactive loss shock is the change in prior year's incurred losses; U.S. and World relative capacity is the average surplus for the year divided by its prior five year average value; Lloyd's relative capacity is the premium income limit divided by its prior five year average value; U.S. owned is equal to one if U.S.-owned insurer and zero otherwise; Direct writer equals one if direct writer and zero otherwise; Group membership is equal to one if member of a group and zero otherwise. Financial quality variables are normalized by dividing by liabilities at time $t-2$ except for surplus at $t-2$, which is divided by liabilities at time $t-3$ and except for log(total assets) at time $t-1$. Best's rating is equal to one if rating is A+ or above and zero otherwise. Price is defined as premiums earned divided by the present value of accident year losses.
***Significant at 1% level; **significant at 5% level; *significant at 10% level.

TABLE 4
Nonproportional Reinsurance

Dependent Variable: Price of Nonproportional Reinsurance	Property				Casualty			
	Model 1 0.1% Market Share		Model 2 0.5% Market Share		Model 3 0.1% Market Share		Model 4 0.5% Market Share	
Independent Variables	Coeff.	*t*-ratio	Coeff.	*t*-ratio	Coeff.	*t*-ratio	Coeff.	*t*-ratio
Intercept	5.3327	4.71***	8.0913	4.71***	2.2659	5.17***	1.9857	2.63**
Financial Quality Related								
Policyholders surplus$_{t-2}$	0.0892	4.07***	0.224	2.41**	0.0875	5.29***	0.0463	0.82
New internal capital$_{t-1}$	0.4352	2.00**	2.2437	3.01***	1.4448	9.25***	1.3326	2.21**
New external capital$_{t-1}$	0.4185	2.26**	0.3502	3.38***	0.1786	8.73***	0.1577	2.82***
Co. retroactive loss shock$_{t-1}$	0.0885	0.15	1.1615	1.43	−0.2345	−1.02	−0.7389	−2.43**
Line retroactive loss shock$_{t-1}$	0.9771	1.51	−2.8915	−0.74	−0.4467	−1.57	0.6187	0.80
Best's rating$_{t-1}$	0.2614	1.44	−0.0368	−0.22	0.0379	0.66	−0.0596	−1.04
Log(total assets)$_{t-1}$	−0.1215	−2.77***	−0.1781	−2.21**	0.0173	0.83	−0.0637	−2.17**
Capacity-Related Variables								
U.S. relative capacity$_{t-1}$	−2.5793	−1.95*	−4.52	−2.70***	0.2344	0.69	−0.3064	−0.52
Lloyd's capacity utilization$_{t-1}$	−0.4529	−1.42	−0.3346	−0.62	0.07	0.40	0.0153	0.08
Relative world capacity$_{t-1}$	−1.0526	−1.88*	−1.3955	−1.46	−0.7292	−2.74***	−0.1131	−0.24
Other Variables								
U.S. (vs. foreign) owned	0.1732	2.18**	0.1651	1.16	−0.0234	−0.50	0.0792	1.00
Direct writer dummy	0.3459	2.33**	0.7342	3.86***	0.1527	3.04***	0.171	3.49***
Group membership dummy	0.4188	3.46***	0.2734	1.37	−0.0746	−1.97*	−0.0361	−0.60
Adjusted R^2		0.37		0.32		0.88		0.42

Note: New internal capital is the sum of underwriting income (net of retroactive loss shock), investment income, other income and other gains in surplus. New external capital is the new capital paid in minus dividends; Retroactive loss shock is the change in prior years' incurred losses; U.S. and World relative capacity is the average surplus for the year divided by its prior five year average value; Lloyd's relative capacity is the premium income limit divded by its prior five year average value. U.S. owned is equal to one if U.S.-owned insurer and zero otherwise; Direct writer equals one if direct writer and zero otherwise; Group membership is equal to one if member of a group and zero otherwise; Best's rating is equal to one if rating is A+ or above and zero otherwise. Financial quality variables normalized by dividing by liabilities at time $t-2$ except for surplus at $t-2$, which is divided by liabilities at time $t-3$ and except for log(total assets) at time $t-1$. Price is defined as premiums earned divided by the present value of accident year losses.
***Significant at 1% level; **significant at 5% level; *significant at 10% level.

This indicates that price is more sensitive to the leverage position of the reinsurer for property nonproportional reinsurance. One explanation for this might be that nonproportional property reinsurers are required to pay very large losses on the sudden occurrence of a catastrophe so more "free and clear" surplus is required.

Similarly, over the sample period, price increased proportionately more for each additional dollar of New External Capital$_{t-1}$ for property compared to casualty reinsurance; that is, the elasticity for New External Capital$_{t-1}$ is larger in the property sample than for the casualty sample. Finally, nonproportional property reinsurance prices overall were more sensitive to United States and world-relative capacity over the sample period than for casualty reinsurance. Taken together, these results signify that capacity was a much more important issue for property reinsurance, consistent with various news reports during this time (e.g., Walsh and Elkind, 1995) and that nonproportional property reinsurance prices were more volatile than for casualty (i.e., because larger relative price changes at the margin are associated with each additional dollar of capital for property reinsurance than for casualty). Also during the sample period, property nonproportional reinsurance prices were more sensitive to loss shocks than for casualty reinsurance (in terms of the absolute value of the elasticities).

Now, we turn to a specific analysis of the casualty nonproportional reinsurer samples in Table 2. Price is positively and significantly related to Policyholders Surplus$_{t-2}$ in all models, consistent with the risky debt model. With respect to the financial quality variables, the coefficients for new internal capital are higher than for external capital in the casualty model, just as Cummins and Danzon (1997) found. Thus the coefficients do not support the hypothesis that external equity is more costly than internal equity. However, this statement should be tempered; new external capital is, in general, much easier to observe than yearly retained earnings because of loss reserving errors.

The results in the 0.5 percent casualty reinsurance samples indicate that prices fall after a retroactive loss shock, which is consistent with the risky debt hypothesis (i.e., prices fall as insolvency risk increases), and the coefficients are significant. Cummins and Danzon (1997) also found a negative coefficient for the loss shock variables. The coefficients for the Best's rating variable are not significant in any model. The coefficient for log(total assets)$_{t-1}$ is significant only in the 0.5 percent casualty sample. Thus, it appears that price is lower for the relatively larger reinsurers in this sample, *ceteris paribus*. Recall from Table 1 that log(total assets)$_{t-1}$ is larger in the 0.5 percent casualty sample already. Hence, the results may mean that diversification benefits accrue to the largest of the large reinsurers writing this business.[37] On the other hand, the possibility that larger insurers benefit from economies of scale and charge lower markups as a result cannot be ruled out.

Some evidence that relative capacity is related to reinsurers' prices is found in Table 2 for the 0.1 percent market share reinsurers. In models 1 and 3, two capacity variables are included. The first is Lloyd's relative capacity (in terms of premium income limits), and relative world capacity (excluding Lloyd's) is the second variable. Price is

[37] As a robustness check, we also ran the models omitting the size variable. The latter results are very similar to the results reported here. The differences are that a few of the coefficients for the company retroactive loss shock variable become significant for property reinsurers in the 0.1 percent sample in Tables 3 and 4, but some of the coefficients for the Best's rating variable are significant and negative.

significantly related to the world-relative capacity in model 1, but Lloyd's relative capacity is not significant in any of these models.

In models 2 and 4, three capacity variables are included. Two of the capacity variables are the same as before, while the third is relative capacity in the U.S. reinsurance market. Since U.S. relative capacity is included in world-relative capacity, one can question whether the U.S. relative capacity variable is adding any new information. The correlation coefficient between relative world capacity and relative U.S. capacity is approximately −12 percent. Thus the two are not highly correlated, indicating that the U.S. relative capacity variable contains different information than the world relative capacity variable. The coefficients for U.S. relative capacity are negative in models 2 and 4, as expected under the capacity constraint theory, but they are not significant. However, the coefficients for the world-relative capacity variable remain negative and significant in the 0.1 percent property sample. These results suggest that world relative capacity may be more important in explaining nonproportional casualty reinsurance prices in the United States than U.S. relative capacity. This could arise due to differences in regulatory and tax costs between the United States and other locations (depending on the competitiveness of the market).

Most of the control variables are significant in Table 2. On average, price is higher for U.S. owned insurers in the 0.5 percent sample and for direct writers in both samples. Group membership is important in both 0.1 percent market share models and is associated with lower prices.

The results for the financial quality variables in Table 3 differ from those in Table 2 for some variables. In the property samples, the loss shock variables are significant and positive in the 0.1 percent sample and insignificant in the 0.5 percent market sample. It is not clear as to why the coefficients are insignificant in the 0.5 percent sample. Perhaps this is due to the lower dispersion in the company-wide retroactive loss shock in the 0.5 percent model. Using the data in Table 1, the coefficient of variation for the company-wide retroactive loss shock in the 0.1 percent sample is 0.099/0.015 or 6.6, while it is 0.073/0.022 or 3.3 in the 0.5 percent sample. So, relatively speaking, the company-wide retroactive loss shock varied much more in the 0.1 percent sample, perhaps making it easier to show how retroactive loss shocks are related to prices.

The coefficient for Best's rating is positive and significant in the 0.1 percent market share sample in Table 3. The positive and significant coefficient for the Best's rating variable is consistent with the risky debt model.[38] In the 0.5 percent sample, the coefficient for the Best's rating variable is not significant however. The coefficient for log(total assets)$_{t-1}$ is negative and significant in all models. The negative coefficient for log(total assets)$_{t-1}$ indicates that lower prices are associated with larger (log) assets.

[38] An alternative specification of Best's rating was tested in which the Best's rating variable was assigned a value of one if the Best's rating was A or better, and zero otherwise. The latter is the rating variable used by Cummins and Danzon (1997). Overall, it had less explanatory power than the actual Best's rating used in this study. One explanation for this is that many professional reinsurers have high ratings already and so the Best's rating may not discriminate very well between professional reinsurers in the sample. For example, approximately 80 percent of reinsurers in the samples had an A or better rating. This is in contrast to the proportion of reinsurers with an A+ or better rating. The proportions of reinsurers in the samples with an A+ rating or greater are found in Table 3.

Thus, it does not appear that policyholders are willing to pay more based on the size of the reinsurer alone. Several possibilities might explain this; larger insurers may benefit from cost economies of scale or better loss diversification (pooling), and hence charge lower relative prices. In fact, the latter may be driving some of the consolidation activity in the reinsurance market over the past few years (Cummins and Weiss, 2000).[39]

Coefficients for world-relative capacity are negative and significant in three models (and in the other model the *t*-statistic is less than negative one). The coefficient for U.S. relative capacity is negative and significant in models 2 and 4, and the negative sign is expected under the capacity constraint theory. Lloyd's relative capacity is negative in all models, too; and it is significant in two of the models. Unlike the casualty samples, it appears that U.S. relative capacity may be more important than world-relative capacity for the 0.5 percent sample, since the U.S. relative capacity variable is the only significant relative capacity variable when all capacity measures are included in the same equation.

In Table 3, the coefficients for direct writer are positive and significant in both the 0.1 and 0.5 percent market share samples. Group membership is positively (and significantly) related to price for the reinsurers in the 0.1 percent market share sample, while U.S. ownership is significant in two models.

Table 3 indicates the coefficients for the retroactive loss shock variables in the property 0.1 percent sample are statistically significant. A positive coefficient for the loss shock variable is not consistent with the risky debt hypothesis; however, such a result could arise if the reinsurer has valuable private information on the policyholder. However, one might think that the role of private information would be more important for casualty rather than property reinsurance because the physical characteristics of property are more directly observable than behavior leading to liability losses.

As discussed in a previous section, as reserving errors arise reinsurers and policyholders may revise upwards their expectations of losses (probability updating). Thus it is useful to look at line specific loss shocks. But the line specific retroactive loss shock is incorporated in the company-wide retroactive loss shock; if the line-specific and company-wide retroactive loss shock are highly correlated, then the positive coefficient on the company-wide loss shock variable might be related to the line-specific loss shock. So, this raises a question as to whether it is the line specific or company-wide loss shock that is more important (or whether both are important).

The correlations between the company-wide retroactive loss shocks and the line-specific loss shocks are approximately 20 percent for all samples except for the 0.1 percent market share property sample, where the correlation is 72 percent. Thus, in all but the latter sample, the line specific loss shocks appear to contain significant different information than the company-wide loss shock.

Therefore, four more regressions were run in which the company-wide and line-specific loss shocks were included in the same model. The results are in Table 4. In these

[39] The negative coefficient for log(total assets)$_{t-1}$ might also indicate that smaller insurers specialize in market niches with higher expenses. That is, a reinsurer might have to be large to reinsure a large company such as State Farm, but reinsuring State Farm is less complex than in niche market types of reinsurance (e.g., airlines).

regressions, the company-wide loss shock is negative and significant in the 0.5 percent casualty reinsurer samples, and the line specific loss shock is not significant. For the property reinsurer samples, no loss shock variables are significant. (For the 0.1 percent market share sample, the two loss shock variables are highly correlated perhaps causing a multicollinearity problem.) Thus, it appears that the company-wide loss shock is more important in pricing than specific line loss shocks, at least for these samples.

CONCLUSION

This research investigates factors related to prices charged by U.S. reinsurers for nonproportional reinsurance. Factors hypothesized to be related to price can be found in the literature, especially, the underwriting cycle theory literature. Two prominent factors identified in the literature are relative capacity (i.e., capacity constraint hypothesis) and financial quality (i.e., risky debt model). And variables representing the two factors are included in the regression models.

A total of four samples of professional reinsurers are analyzed. Two samples consist of reinsurers writing a significant amount of nonproportional property reinsurance, and two more samples are constructed of reinsurers writing a significant amount of nonproportional casualty reinsurance. Overall, the results support the hypothesis that nonproportional reinsurance prices are significantly related to capacity and financial quality. Consistent with the risky debt hypothesis, relative policyholders surplus, new external and new internal capital are positively related to reinsurance prices in nonproportional property and casualty reinsurance. Company-wide retroactive loss shocks for nonproportional casualty and property insurance are found to be significantly related to prices in some models. With respect to the capacity constraint hypothesis, nonproportional property reinsurance prices are significantly related to relative capital in the U.S. insurance industry, and in some models prices were found to be significantly related to reinsurance capacity in other parts of the world.

In addition to explaining nonproportional reinsurance prices, this research sheds light on the validity of the capacity constraint and risky debt models of insurance pricing. For example, both Gron (1994) and Winter (1994) find that the capacity constraint theory cannot explain pricing for liability insurance in the 1980s as they expected. There are several explanations for this, and one of them involves reinsurance. That is, reinsurance capacity and reinsurance prices available to general liability insurers are not controlled for in the latter empirical studies. What governs reinsurance pricing? Is it governed by the same factors as the primary market? The answer to the latter question would be yes based on this research. So to understand pricing in the primary market, reinsurance market developments should be considered, as there might be a flow-through effect.

Finally, the models tested here can be applied to more recent events, such as the terrorist attack on September 11, 2001 and the aftermath of its effect on the global insurance industry. A fruitful avenue of future research would be to test these models on the shock caused by September 11. If the past is any guide, more reserving shocks are yet to occur related to these attacks causing concomitant changes in pricing, especially reinsurance pricing. It will be interesting to observe the effect of the reserve shocks yet to come on reinsurance prices.

APPENDIX A: SAMPLE REINSURERS

Property Nonproportional Reinsurance Sample

0.1 Percent Sample	0.5 Percent Sample
Winterthur Reins. Corp. of America	American Agricultural Insurance Co.
American Agricultural Insurance Co.	Sydney Reinsurance Corp.
Sydney Reinsurance Corp.	American Reinsurance Co.
American Re-Insurance Co.	Underwriters at Lloyd's London
Christiana General Ins. Corp. of NY	Reinsurance Corp. of NY
Yasuda Fire & Marine Ins. Co. of America	Transatlantic Reinsurance Co.
USF Reinsurance Co.	NAC Reinsurance Corp.
United Fire & Casualty Co.	Continental Reinsurance Corp.
Austin Mutual Insurance Co.	San Francisco Reinsurance Co.
Excess Reinsurance Co.	General Reinsurance Corp.
Farmers Mutual Hail In. Co. of IA	CIGNA Reinsurance Co.
Grinnell Mutual Reinsurance Co.	Kemper Reinsurance Co.
Underwriters at Lloyd's London	TIG Reinsurance Co.
Reinsurance Corp. of NY	Mercantile & General Reinsurance Co. of America
Transatlantic Reinsurance Co.	Skandia America Reinsurance Corp.
NAC Reinsurance Corp.	Swiss Reinsurance America Corp.
Continental Reinsurance Corp.	Everest Reinsurance Co.
San Francisco Reinsurance Co.	PXRE Reinsurance Co.
General Reinsurance Corp.	First Excess & Reinsurance Corp.
CIGNA Reinsurance Co.	Munich American Reinsurance Co.
Kemper Reinsurance Co.	Centre Reinsurance Co. of New York
TIG Reinsurance Co.	National Reinsurance Corp.
Mercantile & General Reins. Co. of America	AXA Reinsurance Co.
Skandia America Reinsurance Corp.	Folksamerica Reinsurance Co.
Swiss Reinsurance of America Corp.	Zurich Reinsurance Centre Inc.
Everest Reinsurance Co.	Employers Reinsurance Corp.
Rockford Mutual Ins. Co.	Houston Casualty Co.
Western Atlantic Reinsurance Corp.	
PXRE Reinsurance Co.	
SCOR Reinsurance Co.	
Wisconsin Reinsurance Corp.	
First Excess & Reinsurance Corp.	
Munich American Reinsurance Co.	
Cologne Reinsurance Co. of America	
Centre Reinsurance Co. of New York	
National Reinsurance Corp.	
Trenwick America Reinsurance Corp.	
AXA Reinsurance Co.	
Chartwell Reinsurance Co.	
Insurance Corp. of Hannover	
SAFR Reinsurance Corp. of the U.S.	
Folksamerica Reinsurance Co.	
Zurich Reinsurance Centre Inc.	
Hansa Reinsurance Co. of America	
Sorema North America Reinsurance Co.	
PMA Reinsurance Corp.	
Employers Reinsurance Corp.	
Georgia General Insurance Co.	
American Fuji Fire & Marine Inc.	
Navigators Insurance Co.	
Houston Casualty Co.	
Clarendon America Ins. Co.	

(Continued)

(Continued)
Casualty Nonproportional Reinsurance Sample

0.1 Percent Sample	0.5 Percent Sample
NLC Mutual Insurance Co.	Executive Risk Indemnity Inc.
Houston Casualty Co.	Western Atlantic Reinsurance Corp.
USF Re Insurance Co.	Zurich Reinsurance Centre
Health Providers Insurance Co.	Folksamerica Reinsurance Co.
Classic Fire & Marine Insurance Co.	American Agricultural Insurance Co.
American Fuji Fire & Marine Ins. Co.	North Star Reinsurance Corp.
Folksamerica Reinsurance Co.	Trenwick America Reinsurance Corp.
Toa-Re Insurance Co. of America	Centre Reinsurance Co. of New York
Signet Star Reinsurance Co.	AXA Reinsurance Co.
Insurance Corporation of Hannover	Underwriters at Lloyd's London
Sydney Reinsurance Corp.	North Star Reinsurance Corp.
Underwriters at Lloyd's London	SCOR Reinsurance Co.
Cologne Reinsurance Co. of America	Swiss Reinsurance America Corp.
First Excess & Reinsurance Corp.	NAC Reinsurance Corp.
Reinsurance Corp. of New York	Constitution Reinsurance Corp.
Christiana General Insurance Corp. of NY	PMA Reinsurance Corp.
Executive Risk Indemnity Inc.	Transatlantic Reinsurance Co.
Mercantile & General Reins. Co. of America	National Reinsurance Corp.
Western Atlantic Reinsurance Corp.	TIG Reinsurance Co.
Zurich Reinsurance Centre	Munich American Reinsurance Co.
Sorema North America Reins. Co.	Skandia America Reinsurance Corp.
San Francisco Reinsurance Co.	Kemper Reinsurance Co.
Insurance Corporation of Hannover	Everest Reinsurance Co.
Centre Reinsurance Co. of New York	American Reinsurance Co.
Signet Star Reinsurance Co.	Reliance Insurance Co.
Frankona American Reinsurance Co.	Employers Reinsurance Corp.
American Agricultural Insurance Co.	United States Fidelity & Guaranty Co.
North Star Reinsurance Corp.	St. Paul Fire & Marine Ins. Co.
Republic Western Insurance Co.	General Reinsurance Corp.
Trenwick America Reinsurance Corp.	
SCOR Reinsurance Co.	
AXA Reinsurance Co.	
Winterthur Reinsurance Corp. of America	
Continental Reinsurance Corp.	
United National Insurance Co.	
CIGNA Reinsurance Co.	
Swiss Reinsurance America Corp.	
NAC Reinsurance Corp.	
Constitution Reinsurance Corp.	
PMA Reinsurance Corp.	
Transatlantic Reinsurance Co.	
National Reinsurance Corp.	
TIG Reinsurance Co.	
Munich American Reinsurance Co.	
Skandia America Reinsurance Corp.	
Kemper Reinsurance Co.	
Federated Mutual Insurance Co.	
Everest Reinsurance Co.	
American Reinsurance Co.	
Reliance Insurance Co.	
Employers Reinsurance Corp.	
United States Fidelity & Guaranty Co.	
St. Paul Fire & Marine Insurance Co.	
General Reinsurance Corp.	

APPENDIX B

Elasticities of Regression Coefficients

	Reinsurers With at Least 0.1% Market Share				Reinsurers With at Least 0.5% Market Share			
	Model 1 World Capacity		Model 2 Regional Capacity		Model 3 World Capacity		Model 4 Regional Capacity	
Independent Variables	Casualty	Property	Casualty	Property	Casualty	Property	Casualty	Property
Financial Quality Related								
Policyholders surplus$_{t-2}$	0.0652***	0.0672***	0.0491***	0.0754***	0.0506***	0.1121*	0.0525***	0.1370**
New internal capital$_{t-1}$	0.0315***	−0.0075**	0.0041***	−0.0060*	0.0238**	0.0416**	0.0248*	0.0499***
New external capital$_{t-1}$	0.013***	0.0636***	0.0149***	0.0430**	0.0111***	0.0324***	0.0114***	0.0345***
Co. retroactive loss shock$_{t-1}$	−0.0095	0.0135***	−0.0032	0.0127***	−0.0075**	0.0225	−0.0074**	0.0225
Log(total assets)$_{t-1}$	−0.05	0.0792**	−0.0094	0.0929**	−0.0197**	0.0102**	−0.0195**	0.0095**
Capacity-Related Variables								
U.S. relative capacity$_{t-1}$			0.1767	−3.5216**			−0.0907	−5.2021***
Lloyd's capacity utilization$_{t-1}$	0.0166	−0.7194***	0.1450	−0.3581	0.0015	−1.0102**	0.0136	−0.2825
Relative world capacity$_{t-1}$	−0.2645***	−2.57***	−0.7717**	−1.3541*	−0.3162	−3.8606***	−0.2666	−1.9339

Note: New internal capital is the sum of underwriting income (net of retroactive loss shock), investment income, other income, and other gains in surplus; New external capital is the new capital paid in minus dividends; retroactive loss shock is the change in prior years' incurred losses; U.S. and World relative capacity is the average surplus for the year divided by its prior five year average value; Lloyd's relative capacity is the premium income limit divided by its prior five year average value; financial quality variables normalized by dividing by liabilities at time $t-2$ except for surplus at $t-2$, which is divided by liabilities at time $t-3$ and except for log(total assets).

***Significant at 1% level; **significant at 5% level; *significant at 10% level.

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