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The Trading of Underwriting Risk: An Analysis of Insurance Futures Contracts and Reinsurance

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ABSTRACT

This article analyzes insurance futures contracts versus reinsurance contracts as alternative methods of trading underwriting risk. Insurance futures contracts are based on the systematic portion of underwriting risk within a line of insurance. Because variability in losses due to systematic factors is outside the control of individual insurers, futures can allow for complete shifting of this portion of underwriting risk. In addition, the organization of a futures market is designed to allow for anonymity, which can enhance liquidity in the market for trading underwriting risk. An equilibrium model of an insurance futures market is presented to provide insights about how unregulated insurers may use futures, the determinants of insurance futures prices, and the impact of insurance futures on the primary market.

The Chicago Board of Trade (CBOT) is expected to introduce a futures contract on a pool of homeowners insurance policies in late 1992 or early 1993.[1] Contracts based on other lines of insurance, including group health and auto physical damage, are under consideration. These contracts are based on the underwriting losses of a large pool of policies; accordingly, futures allow for explicit trading of the systematic underwriting risk within a line of insurance,

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[1] The CBOT also plans to introduce options on the futures. This paper, however, deals exclusively with futures contracts. For a discussion of options on insurance futures, see Cox and Schwebach (1992). Hofflander, Nye, and Nettesheim (1991) and D'Arcy and France (1992) also analyze insurance futures.

that is, the underwriting risk that cannot be diversified away by writing policies in one line of insurance. The trading of underwriting risk via a futures market represents a departure from the bilateral trade of underwriting risks typically observed in the reinsurance market to the anonymous trading of a contingent claims market.

One objective of this article is to analyze insurance futures contracts versus reinsurance contracts as alternative methods of trading underwriting risk. An important distinction between these contracts is the manner in which they mitigate incentive problems that arise when underwriting risk is traded. Reinsurance contracts are based on the underwriting losses of a pool of policies written by the ceding insurer. Consequently, an incentive problem arises: The more risk that is shifted to a reinsurer, the less incentive the ceding company has to select low risk policyholders and to reduce loss claims. Reinsurance market participants recognize these incentive problems and attempt to control them through incomplete risk shifting; for example, by using deductibles, coinsurance, contingent prices, and experience rating. Futures contracts provide an alternative way of mitigating the incentive problem associated with trading underwriting risk. Futures payoffs are based on only the systematic risk within a given line of insurance. Because underwriting losses due to systematic factors are largely outside the control of insurers, futures contracts potentially allow for complete risk shifting of the systematic underwriting risk inherent in the policy pool on which the futures contract is based.

Another distinguishing feature of futures markets is the reduced need for contracting parties to monitor the creditworthiness of other parties. Default risk is negligible with futures, because traders post performance bonds (margin) and because the clearinghouse guarantees performance on futures transactions. The reduced need to monitor other parties allows systematic underwriting risk to be traded anonymously (see Telser, 1981). Consequently, a futures market can enhance liquidity in the market for trading underwriting risk. To assess whether greater liquidity is a meaningful innovation, the factors affecting insurer demand for liquidity and the cost of providing liquidity services in an insurance futures market are analyzed.

The second part of this article presents a model of an insurance futures market to analyze how unregulated insurers are likely to use insurance futures, the determinants of insurance futures prices, and the impact of insurance futures on the primary insurance market. An important implication of this analysis is that the extent to which insurers will use futures to hedge underwriting risk is contingent on the value of the equilibrium risk premium embedded in insurance futures prices. This risk premium depends on the compensation necessary to induce market participants to bear underwriting risk that is systematic within a given line of business. If the equilibrium risk premium is small, insurers are likely to find the risk reduction opportunities of futures cost-effective. Lower exposure to underwriting risk can in turn reduce prices in the primary insurance market.

Description of Insurance Futures

This section provides a general description of insurance futures contracts. The specifics of the contracts are subject to change and therefore are not discussed in detail (for details of the contracts, see Chicago Board of Trade, 1992). The implications of the subsequent analysis are unaffected by minor changes in contract specifications.

Insurance futures contracts are based on an index measuring underwriting losses for a pool of policies written by several insurers in a given line of insurance. Construction of the index requires policy information (policy provisions, premiums, losses paid) from a number of different insurers. Initially, the CBOT planned to construct its own pool of policies by having "regular insurers" who would contribute information. However, the CBOT found few insurers willing to participate (see *Wall Street Journal,* September 4, 1991).

For the homeowners contract, the CBOT has contracted with ISO Data Incorporated, a subsidiary of the Insurance Services Office (ISO), to act as pool manager. Each year, ISO Data will construct a pool of policies using data that is submitted to ISO by member insurers. The pool will consist of policies written in December of the previous year. For example, the 1993 pool will consist of policies written in December 1992. The pool will consist of at least 100,000 "house years" or at least $40 million of expected earned premiums. The pool will cover a geographically diverse set of policies with similar contractual provisions, and the demographics of the pool will be published.[2]

There will be four futures contracts traded on each policy pool. The contracts will expire at the end of four consecutive quarters. To illustrate, consider contracts based on a pool written in December of 1992. A futures contract will expire at the end of June 1993, September 1993, December 1993, and March 1994. The payoff on the June 1993 contract will depend on losses incurred in the first quarter and paid in either the first or second quarter of 1993. More specifically, the futures contract is based on an underwriting loss index equal to the ratio of losses paid to earned premiums. Algebraically, the underwriting loss index for a contract expiring in quarter q is

$$\bar{I}(q) = \sum_{i=1}^{N} \bar{l}_i(q) \Big/ \sum_{i=1}^{N} p_i(q-1). \tag{1}$$

where $p_i(q-1)$ = the premium earned on policy i in quarter q-1,

$\bar{l}_i(q)$ = the loss paid on policy i in quarters q and q-1 for losses that occurred in quarter q-1, and

N = the number of contracts included in the pool.

[2] Earthquake endorsements are not included in the pool and policies from Texas are not included. For more information, see Samorajski (1992) and the Chicago Board of Trade (1992).

A tilde over a variable means that its value is unknown prior to the end of the period.[3] In practice, the index will be scaled by multiplying the value in equation (1) by 100,000. For expositional ease, the 100,000 is omitted. Note that the index is based on losses paid over a given interval of time, thus avoiding problems associated with the measurement of loss reserves. For the remainder of the article, $\tilde{I}(q)$ will be referred to as simply $\tilde{I}$, as only one contract will be examined. Appendix A summarizes the notation used in this article.

A potential problem is that insurers whose policies comprise the index can take futures positions and then opportunistically release loss information or alter the payment of losses.[4] Opportunistic behavior of this sort will only become a problem if an individual insurer's policies make up a significant portion of the index. Of course, the CBOT recognizes the issue and has taken steps to mitigate the problem. At least ten different insurers will have policies included in the pool and no single insurer will have more than 15 percent of the included policies. Moreover, an insurer will be unaware of which of its policies (if any) are included in the pool.[5]

Analysis of Insurance Futures

Payoff from a Futures Position

We use a one-period model in which the ending date corresponds to the expiration date of the futures contract. Trading occurs at the beginning of the period and all positions are held until the end of the period. A long position in a futures contract yields a dollar return of $(\tilde{I}\text{-}f)$, where f is the futures price at the time the position is initiated. A long futures position can be thought of as agreeing to pay f in exchange for receiving the underwriting loss ratio on the pool of policies comprising the index. Conversely, a short position can be thought of as receiving f in exchange for paying the underwriting loss ratio on the pool of policies comprising the index. All market participants have homogeneous expectations concerning the index value.[6]

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[3] Earned premiums are assumed to be known once the contracts are sold. In practice, there is some uncertainty about earned premiums because premiums are partially refunded to consumers if the policy is terminated prior to its expiration and because endorsements (changes in insurance contracts) change premium revenue.

[4] In an effort to protect themselves from this opportunistic behavior, traders providing liquidity to the futures market would likely widen their bid/ask spread and therefore increase transaction costs for all traders (Glosten and Milgrom, 1985).

[5] Even though potential manipulation problems exist with most futures contracts, there are numerous successful contracts. For example, despite the fact that the three firm concentration ratio of warehousing space eligible for delivery on the CBOT's soybean contract is 76 percent, the soybean contract has traded successfully for decades (see Peck and Williams, 1991).

[6] Incorporating heterogeneous information, although beyond the scope of this paper, would allow for an analysis of how insurance futures prices can reveal information to market participants.

Since the index is comprised of a large number of policies, its value will differ from its expected value, primarily because losses on the underlying policies are correlated.[7] This correlation is modeled by assuming a single factor model for the index:

$$\tilde{I} = E(\tilde{I}) + \tilde{F}, \tag{2}$$

where $\tilde{F}$ is the unexpected realization of a systematic factor that affects losses on the policies comprising the index.[8] Positive realizations of $\tilde{F}$ indicate higher than expected losses on the underlying policies and therefore a higher index value. For example, a common factor affecting homeowners policies may be the price of construction materials. Accordingly, equation (2) states that if the price of construction materials is higher than expected, the index is higher than expected. An alternative interpretation of equation (2) is that the common factor indicates whether a natural disaster such as a hurricane occurs. The possibility of a natural disaster implies that risks in the affected area are correlated. Consequently, the occurrence of a disaster is equivalent to a positive realization of $\tilde{F}$ and a higher index value.

Define the futures risk premium, ρ, as the difference between the futures price (f) and the expected value of the index; that is, $\rho = f - E(\tilde{I})$. Using the model for the index (equation (2)) and the definition of the risk premium, the payoff from a long futures position becomes $(\tilde{F} - \rho)$. Intuitively, by taking a long position, a trader expects to pay the risk premium; however, if the realization of systematic underwriting losses, $\tilde{F}$, is high, then the long futures position can yield positive profits. A short position yields the opposite payoff. That is, by taking a short position, a trader expects to receive the risk premium. If systematic underwriting losses are high, however, the short position can yield a negative payoff. Thus, an insurer can potentially hedge variability in underwriting losses by taking long futures positions.

Futures Contracts versus Reinsurance Contracts

The reinsurance market also provides opportunities for insurers to reduce their exposure to underwriting risk. In general, the reinsurance market consists of bilateral agreements between insurers. Reinsurance arrangements can be categorized as either proportional contracts (also called pro rata reinsurance) and nonproportional contracts (also called excess of loss reinsurance).[9] With proportional reinsurance, the ceding company shifts a proportion of its premium

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[7] In practice, the variability of the index will depend on the number of policies included in the underlying pool (i.e., the extent to which the pool is diversified).

[8] For expositional ease, the model uses a single factor. The results of the paper are unaltered if $\tilde{F}$ is thought of as a vector of factors. The factor $\tilde{F}$ is referred to as systematic underwriting risk in this line of insurance. The term systematic should not be confused with systematic risk in the sense of the capital asset pricing model, as this risk could possibly be diversified away in a portfolio of other assets.

[9] Ferguson (1980) describes the different types of reinsurance.

to a reinsurer in exchange for the reinsurer paying a proportion of losses. In essence, proportional reinsurance is equivalent to an equity position in the policy pool of the ceding company. Nonproportional reinsurance arrangements have payoffs similar to call options written on the ceding company's policies. If losses are higher than some stated level (i.e., the exercise price), then the reinsurer pays some proportion (usually 90 percent or 100 percent) of the difference between losses and the exercise price. Nonproportional reinsurance can be based on the losses resulting from a single policy, on the losses resulting from a single occurrence (e.g., a hurricane), or on an aggregate basis (i.e., all of the ceding company's policies). Since reinsurance contracts are based on the ceding company's policy pool, reinsurance can influence incentives of the ceding insurer to reduce underwriting losses. In particular, the shifting of underwriting risk to a reinsurer can reduce the ceding insurer's incentive to select policyholders with low expected losses, to reduce claim costs once policyholders file claims,[10] and to classify losses once they have occurred as being covered under the reinsurance contract (Salm, 1980, p. 820). Of course, participants in the reinsurance market recognize these potential incentive problems and have devised various contractual provisions and business practices to temper these problems.

For example, a primary insurer cannot cede all of its underwriting risk from a group of policies or from a given occurrence to a reinsurer. Instead, reinsurance contracts always share risk between the ceding company and the reinsurer. Proportional reinsurance is equivalent to a coinsurance arrangement, and excess reinsurance is equivalent to a deductible arrangement. In addition, explicit contingent pricing schemes are often used. If the reinsurer experiences large losses, the ceding company pays higher reinsurance prices.[11] Even when fixed (noncontingent) pricing is used, prices are often based on the ceding company's past experience. The importance of maintaining a reputation limits the opportunities for ceding companies to shop around after poor loss experience (see Gilliam, 1980). All of these practices are essentially risk sharing arrangements.

Reinsurance contracts also contain provisions to mitigate these incentive problems. For example, a reinsurer can conduct underwriting audits and claims audits of ceding companies (Koehnen, 1980). Incentive problems are also mitigated by the strong tradition in reinsurance that contracts are based on the concept of "utmost good faith." This tradition is given substance by the

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[10] Reinsurance contracts usually have provisions that allow the reinsurer to participate in the investigation, adjustment, and defense of claims. However, any reasonable approach to a claim is generally accepted by a reinsurer (see W. Miller, 1980, p. 593).

[11] Various terms used to describe contingent pricing include contingent commissions, sliding scale commissions, self-rating, and swing rating. There is usually a minimum and maximum price in a given period. In long-term contracts, when the minimum or maximum constraints are reached, the deficit or surplus can be carried forward and charged against the next period's price (see Ferguson, 1980; Coleman, 1980; S. Miller, 1980; Simon, 1980).

provision in reinsurance contracts that disputes will be settled through arbitration. The arbitrators typically are officers of reinsurance companies, and they interpret contracts "according to the customs and traditions of the business as an honorable engagement" rather than according to law (see Salm, 1980, p. 79).

The proposed insurance futures contracts provide an alternative way of alleviating these incentive problems. By trading only the systematic risk in a given line, insurance futures contracts isolate those factors affecting underwriting losses that are unaffected by the actions of individual insurers.[12] Consequently, an insurer that hedges underwriting risk through a futures market maintains an incentive to identify low-risk policyholders and lower claim costs. Isolating systematic factors outside the control of the transacting parties potentially allows for complete shifting of the systematic portion of underwriting risk, as opposed to partial shifting of total underwriting risk via reinsurance contracts. Thus, by creating an index whose value is independent of the contracting parties' actions, insurance futures contracts provide an alternative contracting method for mitigating incentive problems.

Another important distinction between futures and reinsurance is that reinsurance contracts are bilateral agreements that require monitoring of the other party's creditworthiness.[13] A futures market, in contrast, virtually eliminates the need for such monitoring. First, futures contracts are standardized. Second, parties taking futures positions post a performance bond (margin). Third, the futures market clearinghouse acts as a guarantor of futures transactions.[14] Consequently, the payoff on a futures position is independent of the identities of other parties participating in the futures market. A futures market would therefore allow insurers to shift risk to parties they do not even know. This feature can enhance liquidity in the market for trading underwriting risk. That is, an insurance futures market can allow market participants to alter their underwriting risk exposure quickly and with little price concession. Indeed, one of the main arguments for why futures markets exist is to provide liquidity (see Telser, 1981).

Market makers at the exchange supply the liquidity services in a futures market by standing ready to buy and sell contracts. Market participants pay for this liquidity service, in part, through the bid/ask spread. The bid/ask spread compensates market makers for maintaining a market presence, carrying an

[12] An exception would be insurers whose policies comprise a significant proportion of the index.

[13] See Gonye (1980) for a discussion of the importance of the reinsurer monitoring the ceding company. Ceding company monitoring of reinsurers is also important as is evident by recent insolvencies (e.g., Mission and Transit) arising in part because of reinsurers' inability to pay claims.

[14] In reality, not all trades are guaranteed by the clearinghouse. See Jordan and Morgan (1990) for additional discussion of the operations of the clearinghouse. The guarantor function of the clearinghouse raises the issue, not pursued here, of whether the clearinghouse should be subject to insurance regulation.

inventory, and trading with market participants that have superior information (Glosten and Milgrom, 1985).

Demand for Liquidity by Insurers

To assess whether the liquidity that a futures market provides is likely to be valuable to insurers, we address two issues. First, once an insurer establishes an optimal exposure to underwriting risk, how often does the insurer's exposure change relative to its desired exposure? *Ceteris paribus,* the more often risk exposures change, the more often insurers' exposures will deviate from the desired level, and therefore the greater the need to adjust exposure quickly and at low cost, that is, the greater the demand for liquidity services.

An insurer's underwriting risk exposure can change because of unexpected changes in the quantity of business. For example, if an insurer writes more policies than expected, it has more exposure to underwriting risk than expected. In response to this additional risk, the insurer may wish to shift risk to another party. Thus, the greater the variability in quantity of business written, the more often insurers will need to adjust their underwriting risk exposure, and therefore the greater is the demand for liquidity, *ceteris paribus.*

An insurer's risk exposure can also deviate from the desired exposure level due to changes in expected losses on a fixed quantity of business. To illustrate, suppose public information is revealed that losses on existing policies are higher than originally predicted. Higher expected losses reduce economic net worth and increase the likelihood of insolvency. If an insurer prefers to maintain a fixed probability of insolvency, then it may respond by decreasing its underwriting risk exposure (e.g., by going long in insurance futures). Thus, the greater the volatility in expected losses, the more often insurers will need to adjust their underwriting risk exposure, and therefore the greater is the demand for liquidity, *ceteris paribus.*

The second issue to consider when determining whether insurers will value the liquidity that a futures market provides is how costly it is to adjust underwriting risk through the reinsurance market. If underwriting risk exposure can be adjusted quickly and at low cost through the reinsurance market, then the liquidity of a futures market would add little to the existing market arrangements. Adjusting through a reinsurance market entails two types of costs: the costs of negotiating and monitoring reinsurance agreements, and the time delay associated with arranging reinsurance. Grossman and Miller (1988) argue that the cost of the time delay (i.e., the demand for immediacy) increases as the price variability of the underlying commodity increases. Intuitively, greater variability makes it risky for traders to wait to adjust their position, because there is a greater possibility of an adverse price change during the waiting period. If the variability in expected losses is high, then there is a greater possibility that the prices at which risk can be shifted will change significantly during the time it takes to negotiate a reinsurance contract. Consequently, insurer demand for the liquidity that a futures market can provide will probably be higher in lines of business that have high variability in expected losses.

The time delay, and therefore one of the costs of adjusting exposure through reinsurance, can be reduced by treaty reinsurance arrangements (see Coleman, 1980; S. Miller, 1980; Simon, 1980). With treaty reinsurance, the ceding company and the reinsurer agree *ex ante* that the ceding company will automatically cede the policies that it writes to the reinsurer. In other words, the amount of reinsurance ceded depends upon the amount of business written by the ceding company. In contrast, with facultative reinsurance, there is no *ex ante* agreement to cede policies; instead, each risk transfer is negotiated separately. Thus, with treaty reinsurance, insurers can adjust to unexpected changes in risk exposure arising from unexpected changes in the quantity of business with no marginal negotiation costs and with no time delay. If an insurer writes more policies than expected, a proportion of the additional policies are automatically reinsured through a proportional reinsurance treaty.[15] Thus, the demand for liquidity that arises from variability in the quantity of business written is already provided by treaty reinsurance contracts.

The liquidity provided by treaty reinsurance, however, does not extend to situations in which an insurer wishes to alter its risk exposure because of unexpected changes in expected losses on existing policies. Suppose, for example, public information is revealed that losses on homeowners policies will be greater than initially expected. As a consequence, an insurer writing homeowner policies has a reduction in net worth, *ceteris paribus*. Further suppose that the insurer desires to offset its increased risk of default by decreasing its exposure to possible future increases in underwriting losses. One way to accomplish this would be to cede a greater proportion of its homeowners business to a reinsurer. Changing the proportion of policies ceded, however, requires negotiation of a new reinsurance contract. Thus, treaty reinsurance does not provide a liquid mechanism for insurers to adjust to unexpected changes in risk exposure arising from information concerning the losses on policies already written. Futures contracts may fill this gap.

Supply of Liquidity Services in a Futures Market

Another important issue is whether there will be a sufficient supply of liquidity services in an insurance futures market. For most commodities traded in a futures market, there exists a well-defined spot market for the same commodity. A spot market provides a means by which traders can hedge their futures positions and therefore decrease the cost of providing liquidity services. In addition, a well-defined spot market provides opportunities for traders to

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[15] Treaty reinsurance is more likely to be used when policies are relatively homogeneous. Interestingly, homogeneity is also likely to be a necessary characteristic for the policies comprising the futures index.

arbitrage price differences across markets. Arbitragers supply additional liquidity to a futures market.

The insurance futures market does not possess a well-defined spot market in which all market participants can take long and short positions. Insurers and reinsurers have long positions in insurance policies and can increase or decrease these exposures in the reinsurance market. However, other market participants cannot replicate these positions, at least in the short run.[16] Thus, insurers and reinsurers may be the only market participants with the opportunity to hedge their futures positions and to take arbitrage positions. The absence of a well-defined spot market for other market participants may increase the cost of supplying liquidity services.

A related problem is the difficulty traders may have in pricing the contract. When a contract is initiated, the CBOT will publish characteristics of the policy pool on which the contract is based. The purpose is to identify to all market participants exactly what is being traded; in essence, the CBOT standardizes the underlying commodity. An issue arises, however, about whether two policy pools with the same published characteristics are essentially the same commodity. In other words, will the underwriting profits on pools of insurance policies with similar published characteristics be highly correlated over time? If not, it will be difficult to price the contract, because traders will not know what the underlying commodity really is. Pricing may also be made more difficult if historical data on the underwriting profit index is unavailable (D'Arcy and France, 1992). The difficulty in pricing is likely to increase bid/ask spreads as providers of liquidity services attempt to protect themselves from traders who have better information about the value of the underlying index.[17]

Other Differences Between Futures and Reinsurance

Futures contracts and reinsurance contracts differ on several other dimensions. In contrast to reinsurance contracts, futures contracts are standardized and therefore cannot be tailored to meet the specific needs of some parties. In addition, reinsurance can be tied to other services, such as advice on underwriting, investments, and claim reserving (see Baker, 1980, p. 45; Gonye, 1980, p.

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[16] A short position in an insurance futures contract differs from a long position in a portfolio of insurance stocks in several respects. Futures provides a "pure play" in the underwriting losses on recently issued policies in a particular line of insurance. In contrast, the payoff from holding stock in insurers depends on the return an insurer earns on its investment portfolio, on the underwriting profits in possibly other lines of insurance, and on expected profits of policies to be issued in the future.

[17] As previously noted, one potential source of systematic underwriting risk is weather-related natural disasters such as hurricanes and tornados. In this context, the index of underwriting losses on homeowners policies will be driven largely by weather disasters. Thus, those futures market participants that have a superior ability to forecast the weather will be able to price these futures contracts better than others. Futures traders in other markets have exhibited an uncanny ability to forecast weather-related phenomenon (e.g., Roll, 1984).

453). Linking risk bearing services with the provision of information may be efficient because it increases incentives to provide accurate information.

The accounting for reinsurance transactions creates another difference between reinsurance and futures. Under statutory accounting principles, reinsurance can increase the surplus of the ceding insurer. Consider a reinsurance transaction in which an insurer cedes 50 percent of the $100 it has in policyholder liabilities. If the ceding commission is 30 percent of the value of the transaction, then instead of paying the reinsurer $50 (50 percent of $100), the ceding company pays $35 (50 percent of $100 times 1 minus the commission rate, 0.3). The effect is that liabilities are reduced by $50, but assets are reduced by only $35, thus decreasing the ceding company's leverage (see Baker, 1980, pp. 37-38). This increase in surplus can have a real effect on the quantity of business written given regulatory constraints on the premium to surplus ratio. In contrast, futures would be treated as a investment that would not alter the value of assets or liabilities and therefore would not alter regulatory capital.

A Model of the Insurance Futures Market

A model is now constructed to examine how unregulated insurers are likely to use insurance futures and the possible impact of futures on the primary insurance market.[18] The determinants of equilibrium insurance futures prices are also analyzed. Although the model's structure is similar to other (more general) models in the futures literature (see, for example, Feder et al., 1980; Anderson and Danthine, 1983; MacMinn et al., 1984; Kawai, 1983; Hirshleifer, 1988), the model is designed to focus specifically on insurance futures and the behavior of insurers.

Assumptions

Each insurer has the following value function:

$$Max \quad V = [E(\tilde{y}) - \frac{b}{2} Var(\tilde{y})], \quad b>0, \tag{3}$$

where $\tilde{y}$ equals an end of period value, and the parameter b is a measure of the degree to which the insurer is averse to variable cash flows. The value function in expression (3) is similar to the specification used by Doherty (1991), where the second term is referred to as variance related costs.[19] Variance related

[18] Regulations are likely to be developed that would restrict the types of positions insurers can take. For example, insurers may be allowed to use futures for hedging and prohibited from speculative positions. Speculative positions could include taking a short position or an extreme long position. Of course, such regulations would require costly monitoring of insurers' positions.

[19] The objective function assumes that the cost of bearing market risk is the same as the cost of bearing nonmarket risk. A more general specification, but one which does not lead to different implications, would separately price market risk and variance related costs (see Doherty, 1991).

costs arise for a variety of reasons, such as the existence of undiversified risk-averse claimants (Mayers and Smith, 1982), a progressive corporate tax structure (Main, 1983; Smith and Stulz, 1985), bankruptcy costs (Kim, 1978), informed policyholders who are willing to pay a premium for lower default risk (Doherty and Tinic, 1981), or quasi rents from investments in developing a customer base (Harrington, 1992).[20] This objective function captures in a simple manner the market imperfections that cause insurers to act as risk averters in most circumstances.[21] Explicit modeling of these market imperfections would complicate the analysis considerably and divert attention away from insurance futures contracts.[22]

Insurers are price takers and can write policies in two lines of insurance, denoted by the subscripts 1 and 2. Let Q_1 and Q_2 equal the quantity (premium volume) of homogeneous insurance written in the two respective lines. The insurer's policies expire after one period, and the coverage period for the policies corresponds to the listing period for futures contracts. Premiums are received at the beginning of the period, and losses are paid at the end of the period. For simplicity, incentive problems such as those discussed in the previous section are not incorporated in the model. The interest rate is zero, and the insurer has no expenses other than underwriting losses.[23]

The insurer's average loss per dollar of premium (the average loss ratio) in the two lines is $\tilde{L}_1$ and $\tilde{L}_2$, respectively. Insurance futures contracts are available only in line 1, and the average loss ratio in line 1 is further specified to equal

$$\tilde{L}_1 = E(\tilde{L}_1) + \gamma\tilde{F} + \tilde{\varepsilon}, \qquad (4)$$
$$E(\tilde{F})=0, \quad E(\tilde{\varepsilon})=0, \quad E(\tilde{\varepsilon}\tilde{F})=0, \quad E(\tilde{\varepsilon}\tilde{L}_2)=0,$$

[20] Quasi rents are the returns earned in excess of the variable cost associated with the activity. Insurers who have made investments in developing a customer base may wish to protect the quasi rents earned on these investments from insolvency. In essence, the loss of quasi rents is a bankruptcy cost.

[21] An exception to this statement is that, because of limited liability, insurers who are close to insolvency may have an incentive to "go for broke" and therefore increase risk.

[22] The parameter b/2 in the value function measures the insurer's variance related costs per unit of variance. The per unit cost of variance is likely to depend on the amount of insurer capital. In general, the greater the amount of capital, the lower the cost of having variable cash flows (except when additional capital would not likely reduce variance related costs arising from a progressive tax structure). We assume the amount of capital held by the insurer is exogenous.

[23] The assumptions of the model (e.g., no investment risk, no expenses, and the futures contract listing period equals the coverage period for insurance policies) eliminate several potential sources of background risk for an insurer. For a discussion of how background risk affects optimal futures positions, see Briys, Crouhy, and Schlesinger (1991). Also, this formulation ignores the possibility that insurance company assets can hedge liabilities.

where $\tilde{F}$ is the factor determining the random payoff on a futures contract in line 1, and $\tilde{\varepsilon}$ is the unexpected realization of the average loss ratio due to factors that are uncorrelated with $\tilde{F}$. This specification implies that, even though policy specific risk is diversified away (due to sufficient premium volume), there are two sources of underwriting risk to an insurer writing in line 1. The first source, $\tilde{F}$, is the same factor that makes the futures index uncertain. The second source of underwriting risk, $\tilde{\varepsilon}$, is independent of the futures index. For example, suppose the futures contract is based on an index consisting of policies from all across the nation. A regional insurer will have uncertainty concerning its loss ratio because of national factors ($\tilde{F}$) and because of regional factors ($\tilde{\varepsilon}$). The parameter, γ, measures the sensitivity of the insurer's policies to the systematic factor $\tilde{F}$. The model assumes that insurers know the correlation between the losses on their policies and losses on the policies comprising the index. If this information is unknown or is extremely costly to obtain (for example, because of the lack of historical data), then insurance futures are not likely to be an effective hedging tool.

The second line of expression (4) implies that the two sources of risk have zero expected values and that the firm specific source of risk is uncorrelated with the risk associated with the futures contract and with business written in the other line of business.

The number of contracts chosen by the insurer is given by n. A negative value of n indicates a short position, and a positive value indicates a long position. Insurers wishing to hedge their underwriting risk will take long positions ($n > 0$). Combining the payoff from the futures position with the payoff from the underlying policies written in the two lines yields the following end of period value:

$$\tilde{y} = Q_1(1-\tilde{L}_1) + Q_2(1-\tilde{L}_2) + n(\tilde{F}-\rho). \tag{5}$$

Optimal Behavior by Insurers

The insurer chooses the number of policies written in each line, Q_1 and Q_2, and the number of futures contracts in line 1, n, to maximize the objective function given in expression (3).[24] The first-order conditions are[25]

[24] The optimal values of Q_1 and Q_2 are assumed to be non-negative. In addition, position limits in futures contracts are ignored. The Commodity Futures Trading Commission can impose position limits to prevent excessive speculation and/or market manipulation. Hedging positions, defined as futures positions whose fluctuations in value substantially offset changes in the value of the trader's cash position, are exempt from these position limits. State insurance regulations may also impose limits on the size of an insurer's futures position. For example, futures margin is not usually admitted as an asset that can satisfy minimum capital requirements. Once an insurer has satisfied minimum capital requirements with other assets, however, they are not usually limited in the size of their futures positions. In other words, the capital in excess of the minimum required capital can be fully used as margin on futures positions.

[25] The second-order conditions are satisfied if $b>0$, $Var(\tilde{\varepsilon})>0$, $Var(L_2)>0$, and $Var(\tilde{F})Var(L_2)>[Cov(\tilde{F},\tilde{L}_2)]^2$.

$$n^* = \frac{-\rho}{bVar(\tilde{F})} + \gamma Q_1 + \frac{Q_2 Cov(\tilde{F},\tilde{L}_2)}{Var(\tilde{F})}, \tag{6}$$

$$Q_1^* = \frac{\pi_1}{bVar(\tilde{L}_1)} + \frac{n\gamma Var(\tilde{F}) - \gamma Q_2 Cov(\tilde{F},\tilde{L}_2)}{Var(\tilde{L}_1)}, \text{ and} \tag{7}$$

$$Q_2^* = \frac{\pi_2}{bVar(\tilde{L}_2)} + \frac{(n - \gamma Q_1)Cov(\tilde{F},\tilde{L}_2)}{Var(\tilde{L}_2)}, \tag{8}$$

where $\pi_i = 1 - E(\tilde{L}_i)$, the expected profit per dollar of premium on policies written in line i. For now, π_i is assumed to be exogenous; later the equilibrium value of π_i is determined.

The first term in equation (6) is the number of futures contracts taken for speculative purposes. This component is negatively related to the risk premium. The second term in equation (6) is positive and equals the number of contracts needed to hedge all underwriting risk in line 1 business. The more business that is written in line 1 (i.e., as Q_1 increases), the greater the incentive to hedge. The parameter γ measures the sensitivity of the insurer's business in line 1 to the systematic factor in line 1; the greater γ is, the greater the incentive to hedge. The last term is the number of contracts taken to hedge underwriting risk in line 2. If the systematic factors in line 1 covary positively with the loss ratio in line 2, then uncertainty in line 2 business can be hedged by long positions in line 1 futures contracts. The extent to which this cross-hedge is undertaken depends on the amount of exposure that the insurer has in the other line, as measured by Q_2 and the degree to which the lines covary.[26]

Equations (7) and (8) describe the optimal number of policies to write in the two lines of business. Consider expression (7) describing the number of policies written in line 1. The first term would be the number of policies written if the insurer's only operation was writing policies in line 1.[27] The second term is

[26] If premiums and capital are invested in risky assets, the optimal futures position would change. In particular, the optimal futures position would take into account the covariance between systematic underwriting losses and the asset portfolio. Comparative statics for the optimal futures position yield the following results:

$$\frac{\partial n^*}{\partial \rho} < 0, \quad \frac{\partial n^*}{\partial \pi_1} > 0, \quad \frac{\partial n^*}{\partial \pi_2} > 0, \quad \frac{\partial n^*}{\partial Var(\tilde{F})} > 0.$$

[27] This model assumes that the insurer is a price taker. That is, the expected underwriting profit, π_1, is determined at the market level. If the insurer faced a downward sloping demand curve, $\pi_1(Q_1)$, the first term in equation (7) would be

$$\frac{\pi_1}{bVar(\tilde{L}_1) - \pi_1'(Q_1)}, \quad \textit{where} \quad \pi_1'(Q_1) < 0,$$

implying a lower output level, *ceteris paribus*.

the adjustment to take into account the covariance between policies written in line 1 with the other operations of the insurer, that is, any futures positions and policies written in line 2. If the insurer is hedging with futures contracts, n is positive, which increases the number of policies written in line 1 relative to the case when no futures market exists. Intuitively, futures reduce risk bearing costs and therefore lead to an expansion of output.

The effect of writing policies in line 2 on the optimal number of line 1 policies depends on the covariance between $\tilde{F}$ and L_2. If the covariance is positive then additional line 2 business tends to decrease the amount of line 1 business. Intuitively, as the covariance between line 1 and line 2 increases, so does the risk of writing an additional policy in line 1 for any given number of line 2 policies. Expression (8), which describes the number of policies written in line 2, has a similar interpretation to expression (7).

Additional insight concerning the use of insurance futures and their impact on the primary market can be obtained by solving the first-order conditions for n and Q_1. To simplify the algebra, the covariance between the two lines is assumed to be zero. In this case, the optimal values for n and Q_1 are

$$\begin{aligned} \hat{n} &= \frac{Var(\tilde{L}_1)}{bVar(\tilde{\varepsilon})}\left[\frac{-\rho}{Var(\tilde{F})} + \frac{\gamma\pi_1}{Var(\tilde{L}_1)}\right]. \\ \hat{Q}_1 &= \frac{\pi_1 - \gamma\rho}{bVar(\tilde{\varepsilon})}. \end{aligned} \tag{9}$$

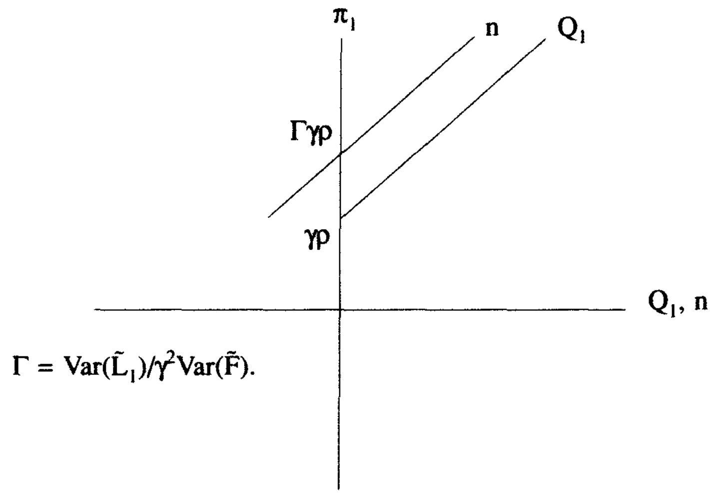
Note that the optimal futures position depends upon the expected profit from writing or reinsuring policies relative to the futures risk premium. Similarly, the quantity of insurance supplied (Q_1) depends on the expected profits relative to the futures risk premium. Thus, an immediate implication is that the futures market and the primary insurance market are interrelated.

This analysis implies that there is a range of values for π_1 for which insurers writing policies in line 1 will be long in futures and a range for which they will be short (see Figure 1). Insurers with high expected underwriting profits will write a large number of policies and hedge underwriting risk by taking long futures positions. In contrast, insurers that have low expected profits from writing policies in line 1 will write fewer policies and are more likely to find short futures positions desirable.

The CBOT literature discusses two uses of futures by insurers (see Chicago Board of Trade, 1990). First, insurers writing in the line with a futures contract can take long futures positions to hedge the underwriting risk of the policies they have written. Second, an insurer writing in another line can cede some of its policies through reinsurance and then take a short futures position to obtain greater diversification. The analysis here, although not inconsistent with the CBOT literature, implies that the expected profits in the primary insurance market determine whether an insurer would take a long or short futures position.[28]

Figure 1

Optimal Futures Position (n) and Quantity of Insurance Written (Q_1) as a Function of Expected Profits in the Primary Market



The analysis heretofore considers the behavior of a representative insurer who is a price taker in the futures market and in the primary insurance market. This model of insurer behavior is now used to analyze equilibrium in the futures market and equilibrium in the primary insurance market.

Futures Market Equilibrium

To provide insights about the futures market equilibrium, consider the simple case in which the proportion of identical insurers participating in the market is α. Insurer behavior is described by n^* given by equation (6). Other market participants, who comprise $(1-\alpha)$ of the market, are assumed to have the same objective function as insurers (expression (3)), except their underlying position (i.e., position net of futures) differs from insurers.[29] Unlike other futures

[28] In a more general model of insurer investment behavior, other investment opportunities may dominate futures positions for insurers.

[29] An alternative way to model equilibrium in the futures market is to assume that insurers are heterogeneous with respect to expected profits from writing insurance in line 1 due to different cost structures. As presented in the previous section, some insurers would then take long positions and some short positions. Yet another alternative is to assume insurers are heterogeneous with respect to variance related costs (different b parameters). See Doherty (1991) and Garven and Louberge (1992) for analyses along this line.

contracts, there is not an obvious party on the other side of the market from insurers, that is, a party for whom a short insurance futures position would hedge their underlying risk. For example, in the commodity futures contracts (e.g., soybeans), farmers can hedge their output price risk by taking short futures positions, and food producers can hedge their input price risk by taking long futures positions.

Although the extent to which there will be short hedgers in the insurance futures market is ultimately an empirical question, it is difficult to identify a major group of futures market participants who are likely to be short hedgers.[30] Therefore, it is assumed that another party with a natural short position does not exist. Instead, other market participants are assumed to be investors holding equal shares of the market portfolio. The end of period value of each investor's share of the market portfolio is denoted $w(1+\tilde{r}_m)$, where w is each participant's initial investment in the market portfolio, and $\tilde{r}_m$ is the random market return. The behavior of other market participants is found by maximizing their objective function with respect to the number of futures contracts, m^*. The resulting first order condition is

$$m^* = \frac{-\rho}{bVar(\tilde{F})} - \frac{wCov(\tilde{r}_m,\tilde{F})}{Var(\tilde{F})}. \tag{10}$$

If the $Cov(\tilde{r}_m,\tilde{F})$ is positive, then other market participants can hedge their investments in the market portfolio by taking short insurance futures positions.

Equilibrium in the futures market requires that the risk premium, ρ, takes on a value that equates $n^*\alpha$ with $-m^*(1-\alpha)$.[31] The equilibrium risk premium is

$$\rho^* = bVar(\tilde{F})\left[\alpha\gamma Q_1 + \alpha Q_2\frac{Cov(\tilde{F},\tilde{L}_2)}{Var(\tilde{F})} - (1-\alpha)\frac{wCov(\tilde{r}_m,\tilde{F})}{Var(\tilde{F})}\right]. \tag{11}$$

The sum of the first two terms in brackets is the hedging component of insurers' positions, and the last term is the hedging component of other market participants' positions. If the hedging components net to zero—that is, if the long hedging component of insurers is exactly offset by the short hedging component of other market participants—then the equilibrium risk premium is zero. If, however, the short hedging component of other market participants is less than the long hedging component of insurers, then the equilibrium risk

[30] For the homeowners contract, a potential (but unlikely) short hedger could be building contractors. By taking short futures positions, large contractors could potentially hedge their risk of unexpected changes in demand arising from less than expected damage to existing buildings.

[31] The assumptions of the model imply that there is always an equilibrium in the market. Appendix B, however, introduces a fixed cost of trading futures which causes the market to fail in some situations.

premium will be positive, indicating that insurers must expect to compensate other market participants for taking on underwriting risk.

This analysis indicates that a determinant of the equilibrium risk premium (and of whether the market fails) is the covariance between underwriting losses and the market return (i.e., $Cov(\tilde{r}_m,\tilde{F})$). If underwriting losses are positively correlated with the market portfolio, a short futures position helps reduce the total risk of a diversified investor's portfolio. On the other hand, if underwriting losses are negatively correlated with the market portfolio, then a short futures position adds risk to an investor holding the market portfolio. The greater the magnitude of the negative correlation, the more compensation investors require to take on this risk, *ceteris paribus*. Cummins and Harrington (1985) estimate the correlation between underwriting profit in property-liability underwriting lines and the market portfolio and find the correlations are low in general.

Primary Insurance Market Equilibrium

To examine the impact of an insurance futures market on primary market prices, the model is closed by assuming a perfectly inelastic demand schedule facing each insurer, where Φ is the quantity demanded. Incorporating an elastic demand does not change the implications of the analysis but does complicate the expressions and the exposition. Equilibrium requires that expected profit, π_1, take on a value so that the quantity demanded equals the quantity supplied, where the supply schedule is given by equation (9). Imposing the equilibrium condition yields the following expected profit with futures:

$$\pi_1 = \Phi b Var(\tilde{\varepsilon}) + \gamma\rho. \tag{12}$$

Since there are no transaction costs in the model, the expected profit is the risk loading fee on insurance. If $\rho = 0$, then the only risk that affects the equilibrium risk load is the risk that cannot be hedged through futures, $Var(\tilde{\varepsilon})$. In general, however, the risk load depends on $Var(\tilde{\varepsilon})$ and the cost of hedging through the futures market, ρ.

Combining the equilibrium futures market condition (equation (11)) with the equilibrium insurance market condition (and assuming $Cov(\tilde{F},\tilde{L}_2) = 0$ to simplify the algebra) yields the following risk load:

$$\pi_1 = b[\Phi Var(\tilde{\varepsilon}) + \alpha\Phi\gamma^2 Var(\tilde{F}) - (1-\alpha)wCov(\tilde{r}_m,\tilde{F})]. \tag{13}$$

The equilibrium risk load depends on the amount of risk that cannot be hedged through futures plus a weighted average of the risk that can be hedged [$Var(\tilde{F})$] and the market risk of underwriting losses [$Cov(\tilde{r}_m,\tilde{F})$]. The smaller α is, the more important the market risk of underwriting losses and the less important the risk that can be hedged through futures.

In the extreme case in which insurers are an infinitesimal part of the futures market (α approaches zero), the insurer's hedging demand has no influence on the equilibrium futures price. In this situation, the expected profit or risk load depends not upon total risk, but upon the risk that cannot be hedged through futures ($Var(\tilde{\varepsilon})$) and the market risk of underwriting losses ($Cov(\tilde{r}_m, \tilde{F})$). Thus, an implication of the model is that the futures market causes primary market prices to be more in line with financial models of market valuation (see Cummins, 1991).

Summary and Conclusion

Insurance futures represent a competing secondary market to a reinsurance market for trading underwriting risk. A major function of secondary markets is to allow market participants to adjust their portfolio holdings (i.e., adjust their exposure to risk).[32] On this dimension, a futures market differs from a reinsurance market in several important respects. Although contracts can be tailored to meet specific needs through a reinsurance market, insurers expend costs in searching for a counterparty and negotiating the terms of a contract. Each party to a reinsurance contract must also monitor the other party's default risk. Futures contracts, on the other hand, are standardized, and the clearinghouse guarantees performance of opposing parties to a futures contract. These features allow participants to adjust their risk exposure quickly, so they need not bear the risk of adverse price changes. In addition, the payoff on an insurance futures position is based on a pool of policies that is largely outside the control of the transacting parties. This feature mitigates incentive problems with respect to loss control and allows for risk shifting opportunities that are unavailable from reinsurance contracts.

If insurance futures are successfully introduced and insurers use them to reduce underwriting risk, then a beneficial impact on the primary insurance market is likely. However, the use of futures by insurers depends upon the equilibrium futures risk premium, which depends upon the compensation required to induce other parties to bear underwriting risk. If traders require a large risk premium, then insurers are less likely to use futures.

The success of insurance futures contracts ultimately depends upon whether futures would allow insurers to hedge underwriting risk at low costs relative to reinsurance contracts. This is an empirical issue that can only be addressed once the contracts are introduced. Meanwhile, a more limited research issue could be addressed. A necessary condition for insurance futures to be successful is for futures to provide an effective hedge. This issue could be addressed empirically by constructing an underwriting loss index and examining the correlation between this index and individual insurers' underwriting profits in a particular line of business. Finding significant

[32] Secondary markets also provide, via the equilibrium price, market participants' assessment of a commodity's value. The potential revelation of information through the futures price was ignored in this paper by the assumption of homogeneous expectations. Nevertheless, another potential contribution of an insurance futures market is the aggregation of heterogeneous expectations concerning underwriting losses.

correlations is not, however, sufficient to conclude that futures will be successful, as such an analysis does not consider the potential cost of using futures (the risk premium paid to other participants) relative to the cost of using existing reinsurance markets. Indeed, in order for insurance futures to be successful, these contracts must provide a cost-effective method of reducing underwriting risk relative to reinsurance contracts.

Appendix A

Summary of Notation

- $\tilde{I}$ End of period index value on which the futures contract is based.
- p_i Premium on policy i which is included in the pool of policies comprising the index.
- l_i Loss on policy i which is included in the pool of policies comprising the index.
- N Number of policies in the pool comprising the index.
- f Futures price.
- $\tilde{F}$ Random systematic factor determining losses on policies in line 1.
- ρ Risk premium on the futures contract in line 1 = $E(\tilde{I}) - f$.
- V Beginning of period value of an insurer.
- $\tilde{y}$ Random end of period value of insurer.
- b Variance related cost per unit of variance (a measure of risk aversion).
- Q_i Quantity (premium volume) of insurance written by insurer in line i.
- $\tilde{L}_i$ Loss per dollar of premium (loss ratio) experienced by insurer in line i.
- γ Sensitivity of insurer's policies in line 1 to systematic factor ($\tilde{F}$) in line 1.
- $\tilde{\varepsilon}$ Random factor affecting losses in line 1 that is uncorrelated with systematic factor in line 1.
- n Number of futures contracts in line 1 used by insurer.
- π_i Expected profit from writing insurance policies in line i.
- w Initial investment in market portfolio by other futures market participants.
- $\tilde{r}_m$ Random return on market portfolio.
- m Number of futures contracts in line 1 used by other futures market participants.
- α Proportion of futures market participants that are insurers.
- Φ Inelastic quantity of insurance demanded.
- C Fixed transaction cost.
- V^* Maximum value of insurer's objective function.

Appendix B

To analyze the possibility of a futures market failure, a fixed cost associated with trading futures is incorporated in the model (see Black, 1986, for an extensive analysis of success and failure of futures contracts). This cost includes the cost of becoming informed about insurance futures contracts, the costs associated with setting up the operations necessary to trade and monitor futures positions, and any regulatory costs associated with trading futures. The fixed cost implies that if the benefits of trading futures do not exceed the costs, then potential traders will not take positions. If a sufficient number of potential traders do not take positions, the market will fail.

Maintaining the assumption of homogeneous insurers and other market participants, the market will fail if the equilibrium risk premium, ρ^* given in equation (11) falls in the range in which, because of transaction costs, either insurers or other market participants do not trade.[33] The following proposition provides a necessary and sufficient condition for market failure.

Proposition: The insurance futures market will fail if and only if

$$\frac{\mu\sqrt{b}\,[\gamma Q_1^* Var(\tilde{F}) + Q_2^* Cov(\tilde{F},\tilde{L}_2) + wCov(\tilde{r}_m,\tilde{F})]}{\sqrt{2}\,Std(\tilde{F})} \leq \sqrt{C}, \qquad (14)$$

where $\mu = \min(\alpha, 1-\alpha)$, and C = fixed transaction cost.
Intuitively, the condition states that the benefits from hedging to insurers and other participants are less than the cost of hedging.

Several implications follow directly from the proposition. Market failure is more likely to occur as transaction costs, C, increase; the amount of insurance written in the underlying line decreases; and the covariance between systematic underwriting losses and the underlying positions of other market participants decreases. If it is assumed that the covariance between lines 1 and 2 is zero, then it can be shown that the inequality is less likely to be satisfied if systematic underwriting risk in line 1, $Var(\tilde{F})$, increases. Intuitively, if there is little systematic underwriting risk, then insurers' incentive to hedge using futures is low.

To illustrate the model, parameter values are now specified. Assume insurers comprise 50 percent of the market ($\alpha = .5$), the covariance between the systematic factor in line 1 ($\tilde{F}$) and losses in line 2 business ($\tilde{L}_2$) is zero, the covariance between the systematic factor in line 1 ($\tilde{F}$) and the market return ($\tilde{r}_m$) is zero, and the sensitivity of an insurer's policies to the systematic factor (γ) is one. The standard deviation of $\tilde{F}$ is assumed to be 0.06. This number is the estimated standard deviation of the loss ratio (incurred losses divided by earned premiums) on homeowners policies calculated using annual data from

[33] To simplify the presentation, it is assumed that insurers have long futures positions in equilibrium, and other market participants have short futures positions.

1973 through 1990 obtained from *Bests' Aggregates and Averages*. Empirical estimates of the variance related cost per unit of variance (b) do not currently exist. It was argued above that b is likely to be inversely related to an insurer's capital. Therefore, b is set (rather arbitrarily) to one over surplus. Finally, assume premium volume in line 1 (Q_1) is 50 percent of surplus. Substituting these values into inequality (14) yields the relation:

$$C \geq 0.00011 \; surplus \; , \tag{15}$$

suggesting that the market will fail if fixed costs exceed 0.11 percent of surplus. For example, if each insurer's surplus equaled $500 million, then fixed costs of approximately $56,000 would cause the market to fail. We must emphasize that this example is meant to illustrate the model, rather than provide a prediction. A complete analysis would require additional research on appropriate parameter values.

It is also important to note that insurers are not homogeneous, as is assumed in this model. Indeed, insurers are likely to vary in terms of their marginal variance related costs, b; their transaction costs in using futures, C; and their size (capital). Heterogeneity will give rise to different "demands" for futures (i.e., different n functions) and some insurers will find it optimal to use futures and others will not. Thus, even if the condition stated in the proposition held for a subset of insurers, the market would not necessarily fail.

Proof of Proposition:

The market will succeed if both insurers and other market participants find it optimal to use futures. A trader will use futures if the following condition is satisfied:

$$V^* - \{V^* |\; n{=}0\} > C, \tag{16}$$

where C is the fixed cost of trading, and V^* indicates the maximum value of the trader's objective function. The left side of inequality (16) is the difference between the value of the trader's objective function when futures are and are not used. The right side is the cost of taking a futures position.

For insurers, inequality (16) is satisfied if

$$\begin{aligned} -Std(\tilde{F})\sqrt{2Cb} + bQ_1^*\gamma Var(\tilde{F}) + bQ_2^*Cov(\tilde{F},\tilde{L}_2) \geq \rho^* \geq \\ Std(\tilde{F})\sqrt{2Cb} + bQ_1^*\gamma Var(\tilde{F}) + bQ_2^*Cov(\tilde{F},\tilde{L}_2). \end{aligned} \tag{17}$$

For other market participants, inequality (16) is satisfied if

$$-Std(\tilde{F})\sqrt{2Cb} - bwCov(\tilde{r}_m,\tilde{F}) \geq \rho^* \geq Std(\tilde{F})\sqrt{2Cb} - bwCov(\tilde{r}_m,\tilde{F}). \tag{18}$$

Assuming insurers take long positions and other market participants take short positions, the left side of expression (17) is irrelevant, and the right side of expression (18) is irrelevant. The condition for a successful market is, therefore,

$$Std(\tilde{F})\sqrt{2Cb} - bwCov(\tilde{r}_m,\tilde{F}) \leq \rho^* \leq -Std(\tilde{F})\sqrt{2Cb} + Q_1^*\gamma Var(\tilde{F}) + Q_2^*Cov(\tilde{F},\tilde{L}_2). \tag{19}$$

Substituting expression (11) for ρ^* and rearranging terms yields the condition given in the proposition.

References

A. M. Best Company, *Best's Aggregates and Averages: Property-Liability,* various editions (Oldwick, N.J.: A. M. Best).

Anderson, Ronald and Jean-Pierre Danthine, 1983, Hedger Diversity in Futures Markets, *Economic Journal,* 93: 370-389.

Baker, Robert A., 1980, The Purpose of Reinsurance, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 33-50.

Black, Deborah, 1986, Success and Failure of Futures Contracts: Theory and Empirical Evidence, Monograph 1986-1, Salomon Brothers Center for the Study of Financial Institutions, New York University.

Briys, Eric, Michael Crouhy, and Harris Schlesinger, 1991, Optimal Hedging in a Futures Market with Background Noise and Basis Risk, Working Paper, University of Alabama, Tuscaloosa.

Chicago Board of Trade, 1990, Overview of Insurance Futures Contracts, Chicago, August.

Chicago Board of Trade, 1992, Homeowners Insurance Futures Contract Terms, Chicago.

Coleman, Walter, 1980, The Pro Rata Treaty in Property Insurance, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 143-160.

Cox, Samuel H. and Robert G. Schwebach, 1992, Insurance Futures and Hedging Insurance Price Risk, *Journal of Risk and Insurance,* 59: 628-644.

Cummins, David, 1991, Statistical and Financial Models of Insurance Pricing and the Insurance Firm, *Journal of Risk and Insurance,* 58: 261-302.

Cummins, David and Scott Harrington, 1985, Property-Liability Insurance Rate Regulation: Estimation of Underwriting Betas Using Quarterly Profit Data, *Journal of Risk and Insurance,* 52: 16-43.

Danzon, Patricia and Scott Harrington, 1990, Price Cutting in Liability Insurance Markets, Working Paper, Wharton School, University of Pennsylvania, Philadelphia, November.

D'Arcy, Stephen P. and Virginia Grace France, 1992, Catastrophe Futures: A Better Hedge for Insurers, *Journal of Risk and Insurance,* 59: 575-600.

Doherty, Neil, 1991, The Design of Insurance Contracts When Liability Rules Are Unstable, *Journal of Risk and Insurance,* 58: 227-246.

Doherty, Neil and Seha Tinic, 1981, Reinsurance Under Conditions of Capital Market Equilibrium: A Note, *Journal of Finance,* 36: 949-953.

Feder, Gershan, Richard Just, and Andrew Schmitz, 1980, Futures Markets and the Theory of the Firm Under Price Uncertainty, *Quarterly Journal of Economics,* 95: 317-328.

Ferguson, Ronald, 1980, The Basics of Reinsurance, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 51-78.

Garven, Jim and Henri Louberge, 1991, Reinsurance and Taxes: A Contingent Claims Approach, Working Paper, University of Texas at Austin.

Gilliam, Robert, 1980, The Property Catastrophe Reinsurance Contract, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 185-212.

Gilliam, Robert, 1980, The Property Catastrophe Reinsurance Contract, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 185-212.

Glosten, Lawrence and Paul Milgrom, 1985, Bid, Ask and Transaction Prices in a Speculative Market with Heterogeneously Informed Traders, *Journal of Financial Economics,* 14: 71-100.

Gonye, Laszlo, 1980, Underwriting the Reinsured, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 439-490.

Grossman, Sanford and Merton Miller, 1988, Liquidity and Market Structure, *Journal of Finance,* 43: 617-633.

Harrington, Scott, 1992, Presidential Address: Rate Suppression, *Journal of Risk and Insurance,* 59: 185-202.

Hirshleifer, David, 1988, Residual Risk, Trading Costs, and Commodity Futures Risk Premia, *Review of Financial Studies,* 1: 173-193.

Hofflander, Alfred, Blaine Nye, and Jane Nettesheim, 1991, The Impact of Insurance Futures on the Insurance Cash Market, Working Paper, Stanford Consulting Group, Menlo Park, California.

Jordan, James and George Morgan, 1990, Default Risk in Futures Markets: The Customer-Broker Relationship, *Journal of Finance,* 45: 909-934.

Kawai, Masahiro, 1983, Spot and Futures Prices of Nonstorable Commodities Under Rational Expectations, *Quarterly Journal of Economics,* 98: 235-254.

Kim, E. Han, 1978, A Mean-Variance Theory of Optimal Capital Structure and Corporate Debt, *Journal of Finance,* 33: 301-319.

Koehnen, James, 1980, Administration and Maintenance of Business in Force, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 491-514.

MacMinn, Richard, George E. Morgan, and Stephen Smith, 1984, Forward Market Equilibrium, *Southern Economic Journal,* 51: 41-58.

Main, Brian, 1983, Corporate Insurance and Taxes, *Journal of Risk and Insurance,* 50: 197-223.

Mayers, David and Clifford Smith, 1990, On the Corporate Demand for Insurance: Evidence from the Reinsurance Market, *Journal of Business*: 19-40.

Miller, Sanford, 1980, The Working Excess of Loss Treaty in Property Insurance, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 161-184.

Miller, William, 1980, Budgeting and Controlling Internal Expenses, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 581-598.

Peck, Anne and Jeffrey Williams, 1991, An Evaluation of the Performance of the Chicago Board of Trade Wheat, Corn, and Soybean Futures Contracts During Delivery Periods from 1964-65 through 1988-89, A Report to the National Grain and Feed Association, Food Research Institute, Stanford University, Stanford, California.

Roll, Richard, 1984, Orange Juice and Weather, *American Economic Review,* 74: 861-880.

Salm, Robert, 1980, Reinsurance Contract Wording, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 79-116.

Samorajski, Gregory, 1992, Pricing Homeowners Insurance Futures: A Draft Outline, Working Paper, Department of Economic Analysis and Planning, Chicago Board of Trade, Chicago.

Simon, Leroy, 1980, The Excess of Loss Treaty in Casualty Insurance, in: Robert W. Strain, ed., *Reinsurance* (New York: College of Insurance), 213-252.

Smith, Clifford and Rene Stulz, 1985, The Determinants of Firm's Hedging Policies, *Journal of Financial and Quantitative Analysis*, 20: 391-406.

Taylor, Jeffrey, 1991, CBOT Puts Insurance Futures on Hold, *Wall Street Journal*, September 4, C1.

Telser, Lester, 1981, Why There Are Organized Futures Markets, *Journal of Law and Economics*, 24: 1-22.