PRICING CATASTROPHE RISK:
COULD CAT FUTURES HAVE COPED WITH ANDREW?

by

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1999 Casualty Actuarial Society
"Securitization of Risk"
Discussion Paper Program

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Abstract

Insurance futures and options have been trading on the Chicago Board of Trade since December, 1992. This paper describes these derivative instruments, explains how they have changed over time, illustrates trading volume and price levels, discusses the safety of the financial guarantees backing these contracts, analyzes trends in catastrophe losses, summarizes the literature relating to insurance derivatives and briefly describes some additional capital market securities that attempt to deal with catastrophe risk. We suggest that if derivatives were widely used to cope with catastrophe risk, then a disaster the magnitude of Hurricane Andrew would have severely stressed the financial markets, possibly leading to significant defaults. If the insurance industry is not successful in coping with catastrophe risk in some manner, either through insurance derivatives or other means, then more drastic steps, as outlined in this paper, will have to be taken to cope with this risk to avoid widespread insurer insolvency when a devastating catastrophe next occurs.

Introduction

It was a long time before the idea of an insurance derivative contract, as proposed by Goshay and Sandor (1973), became a reality when catastrophe futures began trading in December, 1992. Even then, trading volume on the original contracts was, and has remained, virtually negligible. However, despite the slow development process and modest trading volume, this initial contract has spawned a plethora of research articles and related insurance derivatives. This research productivity and the development of other securitized instruments attest to the importance of the insurance derivative concept, even though lack of trading in the current Chicago Board of Trade (CBOT) contract demonstrates that educational and institutional hurdles must still be overcome.

This article will first review and compare the types of insurance derivatives that have been and are currently being traded on the Chicago Board of Trade, and summarize the extensive academic literature on the topic of insurance derivatives. One major concern of potential purchasers of insurance derivative contracts is the ability of the sellers to assure payment in the case of a major loss. Using Hurricane Andrew as an example, the viability of the guarantees behind the contracts will be examined. Finally, alternative institutional and capital market approaches to the handling of catastrophic risk will be explored.

General Description of Insurance Derivatives

A "derivative" is an investment whose value is based on, or derived from, the value of another financial instrument or product. Examples of derivatives include options, which give the holder the right (but not the obligation) to buy or sell a security or product at a predetermined price, and futures, which are contractual agreements (obligations) to engage in a transaction at a set time.

The rationale for using insurance derivatives is that they may shift risk more efficiently than current institutional methods. Avoiding entry costs into the insurance or reinsurance business, reducing contract design costs, lowering informational asymmetries, and offering ready markets to allow participants to reverse or otherwise revise positions as conditions change, are all possible ways that derivatives could lower the cost of hedging insurance risk.

The Original CBOT Insurance Futures

Insurance futures were developed by the CBOT, the largest futures exchange in the United States. Early plans called for offering health, homeowners, and automobile physical damage insurance futures. These lines were considered most tractable for a futures exchange, since they settle fairly quickly. However, the first contract traded was the catastrophe future, primarily due to the greater need and demand for a derivative which might address this important source of risk.

The catastrophe futures contract worked as follows. Two contracts were available: a National contract, based on the entire country; and an Eastern contract, based principally on Atlantic and Gulf of Mexico coastal states. Later, Midwestern and Western contracts were offered as well. The buyer and seller agreed to settle the contract at a point approximately six months following the end of the calendar quarter on which the contract was based. The settlement price was based on an index calculated by Insurance Services Office (ISO). The index was based on reported incurred claims, for 22 insurers, on specific perils -- e.g., wind, hail, earthquake, riot, and flood -- that normally are associated with a catastrophe. As these 22 insurers represented only a portion of the insurance industry, and that proportion varied by region, the actual claims reported were multiplied by a factor which varied by line and by state, resulting in a product that approximated total industry experience. The value for claims was then divided by earned premiums and multiplied by $25,000. Thus, the futures price was, in essence, the catastrophe loss ratio, multiplied by $25,000 to arrive at the futures price. (See Harrington, Mann and Niehaus (1995) for a detailed description of the calculations involved in this contract.) The price of the future was capped at $50,000 to limit adverse exposure. However, since the initial price of the National contract was $2,000 (12/11/92), the seller was still exposed to a considerable potential loss.

As with a typical forward or futures contract, no money changed hands at the inception of the contract. Instead, each side posted a margin, which was $1350 on the National catastrophe future, to assure the ability to complete the transaction at the settlement date. Margin can be an additional investment into, or pledged securities that are already in, the account of the futures investor.

Over time, the price of the future is likely to change, as the result of either new information or, more generally, a shift in the market's perception of the value of the contract. When the price changes, money changes hands the same day -- a process called “marking to market.” The side gaining from the price change -- the buyer for an increase, or the seller for a decrease -- receives an amount, equal to the price change, transferred from the other party's account. If the transfer of funds from the losing party reduces the margin account below the required level, then that party will be required to provide more funds to the broker, restoring its margin to a required level.

An insurer using catastrophe futures to hedge underwriting risk would buy futures; if catastrophe losses were high, then the value of the future would increase, offsetting the likely underwriting losses the insurer would experience on its insurance portfolio. If catastrophe losses were less than expected, then the futures price would fall, causing the insurer to lose money on the futures position. Although this fluctuation serves as an effective hedge, the prospect of losing money on the futures when losses are low could generate psychological, as well as regulatory, barriers. Insurers are accustomed to reinsurance contracts that cover their losses -- prices do not rise if losses do not occur. This is different from the essentially linear relationship between loss experience and the profit or loss from a futures contract. However, a new derivative, options on futures, functions more in line with traditional reinsurance.

Options on Insurance Futures

Options involve the right, but not the obligation, to enter into a financial transaction at some future date. If the buyer of an option does not elect to exercise it, the most that is lost is the original cost of the option. If an option is not purchased on margin, there is no daily marking-to-market and no requirement of additional cash to meet margin calls.

An option on a catastrophe future is similar to an insurance policy with a large deductible or an excess of loss reinsurance policy. Options on the initial catastrophe insurance future have experienced a greater, although still limited, trading volume than the future itself. One problem is the reluctance of sellers to bear the risk of a loss that could be as high as $50,000 per contract. To encourage more sellers, the CBOT developed CAT spreads to limit this loss exposure.

Catastrophe Spreads

CAT spreads offer a slice of a catastrophe future that has a payoff similar to a layer of reinsurance. An example of a CAT spread is the 50/70 contract. One party, termed the buyer, buys the option at a strike price of 50 and simultaneously sells an option at a strike price of 70. The other party, termed the seller, sells the option at the 50 strike price and buys the option at the 70 strike price. If the catastrophe losses are less than 50 percent of premiums, which they would have been in every quarter since 1989 except the third quarter of 1992 (when hurricanes Andrew and Iniki hit Florida and Hawaii, respectively (Karras, 1995)), then neither option would be exercised and the buyer would lose the initial cost of the spread. If the catastrophe loss ratio exceeded 70 percent, then both contracts would be exercised, but the value of the 50 option would be more than the 70 option. This gain would help hedge the higher catastrophe losses to which the buyer would likely be exposed. As each of the four futures contracts -- National, Eastern, Midwestern, and Western -- have many option spreads that could potentially be traded, this innovation significantly expanded the number of insurance derivatives.

PCS Catastrophe Insurance Options

On September 29, 1995, the CBOT introduced another new derivative insurance contract. These contracts, termed PCS Catastrophe Insurance Options, differ from the initial catastrophe insurance future in several significant respects. First, they are based, not on ISO data on certain perils for a sample of insurers, but on the Property Claim Services (PCS) estimate of all insured losses from catastrophes. Since 1949, PCS has been providing estimates of catastrophe losses that are commonly accepted as the most reliable values available. Second, the futures price is not a loss ratio, but an actual dollar value. Each 1 point in the PCS Loss Index Value represents $100 million in reported catastrophe losses. The PCS Options cash equivalent is $200 per point. Thus, if the PCS estimate of catastrophe losses for a loss period were $10 billion, the PCS Loss Index Value would be 100 and the PCS Options Cash Equivalent would be $20,000.

A wide variety of PCS Catastrophe Insurance options are available. Nine different geographic areas -- National, Eastern, Northeastern, Southeastern, Midwestern, Western, Florida, Texas, and California -- are available. In addition, on each option a small cap contract (for losses up to $20 billion) and a large cap contract (for losses from $20 billion to $50 billion) are traded. The Western and California contracts, which primarily cover earthquakes, cover annual periods, on the theory that earthquake risk is not particularly seasonal; each of the other contracts is written on a quarterly basis. Finally, the contract can have a 6 month or

12 month development period, which indicates how long the estimation period extends beyond the end of the loss period.

With all of these alternative option characteristics, which can be packaged in different combinations, there could be as many as 120 different PCS options traded within a given year, allowing for extensive customization of a risk hedging strategy. In addition, on each of these contracts, a large number of option spreads (or excess layers) can be written, further increasing the number of insurance derivatives traded.

Figure 1 illustrates the trading volume on all PCS Cat Options from the beginning of trading through October 1998. Figure 2 illustrates the total premiums paid on these contracts. Despite an upward spike in September, 1996, when Hurricane Fran hit, trading remains limited in both number of contracts and premium volume. Figure 3 shows the price of one option spread, the 40/60 September 1996 Eastern spread, which covers the hurricane period July 1 through September 30, 1996, in the states most exposed to hurricane risk. On January 5, 1996, the average of the bid/asked prices was 4.3 ($860). The buyer of the contract would buy the 40 contract and simultaneously sell the 60 contract, both with the same party. If losses for this period are less than $4 billion (40 times $100 million) according to PCS, then neither option will be exercised. If losses exceed $6 billion, they will both be exercised and the buyer will receive $4,000 ({60-40} times $200). If losses are between these two levels, then only the 40 contract would be exercised. This CAT spread is very similar to a reinsurance layer for which the insurer pays $830 for every $4000 of coverage.

Literature Review

The CBOT originally filed for regulatory approval of two insurance futures, one based on automobile physical damage and one on health insurance, in 1990. Shortly thereafter, a homeowners insurance future was proposed. During this time, many articles were written that explained, evaluated, or critiqued these contracts. The CBOT (1990 and 1992) provided a detailed description of the proposed contracts. D'Arcy and France (1990) discuss some of the pitfalls facing these contracts. Cox (1991), Eramo (1991), Hayes (1991 and 1992), Hogue (1992), Lewis (1990), Robertson (1992) Rosenthal (1991a, 1991b and 1991c), and Sherman (1990, 1991a and 1991b) all describe various types of insurance futures and explain how they can be used. Hofflander, Nye and Nettesheim (1991) provide a specific model to measure the risk reduction benefits of insurance futures and the effect on insurance prices. Three articles comprising a *Journal of Risk and Insurance* Symposium on Insurance Futures (1992) examined different aspects of insurance futures: Niehaus and Mann demonstrate the potential for insurance futures to lower primary insurance premiums; Cox and Schwebach examine the advantages and disadvantages of insurance futures and options to reinsurance; D'Arcy and France propose that, instead of offering health and auto physical damage futures, an insurance futures contract based on catastrophe losses as reported by the Property Claims Services be developed, which is what occurred in 1995.

Subsequent to the December 1992 commencement of trading in catastrophe futures, many additional articles explained the benefits of insurance futures or evaluated their future. Foppert (1993), Karras (1995), Pickles and Mathewson (1993), and Walsh (1994) provide overviews of the contracts and their prospects. Cooper (1994) explains the current contracts and plans for additional contracts. The Central Illinois Chapter of the Society of CPCU (1993) performed an extensive analysis of these contracts, including a report of prices and volume since they were first introduced and surveys of brokers, regulators, and insurance companies. They report that almost all the trading in insurance futures that took place between December 11, 1992 and April 19, 1993 was based on the March 1993 Eastern and National contracts. These contracts cover losses that occurred from October 1, 1992 through December 31, 1992, based on the (very confusing) method the CBOT originally used to classify contracts. (Later, the terminology was changed so that the contract is now named after the month in which the loss period ends.) Most trading occurred after the loss period had elapsed, when the only uncertainty was in the value of losses to be reported (since all catastrophic incidents would have already occurred and been known about). Thus, the contracts were not being used to hedge catastrophe losses, but to speculate on the settlement price.

The survey results showed significant interest by insurers, with half of the 92 responding indicating that they tried to learn about catastrophe insurance futures, 30 percent indicating that they had considered using them to manage catastrophe exposure, and 9 percent expecting to trade them within the next five years. The response from brokers was much more limited, with only 14 of 73 brokers responding to the survey. One-half of the responding brokers had been contacted by clients about catastrophe futures, but only 3 brokers had placed any orders on these contracts. The report concludes with the apt observation that the future of insurance futures is quite uncertain.

Boose and Graham (1993) apply a model to estimate potential trading volume for the original CBOT catastrophe futures, and find that only the third-quarter contract -- the one that covers the hurricane season -- is likely to generate enough trading volume to be a successful contract. In another paper, Boose and Graham (1994) describe the original CBOT catastrophe futures contract and detail its shortcomings. They cite that the value is based on the experiences of only 22 insurers, that a viable reinsurance market exists as a substitute hedging mechanism, and that the regulatory environment for insurers discourages investing in futures contracts. D'Arcy and France (1993) explain how the contract works, illustrate price movements over time, and compare futures to reinsurance contracts. Flanigan and Scott (1994) describe how trading in options on futures can provide insurers with an effective method of risk transfer. Himick (1995) demonstrates that the PCS Catastrophe Options are zero-beta assets and explains why a diversified investor should have some assets invested in this manner.

The CBOT insurance futures gained international attention. A task force of the Institute of Actuaries (Great Britain) provided an in-depth analysis of the initial contracts (Ryan, et al., 1993). Cummins and Geman (1994, 1995) and Geman (1994) apply a sophisticated financial approach to pricing futures and options by using an arbitrage-free contingent claims model. This model, although not an exact representation of the CBOT contract, provides a closed-form solution that allows for more accurate pricing than the approaches that assume the futures price is simply a random sum of losses over time. Kielholz and Durrer (1997) apply portfolio theory to make the case that the CBOT options and other insurance derivatives provide a viable investment alternative for investors. (A similar approach is taken by Litzenberger, Beaglehole and Reynolds (1996).) Smith, Canelo and Di Dio (1997) discuss the impact that a variety of catastrophe insurance derivative contracts, including the CBOT options, will have on reinsurance markets. Loubergé, Kellezi and Gilli (1998) describe the risks inherent in CBOT options and catastrophe bonds, and warn that mean-variance analysis does not adequately assess the risk of these instruments.

Lane (1995) determines the appropriate price of options on insurance futures by calculating an Implied loss distribution from actual trades and quotes. Harrington, Mann and Niehaus (1995) examine correlated insurance risk in general and, specifically, whether the original CBOT insurance futures can be used to reduce the cost of risk. They find that the original contracts are likely to be effective only for Homeowners/Farmowners coverage. Their analysis leads to a recommendation that other, line-specific, contracts would be useful tools for managing risk. Harrington and Niehaus (1998) illustrate how state specific insurance derivatives would provide a more viable alternative to reinsurance then the current regional contracts traded on the CBOT.

The numerous articles on insurance futures address one of the drawbacks currently facing these contracts: the lack of understanding of these instruments by those who would benefit from this market. The new contracts, options and option spreads, help deal with the problem of excessive riskiness of selling contracts. With these developments, and changes in regulations that allow futures trading, the market for insurance futures could develop into one that would merit such attention as it is now receiving.

Pricing Catastrophe Losses

In order to develop a price for the futures contract, participants must make an estimate of future catastrophe losses. Annual catastrophe losses have increased in both nominal and real values over the period 1949 through 1997. However, much of this increase is a function of increased coverage provided by insurance. As can be seen in Figure 4, when the ratios of nominal catastrophe losses to earned premiums[1] are fitted against time, the trend is much less apparent. The coefficient for time is not significant for the period 1949 through 1991. Only

[1] The ideal divisor would be the portion of insurance premiums that reflect catastrophe risk, but this is not available in any source. Another alternative would be to use property insurance premiums, on the basis that any property could be exposed to a catastrophic loss. However, given multiple line policies, such as Homeowners and Commercial Multi-Peril, and the fact that the line of business reporting requirements have changed several times during the time period involved in this study, even this value cannot be accurately obtained. Thus, total industry premiums from all lines is used in the absence of a more reliable alternative.

when 1992 (hurricanes Andrew and Iniki) and subsequent years (the Northridge earthquake) are included does an upward trend become significant:

$$(\text{Catastrophe Losses/Industry Earned Premium})_t = a + b \text{ Year}_t$$

Period	Coefficient/Standard Error
1949-1990	0.838
1949-1991	1.032
1949-1992	1.987
1949-1993	2.160
1949-1994	2.820
1949-1995	3.071
1949-1996	3.237
1949-1997	3.028

Since the issue of whether catastrophe losses are increasing over time is so important in pricing futures contracts, and only the results of a few years, albeit recent years, produces the upward trend, there is a need for additional analysis. Hurricane losses create the greatest uncertainty as they are relatively low in number (compared with other weather-related catastrophes), and the size of loss is extremely variable. The CBOT recognizes this uncertainty by requiring higher margins during the hurricane season (July-September).

Exchange-Traded Insurance Derivatives -- Protections and Guarantees

An extensive system of contract guarantees and posting collateral has evolved in exchange-traded derivatives to guard against the risk of contract default. If trading in CAT spreads becomes large, the efficacy of this guarantee system could become of overwhelming importance to anyone using the contracts. Those who are thinking of using the system also need to understand how it operates; the system involves more frequent cash flows than most collateral systems.[2]

Derivatives contracts are usually designed to result in large payoffs when certain events occur. A movement of a few points in interest rates, for instance, will result in large changes in the values of interest rate futures and options. Since the value of a derivative is usually a function of a volatile underlying asset or index, and since derivatives are usually highly leveraged instruments, these changes in value tend to be frequent and large. This makes derivatives very powerful tools for manipulating payoffs with low transactions costs. However, it also means counterparty default (the customer on the other side of a trade is called the "counterparty") is a real danger.

Futures exchanges have evolved an elaborate system to protect against counterparty default. This system has two levels. The upper level, usually administered by a futures clearinghouse, involves counterparties who are members of the clearinghouse (clearing firms). The lower level, enforced largely by exchange rules and by self-interest, involves payments between other counterparties, including traders who are not members of clearing firms and members of the general public.

Default Protection at the Clearing Firm Level

[2] This discussion of necessity ignores many details. For a more complete discussion of clearinghouse functions and the rules governing margin deposits, see Baer, France, and Moser (1995), or Edwards (1984).

The strongest contract guarantees are those extended by the clearinghouse to the clearing firms. Among these counterparties, the clearinghouse itself guarantees that all net payments due will be paid; if one counterparty defaults, the clearinghouse will make up any shortfall, usually out of a central fund set aside for that purpose. Because this strong guarantee is backed by the clearinghouse, the clearinghouse takes steps to minimize credit risk from the clearing firms. Though rules differ somewhat across clearinghouses, clearing firms are normally required to put up a substantial sum of capital. The clearinghouse also carefully monitors each clearing firm's position and net capital. In addition, the clearinghouse requires an explicit deposit of collateral called a margin, which is proportional to the overall exposure of the clearinghouse to that firm. Margin has special status in the event of bankruptcy: the clearinghouse's claim on margin bypasses normal rules of creditor precedence to give the clearinghouse timely and certain access to those funds. Thus, even if the clearinghouse's monitoring of the health of a clearing firm is imperfect, the margin protects the clearinghouse against having to make good on a default.

Protection for Non-Clearing Counterparties

Futures exchanges are hierarchies, with the clearinghouse at the apex and the clearing firms under it. The clearing firms handle transactions for those individual traders, trading firms, and brokers who are not themselves clearing firms. The brokers handle transactions for individuals or firms which are not members of the exchange; unless an insurance company bought or leased a seat, it would be trading through a broker. If the broker's firm is not itself a clearing firm, the broker, or anyone else executing a trade, must have the explicit backing of a clearing firm before being allowed to execute trades.

The clearinghouse guarantees payments between clearing firms only. An individual who is owed money by a defaulting broker will not necessarily be made good by the exchange clearinghouse. The individual would first try to recover funds under bankruptcy law from the broker, and, failing that, from the clearing firm which backed the transaction, but the clearinghouse itself has no legal obligation to make good the defaulted payment. In general, clearing firms have excellent credit ratings, and are very well capitalized. However, futures clearinghouses are even stronger from a credit standpoint. Thus, the clearinghouse guarantee of payments between clearing firms affords an even greater degree of protection from default risk.

That said, exchange rules are set up to minimize default at any level. Each participant puts up collateral in the form of margin. Customers provide collateral with their brokers, which is deposited in a margin account, under the control of the broker. Brokers in turn deposit margin with their clearing firm; in most cases, they can simply pass along the margin they receive from their customers. (Rules forbid commingling of customer margin with any margin due on the broker's own position, a practice called "segregation of customer funds.") If these rules are followed, each level of the hierarchy has protection against default. If a broker, in violation of exchange rules, does not take adequate margin from a customer, and the customer defaults, the broker is liable to make good the payment. Thus, exchange rules are reinforced by self-interest.

Marking to Market

The whole guarantee system is made much stronger by the practice of "marking to market" each position on a daily or twice-daily basis ("daily settlement"). At the close of each trading day, or on some exchanges twice daily, each position is revalued based on current market prices. If an individual's position has resulted in a paper loss, the amount of that loss is deducted from the loser's margin account. If this results in too low an account balance, the loser must deposit more funds in order to bring the collateral balance up to the required level. If a broker notifies a customer that more margin is necessary, and the customer does not have funds on deposit by the next business day, the broker can legally close the customer's position that same day. As a result, margin deposits need normally offer protection against only one day's price change; losses cannot be run up indefinitely.

One result of the practice of marking to market is that payments are made to or from a margin account on a daily basis. Firms or individuals who have derivatives positions on organized exchanges have to be prepared to deposit collateral in the form of margin in order to maintain those positions, and they need to be prepared to deposit additional margin that same day if the position shows a loss.

Margin for Futures and Options Combinations

Catastrophe insurance derivatives currently traded on the Chicago Board of Trade are spread positions in call options on futures. The original system of contract guarantees on futures exchanges was designed to deal with futures positions. The method of collateralizing positions had to be modified to encompass trading in options on futures. The technique used to calculate the necessary margin, called SPAN (Standard Portfolio Analysis of Risk), was derived from the way over-the-counter options traders monitor their positions. Although developed first at the Chicago Mercantile Exchange, modifications of SPAN are used on almost every futures exchange throughout the world.

Since SPAN is designed to deal with individual default risk resulting from movements in the underlying contracts, it deals with a participant's total position across all contracts, not the position in each contract. For instance, a trader who has a combination of positions which are partially or wholly offsetting, such as a long position in the futures contract and a short position in another futures contract, would not have to deposit as much margin as someone who had a simple long position. SPAN looks at groups of positions and assesses the total payoff or loss from that group under a range of scenarios, looking for the margin necessary to cover the worst-case loss.

In the case of a call option spread, normally one side of that spread would have lost money and the other gained. SPAN would assess the net gain or loss from the two sides of the spread. The scenarios considered by the SPAN program include not only changes in the price of the underlying asset, but also changes in the volatility of that price. Since an increase in volatility normally raises the price of a call, a spread which involves buying one call and selling another would also have partially offsetting losses and gains. SPAN looks at a range of prices and volatilities, scanning across the two dimensions for the maximum loss possible within that rectangle. The range is set by an exchange committee of knowledgeable market participants and exchange officials, and is changed whenever market conditions warrant it.

The margins calculated using SPAN and similar systems are sometimes known as minimum margins. Brokers are required to collect at least this minimum, but they may demand a higher margin if it seems prudent for ordinary business reasons given the characteristics and trading record of the client involved.

Price limits

Futures markets have always been bastions of free-market capitalism: their business is providing competitive market prices. As such, they have a long tradition of allowing unfettered trade, no matter how feverish it may seem to outsiders. However, there is one major exception to this laissez-aller rule: daily price change limits.

Daily price change limits are closely related to the more familiar "circuit breakers" which shut down stock trading during a crash. They typically forbid trading at prices which are more than a pre-specified dollar amount from the previous day's closing price. They are symmetric: if prices rise *or fall* by more than a certain amount, trading stops. Unlike circuit breakers, there is no pre-set time out: trading can resume at any time, if counterparties are again willing to trade at prices within the limits. Usually, however, if a market "goes limit up" or “down” it does so in response to news which drives the equilibrium price out of the limit range, and trading closes down for the day. Trading can resume the following day as long as it is within the limit relative to the previous day's close. The price may move by the limit amount several days in a row before reaching a new equilibrium price. The rationale for price change limits is to give traders time to evaluate prices without time pressure. One young father described it as "giving the market a time-out." It may give brokers time to contact their clients to receive instructions. It gives all participants time to collect margin after a preliminary mark-to-market based on the limit price.

Price limits are important for a couple of reasons. First, they limit losses during any one day; if the price can only move by a certain amount, each contract can only gain or lose a certain amount in value. For this reason, some have suggested that price limits decrease the amount of margin brokers need to protect against customer default. Actually, the relationship is not quite so simple. If a contract closes limit up or down, the day's losses are indeed limited, but a broker may be unable to close out the position at, or close to, the closing price.

Possible Guarantee Weaknesses

An event which produces a large revision in expected catastrophe losses -- for instance, a major earthquake or a hurricane -- would result in large movements in the value of spread positions. These, in turn, would result in large payments from losers to gainers when the contracts are marked to market at the end of the day.

Even a very large insurance or reinsurance company needs to be aware of two situations in which the payments received from an option spread could be less than the full amount due. The first situation occurs only rarely; the second situation has *never* occurred. The first situation occurs when a clearing firm fails and defaults on claims that it owes to its customers. The second, which has never happened, is that the clearinghouse itself defaults on its obligations.

Clearing Firm Failure

The first situation, clearing firm failure, is usually illustrated by the Volume Investors case. This clearing firm had customers with a variety of positions in different contracts. Some of their customers had very exposed positions, resulting in very large losses. The customers defaulted, and Volume Investors did not have enough margin on deposit to cover the customers' obligations.

The loss should have been transferred out of the defaulting customers' accounts and given to accounts which had gains. When it became apparent that the money was not forthcoming, some of the accounts which were owed money were paid and some where not. Any winner who cleared (directly or via broker) through another clearing firm was paid. This is because the clearinghouse made good the payments which were owed between clearing firms (level one guarantee). However, those unlucky "winners" who were owed money and cleared through Volume Investors itself were not covered by the clearinghouse-level guarantee.

When Volume Investors defaulted, the unlucky investors were left to pursue their claims in bankruptcy court.

This case is described in considerable detail in Jordan and Morgan (1990). One implication of their analysis is counter-intuitive: to avoid being caught by a clearing firm failure, do not choose a clearing firm which has a nice balance of customers on each side of a number of contracts. When a contract makes a major move, the net payments owed to the clearing firm from the clearinghouse will be relatively small because many of the firm's customer positions net against each other. If a clearing firm has customers who are largely on the same side of a contract, a major market move will result in a large payment to the clearing firm from the clearinghouse, making default by the firm less likely.

In addition to clearing through a clearing firm with unbalanced positions, try to be on the same side as the bulk of the other customers. Suppose you and all the other clearing customers will lose if the market drops. If the market makes a major move up, you and the other customers are owed money; the clearinghouse will pay the net owed to the clearing firm, and since in this example the customers were all on the same side of the market, they will pay the full amount. If the market makes a major move down, some of the customers might default, and the clearing firm might be driven into bankruptcy. However, if you are on the same side of the market as the other customers, you will have made losses yourself. While you might have trouble recovering the remaining balance of your account, you will probably not be trying to recover substantial winnings.

Clearinghouse Failure

The second situation in which contract default could conceivably occur is the failure of the clearinghouse itself. No U.S. futures clearinghouse has ever failed. During the Crash of 1987, when the value of stock index futures declined by over 20% in one day, futures clearinghouses were able to cope.

If trading in insurance spreads becomes widespread, a significant portion of catastrophe risk could be transferred in this way. How large could open interest become? To get an idea, look at the traditional agricultural futures contracts. These are used routinely by all levels of the marketing chain to hedge risk. Advocates of insurance derivatives can visualize both insurers and reinsurers using the market. In traditional futures, open interest roughly follows the amount of underlying risk to be hedged; as the amount of the crop in storage increases and decreases seasonally or between years, open interest will also wax and wane.

There is one additional risk associated with insurance spreads that should be considered in the event that trading in catastrophe insurance option spreads becomes widespread. In the case of a massive catastrophe that caused a clearinghouse failure, the insurer might not be able to collect on the option that it purchased. However, the insurer might be held liable to pay on the option that it sold at the higher strike price, since that would be an asset of the bankrupt clearinghouse. If this were the case, then rather than reducing the risk of a catastrophe for an insurer, the option spread strategy would actually increase this risk. (The actual resolution is uncertain because a clearinghouse failure has never happened, so there is no precedent. Most members of the investment community consider this to be extremely unlikely to occur; in contrast, the insurance community tends to focus on events that are extremely unlikely to occur.)

Hurricane Andrew

On August 24, 1992, Hurricane Andrew moved across the state of Florida, continued over the Gulf of Mexico, and then hit Louisiana. This was the largest individual catastrophe ever. Less than five weeks later, Hawaii was hit by Hurricane Iniki, at the time, the third most costly U. S. disaster. On December 11, 1992, the CBOT began trading catastrophe futures for the loss period October through December, 1992, the quarter just following this most costly quarter. What would have happened if catastrophe futures had been in place and widely traded prior to Andrew? Would the CBOT have been able to withstand this catastrophe?

Using quarterly PCS data from 1949 through 1991, the expected losses on the third quarter National contract would have been $2,029. It is not known what the risk premium would have been for this contract. However, assume that the contract was priced at $2,500 prior to Andrew. Karras (1995) estimates that a National contract covering this time period would have settled at $24,802.50 and an Eastern contract at $44,732.50.

The week that Hurricane Andrew occurred, estimates of the total insured losses varied widely. The preliminary PCS estimate was $4 billion to $4.5 billion. Major reinsurers provided estimates from $4 billion to $12 billion. In retrospect, the most accurate assessment was made by the Dade County Emergency Manager, who placed insured losses in the $15-20 billion range (Lenckus (1992)). The following week, PCS revised its estimate to $7.8 billion. Later revisions, occurring almost monthly, raised the value to $10.2 billion, $13.4 billion and then $16.5 billion by the end of the year.

These estimates were all for total incurred losses. The original catastrophe future was based on reported paid losses. In order to determine the appropriate price of the catastrophe future after Andrew, futures traders would have had to estimate total insured losses and then estimate how many would be paid and reported to ISO by June, 1993. This value would then be divided by $12.2 billion, the National premium volume established by CBOT for 1992 and 1993. Based on historical simulations calculated by the CBOT, approximately 75 percent of catastrophe losses are paid within this period. Thus, the $7.8 billion estimate would have led to a futures price of almost $12,000 (= (7.8 x .75/12.2) x 25,000). Assuming nothing was known about this loss until the Friday before it hit, then the futures price would have moved from $2,500 on August 20 to $12,000 on September 1, eight trading days later. During this time, limit moves of $1,350 would have occurred each day, but no trading would have taken place. Investors who were short catastrophe futures would have had to meet margin calls of $1,350 per contract each day. If any investor defaulted, then the broker would have had the right to close out the position, but this would have been impossible as the limit price prevented any transactions from being made at the new value. When the trading range had moved enough to allow trading again, then the built-up buying pressure generated by brokers liquidating defaulting traders' positions would lead to additional price momentum, leading to additional limit moves. This, coupled with the impact of Hurricane Iniki at the end of September and periodically higher loss estimates for Andrew, would most likely have led to the futures price overshooting the estimated $24,800 final settlement value, before approaching this level.

However, assume that the price moved directly to its final level in stages as loss estimates increased. Short sellers would have lost $22,300 per contract. Their initial margin would have been only $1,350, so this would be a 1,652 percent loss. At least $9,500 in losses, and probably much more as defaults drove up prices, would have occurred immediately after the hurricane, before they could liquidate their positions. Thus, a large number of customer defaults could be expected, which could have led to broker defaults as well.

The amount of capital and guarantee funds, including lines of credit, of the Board of Trade Clearing Corporation (BOTCC) was $184 million as of 1989 (Rutz (1988)), although it would have been slightly higher by 1992. (As of 1995, the BOTCC had $140 million in capital and $300 million in lines of credit (CBOT, 1995).) Also, 139 firms are members of the exchange, and the capital of any of these clearing members involved in catastrophe futures would have also been at risk in the case of defaults. If the insurance industry had been using catastrophe futures to hedge, for example, 25 percent of its exposure, it would have stood to collect $4.5 billion in gains for the third quarter of 1992. Since futures are a zero sum transaction, then other parties would have had to bear this much in losses. In effect, there were clearinghouse assets of under $0.5 billion to guarantee the difference between customer personal assets plus the assets of their brokers and the total payable losses. Hurricane Andrew could have completely depleted the capital of the futures markets, affecting trading in all other futures. In retrospect, the delayed introduction of, and limited initial trading in, catastrophe futures was fortuitous. Given the magnitude of potential losses that catastrophe futures could generate, it is easy to understand the shift to option spreads. Option spreads do not provide the same level of protection that futures would, but they limit the potential losses of sellers. Whereas it is still possible for an insurer to gain full protection by buying a series of option spreads, and for a speculator to assume the total risk by selling this series, the number of transactions and associated transaction costs would discourage this. Through March, 1998, the total capacity of the CBOT options spreads traded to date was under $100 million.

Alternative Approaches to Dealing with Catastrophe Risk

A. "Institutional" Approaches

The insurance industry, battered by Andrew and Northridge and wary of future disasters, is searching for ways to deal with catastrophe exposure. (See Jaffee and Russell (1997), Doherty (1997) and Harrington (1997) for a detailed analysis of this problem and some possible solutions.) Some insurers have begun aggressively managing their loss exposures, in some cases issuing large-scale cancellations as they attempt to reduce their exposure to catastrophes. Proposals for catastrophe pools have been evaluated in several states and at the Federal level. The Florida Hurricane Catastrophe Fund, established in 1993, provides some reimbursement for insurers in the event of a loss in excess of $3 billion. The

California Earthquake Authority, which addresses the earthquake market for California homeowners, began operating on December 2, 1996. This state-run fund provides capacity of $10.5 billion, financed by several sources: premiums, insurer-provided funds, investor funds, reinsurance, and the authority to tax. The Florida and California programs help manage the catastrophe risk of insurers.

Insurers face the problem that every policy written potentially exposes the company to a policy limit (or larger, in the case of the Northridge earthquake and Oakland fire) loss. Highly correlated losses can expose the insurer to bankruptcy in the event of a catastrophic event, which would subject all customers to a loss of coverage. Whereas catastrophe losses represent property coverage, an analogy can be drawn from liability coverage.

Insurers traditionally offered liability coverage to businesses with a per occurrence maximum. For example, if the limit were $100,000, then the insurer would pay no more than $100,000 for any single occurrence. As occurrences were assumed to be independent, and large losses relatively rare, the insurer in general capped its losses on a policy at the policy limit. However, ingenious interpretations of policy limits changed this situation. Courts would occasionally make such rulings as: every single drip of pollutant, every breath drawn by an exposed claimant, or every individual affected by a faulty product, was a separate occurrence. As these events are not independent, the insurer became exposed to a loss many times the policy limit.

Insurers have counteracted this expansion of liability by now issuing aggregate limit liability policies for commercial risks. Thus, once an insurer has paid the aggregate limits, no additional coverage exists for the policyholder in the event of any other occurrences. By limiting the maximum loss that the insurer can suffer on a policy, the company is protected against insolvency from correlated losses.

Could the concept of aggregate limits be applied to property coverage? One important distinction exists between liability policies and property coverage. The aggregate limits on liability policies apply to a single insured. On property coverage, aggregate limits would apply to different policyholders, so that the losses of other insureds would affect the loss payments an insured would receive. Although this is exactly what happens when a loss is so large that it drives the insurer into liquidation, the aggregate limits would be established at levels designed to prevent insolvency. There is also a timing problem involved, as some policyholders may have their claims submitted, and paid, before the aggregate limit is reached, which would spread the impact of the limit unevenly over policyholders.

The concept behind an aggregate limit is that if a truly catastrophic event occurred, policyholders would receive a proportional settlement on their claims. If the aggregate limit were $1 billion and an insurer incurred losses of $3 billion from one event, then each claim would be settled at one-third of its value. Although this is not the same level of protection that current policies offer, the advantages would be two-fold. First, in some markets property coverage is simply not available due to catastrophe exposure. Aggregate limit policies could provide coverage that would be perfectly adequate in all but the largest disasters, which is much better than having no coverage at all. Second, the cost of this policy should be less than full coverage.

A similar approach to aggregate limits on property losses would be for an insurance company group to establish adequately capitalized subsidiaries in each catastrophe-prone area, but inform policyholders and regulators that the parent company will not provide additional capital in the case of a major catastrophe. If an industry-impacting disaster were to occur, then the subsidiary could immediately be placed in liquidation and each claim covered proportionally. Such an arrangement would protect the other policyholders of the insurance group from having their coverage lost as the result of a catastrophe in another state. By being forewarned that the parent company will not rescue the subsidiary, policyholders can take more initiative in dealing with catastrophe risk, such as obtaining coverage from the most adequately capitalized insurer even though the price might be higher, paying more for stronger home construction, or locating in less catastrophe-prone areas, such as away from seacoasts.

Another proposal involves excluding hurricanes and earthquakes from property policies. Flood and nuclear exposures, reflecting catastrophe risk, are already excluded. As it is irresponsible to risk the solvency of a company on a single event, then unless other solutions can be developed, it may now be time to exclude these perils that create the possibility of insolvency.

B. Capital Market Approaches

One of the underlying ideas behind exchange-traded insurance derivatives is the tapping of the capital markets as a source of funding for the insurance industry. The theory is that, although a significant catastrophic loss to the property-liability industry could threaten the industry's solvency, such a loss would be far less significant in the context of the overall capital markets. This can be exemplified by looking at the relative sizes of both markets. Whereas the total net worth of the property-liability insurance industry is perhaps in the range of $250 billion or so, the value of the U.S. equity markets occasionally fluctuate by that much in a single *day*. (Such an amount corresponds with perhaps a 1 to 2 percent movement in the equity markets, a not particularly uncommon occurrence these days.) Thus, it is felt that if sufficient interest can be generated in the capital markets to take on insurance underwriting risk, exchange-traded derivatives will offer an efficient way of transferring significant funds into the insurance industry.

The CBOT contracts described in this paper represent one sector of a larger, relatively new industry: insurance securitization. Significant adjustments have been made, as described above, to the original CBOT insurance derivatives over the last five or six years. Similarly, additional products have recently been developed which also attempt to address the need by insurers to hedge catastrophe losses. The remainder of this section describes some of these securitized products.

One additional development with regard to CBOT PCS derivatives, beyond those mentioned in prior sections of this paper, involves single-event contracts, planned for introduction in the fourth quarter of 1998. Rather than basing the derivative value on aggregate catastrophe losses over the course of the period (either one quarter or one year), single-event contracts are based upon the occurrence of a single catastrophe.

The Chicago Board of Trade, however, is not the only exchange providing the opportunity to trade insurance derivatives. The Bermuda Commodities Exchange (BCOE), incorporated on July 22, 1996, has recently begun offering its own series of catastrophe options. (See Major, 1997 and Powers and Powers, 1997.) There are some interesting differences between the CBOT and BCOE. Some of the specific BCOE insurance derivative parameters include the following.

- *Trigger*: based on the Guy Carpenter Catastrophe Index, which is in the form of a loss-to-value or damage ratio (paid homeowners losses divided by housing values). Values for the index are available as finely as by zip code, and are updated quarterly. The index reflects homeowners loss experience of companies (representing about 25% of homeowners premiums) reporting to ISO.
- *Geographic contracts available*: national, northeastern states, southeastern states, Gulf states, mid-western/western states, Florida, and Texas.
- *Catastrophe basis*: three different types of catastrophe options are available – single loss (largest catastrophic event during a period), secondary loss (the second largest event), and aggregate cat.
- *Risk periods*: semi-annual (first-half or second-half of calendar year).

- *Exercise*: binary option payoffs. Thus, the option either pays off $0 or $5,000 at expiration, depending on whether the option ends up out-of-the-money or in-the-money (i.e., whether the index value is below or above the strike price).
- *Settlement*: the value of the index is determined at quarterly intervals (1,4,7,10, and 13 months after the end of the risk period). The option, rather than European, is similar to what is called a "Bermuda option" (appropriately enough), since at each of the above quarterly intervals (and only then), the option may or may not be settled (depending on how far below or above the strike price is the index value).

In some ways, then, the BCOE options are more, and in some ways less, complicated than the CBOT options. For example, payoff is simpler (either $0 or $5,000), but the timing of settlement is more complicated. The interesting thing about BCOE insurance derivatives is the potential ability to tailor an index to a company's specific geographical exposure distribution. Rather than use an overall industry index (as do the PCS CBOT options), zip code data can be combined in appropriate ways. The potential disadvantage is that the BCOE index is updated only quarterly, and covers only a fraction of the industry.

Exchange-traded derivatives are not the only securitization products that have been introduced recently in the insurance industry. In the last two years, significant publicity has been garnered by catastrophe bonds (Canter, Cole and Sandor, 1996, Gorvett, 1997 and Zolkos, 1997). These are bonds – debt instruments – issued by insurance companies to the capital markets. Like other corporate bonds, they have promised coupon (interest) and principal payments. However, with a catastrophe bond, the degree of payment of principal and/or interest is contingent upon the occurrence or non-occurrence of an "event" (such as a major hurricane or earthquake): if an event occurs, there may be some degree of debt forgiveness (the reduction of, elimination of, or delay in principal and/or interest payments by the insurer to the investors). Generally, these bonds are sold in multiple tranches, the coupon rates of which vary according to the relative risks of principal or interest reduction.

Generally, catastrophe bonds are issued by insurers to investors through a "special purpose vehicle" (SPV). The SPV functions similarly to an off-shore captive reinsurer, by providing a reinsurance policy to the issuing company. The reinsurance contract is funded largely by the proceeds from the catastrophe bonds which are issued by the SPV. Examples of companies that have followed this process are USAA with Residential Re, Tokio Marine and Fire with Parametric Re and Centre Re with Trinity Re.

Several other securitization products have appeared recently. Catastrophe equity puts, for example, allow a company to issue (usually preferred) stock at a pre-specified price in the event of a catastrophe. These types of "over-the-counter" instruments – cat bonds, catastrophe equity puts, etc. – have advantages and disadvantages relative to exchange-traded insurance derivatives. While they are not as "liquid" or as tradable as CBOT or BCOE options, they can be more closely tailored to suit particular insurers' needs. In addition, as long as a sufficient volume can be sold, they are capable of covering the loss to an insurer from a major catastrophe. With regard to volume, it is interesting that, while CBOT insurance derivatives have generated rather low volume, the capital markets have tended to oversubscribe catastrophe bond offerings. While this may indicate a preference for these types of instruments, this may also be due to relative pricing, product familiarity, and many other factors.

Summary and Conclusions

Recent large losses have caused the insurance industry to reevaluate catastrophe exposures. Many companies, realizing the extent of the risk they currently face, are taking steps to reduce this risk. The nascent insurance futures market is one potential method for transferring a portion of this risk. In addition, other alternative capital market solutions have developed as well.

Determining the proper price for catastrophe futures depends on interpreting historical data to forecast expected losses. The nominal value of catastrophe losses has increased dramatically, but, when adjusted for premium growth, only when including data for the last few years (1992-1997) does a significant trend appear. Thus, the trend may result from the impact of a few unusual events. Regardless of the existence of an upward trend, the occurrence of significant losses has significantly affected the willingness of the insurance industry to write policies with severe catastrophe potential.

This paper demonstrates the financial impact that a hurricane the magnitude of Andrew would have on futures markets, likely leading to defaults and unfulfilled contractual obligations if such instruments are used to hedge a significant portion of the catastrophe exposure. This possibility partially explains the movement toward option spreads, instead of the more risky futures, and the increasing popularity of alternative capital market securities in which the risk of default in the event of a major disaster is reduced or eliminated.

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Figure 1
CBOT PCS Options: Trading Activity

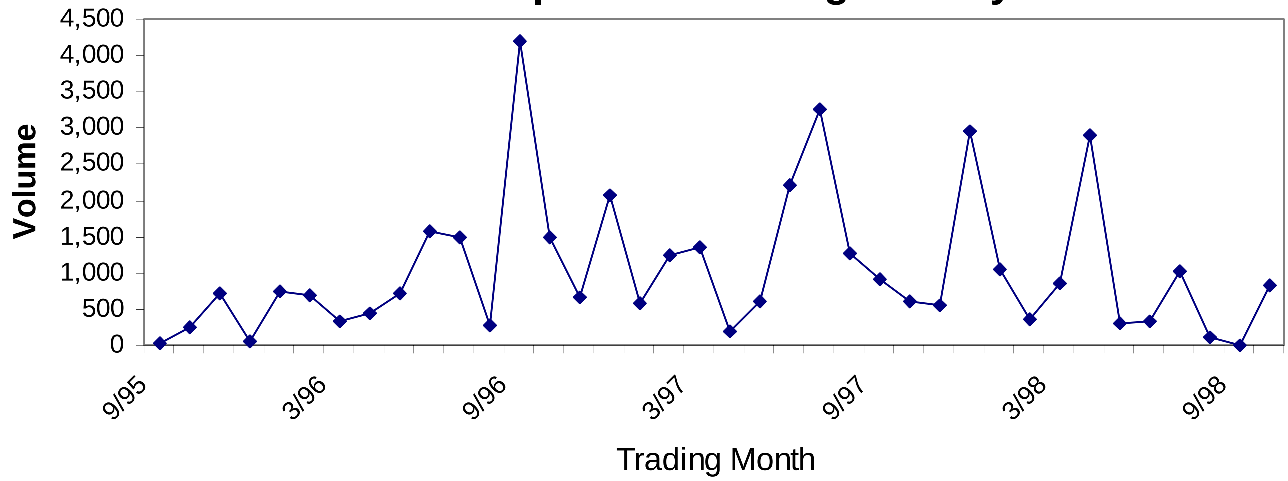
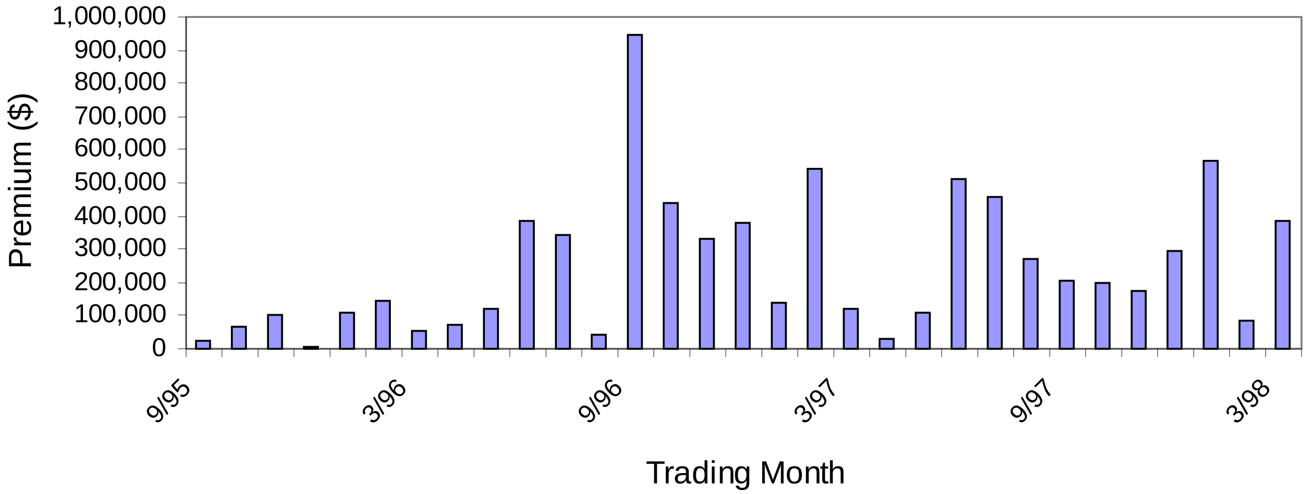


Figure 2
CBOT PCS Options: Premiums



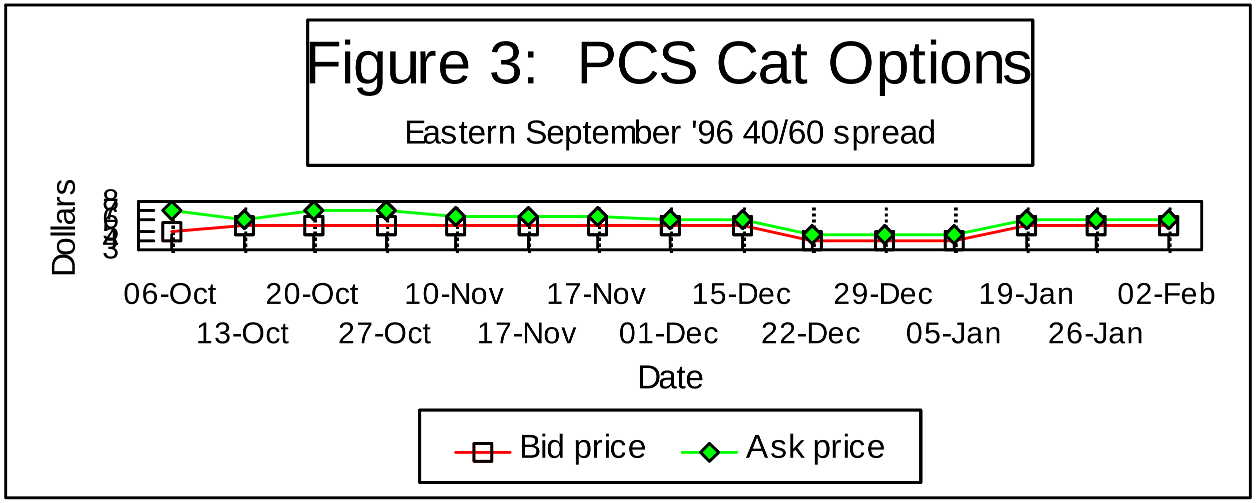


Figure 3: PCS Cat Options
Eastern September '96 40/60 spread
Dollars
06-Oct
13-Oct
20-Oct
27-Oct
10-Nov
17-Nov
17-Nov
01-Dec
15-Dec
22-Dec
29-Dec
05-Jan
19-Jan
26-Jan
02-Feb
Date
Bid price
Ask price

Figure 4
Catastrophe Losses/Earned Premium