AN INTRODUCTION TO CATASTROPHE INSURANCE FUTURES

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SUMMARY

The goal of the paper is to introduce catastrophe insurance futures and options. We first provide background on natural catastrophes and the associated financial effects on both the primary and reinsurance markets for property insurance. Next, we describe the recently introduced catastrophe insurance futures product and present a general framework for its pricing. We then illustrate the risk management and speculation potential of the futures contracts with several examples. In conclusion, we discuss the future of the contract and suggest several areas for further research.

Introduction aux contrats à terme sur assurance des risques de catastrophe

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Résumé

Le but du présent exposé est d'introduire les options et contrats à terme sur l'assurance des risques de catastrophe. Nous présentons tout d'abord des données générales sur les catastrophes naturelles et leur impact financier à la fois sur les marchés primaires et sur les marchés de réassurance de la propriété. Nous décrivons ensuite le produit récemment introduit de contrats à terme sur assurance des risques de catastrophe et présentons un cadre général permettant d'établir son prix. Nous illustrons ensuite la gestion du risque et le potentiel de spéculation des contrats à terme à l'aide de quelques exemples. En conclusion, nous traitons de l'avenir du contrat et suggérons plusieurs secteurs pouvant faire l'objet de recherches supplémentaires.

INTRODUCTION

Natural catastrophes place significant financial demands on society. In recent years the magnitude of catastrophe losses (both insured and uninsured) has been staggering. Insurance markets are faced with the dilemma of increasing consumer demand and decreasing reinsurance supply. Partly in response to and partly in anticipation of current insurance (and reinsurance) market conditions, financial markets have responded. Derivative financial instruments linked to the level of catastrophe losses have been introduced in the United States and are under consideration in Europe. To date market activity has been thin (in the sense of few players and minimal volume) with the notable exception of call option spreads on the futures contract.

In the sections that follow more background is given on natural catastrophes and the insurance/reinsurance markets (in particular current market conditions for property insurance and property catastrophe reinsurance.) Then, the catastrophe insurance futures product is described, and pricing considerations are set forth relative to the empirical evidence from the market. A general pricing structure is introduced. Several illustrative examples of hedging applications are presented. In conclusion, the future of catastrophe insurance futures is discussed.

NATURAL CATASTROPHES AND INSURANCE/REINSURANCE MARKETS

Natural catastrophes cause significant loss to life and damage to property. Large international reinsurers and others devote significant resources to the analysis of such catastrophes (Munich Reinsurance, 1988; Swiss Reinsurance, 1993).

Although natural catastrophes are at least as devastating outside the United States, for the current purpose, we will concentrate on natural catastrophes within the United States. Appendix Exhibit 1 shows quarterly catastrophe loss ratios defined as quarterly catastrophe losses estimated by Property Claim Services (PCS), a subsidiary of the American Insurance Association, divided by quarterly earned premium from AM Best Company. Particularly noteworthy are the loss ratios for the third quarters of 1989 and 1992 which include the catastrophe losses arising from Hurricanes Hugo and Andrew, respectively.

The following chart shows the statistics arising from the quarterly PCS/AM Best catastrophe loss ratios:

CATASTROPHE LOSS RATIO STATISTICS, -1992			
	Range	Mean	Std. Deviation
FIRST QTR	0.39% - 6.62%	1.82%	1.43%
SECOND QTR	0.40% - 27.57%	5.35%	5.34%
THIRD QTR	0.23% - 103.17%	7.72%	20.72%
FOURTH QTR	0.09% - 8.47%	2.14%	2.47%

The previously mentioned Hurricanes Hugo and Andrew contribute to the loss quarter of their occurrence being at the 99th and 100th percentile for the historical period studied.

The uncertainty associated with catastrophes plus recent record loss levels have required enormous economic and social resources. Property owners have dealt with physical injury and death in addition to loss of property. Insurance company resources and government aid programs have been stressed responding to financial claims for disaster relief. Reinsurers stand behind the insurance companies providing financial resources, and taxpayers ultimately fund government relief programs.

Property owners, especially in catastrophe prone areas, are faced with the unavailability of insurance coverage as well as an increased deductible level, restricted coverage and increased prices when coverage is available. Insurance companies are faced with increased demand from insureds, regulatory restrictions on price increases, and increasing retention levels and prices associated with decreasing reinsurance capacity. Reinsurers, once able to retrocede risk to other reinsurers, are now accepting business from ceding companies with extremely limited retrocession support (Schnieper, 1993). Governments, as regulators of the insurance markets, play a role administering the estates of companies rendered insolvent by catastrophes, and organizing governmental or quasi-governmental facilities providing primary insurance or reinsurance capacity. Governments are also involved in financing risk handling facilities, providing disaster relief assistance directly and through government loans.

Financial institutions, particularly those with large mortgage portfolios, are recognizing the risks and examining mechanisms for managing the risk. The same risk management approach would apply to large property owners.

There are clear signals of a crisis with financial and social implications. In the spirit of innovation, the Chicago Board of Trade (CBOT) launched catastrophe insurance futures and options in late 1992. The financial market features of market price discovery and the potential for additional liquidity provide an interesting alternative to consider for mitigating the crisis.

The next section describes the catastrophe insurance futures and options.

CATASTROPHE INSURANCE FUTURES & OPTIONS

Although insurance futures and options have been considered for many years prior to 1992, the CBOT has been the first organization to devote the developmental resources to bring such products to market. After consideration of health insurance and automobile physical damage insurance futures contracts, the CBOT introduced catastrophe insurance futures and options on futures in December 1992.

The futures contracts settlement price was based on an index calculated by dividing quarterly "catastrophe" losses incurred in a given loss quarter and reported during that quarter or the next quarter by earned premium based on overall historical market statistics. The "catastrophe" losses were defined as losses for a particular line of business and cause of loss from data reported to ISODATA, Inc. (ISODATA), an insurance industry statistical organization, by a group of 22 insurance companies. The reported catastrophe losses are adjusted to total market levels based on the relationship of reporting company premiums to market premiums. The plan was to introduce National, Eastern, Midwestern and Western contracts. National and Eastern contracts were released in December 1992; the Midwestern in May 1993.

In an effort to educate the marketplace, the CBOT released historical "simulations" of final settlement prices based on reconstruction of loss data reported to ISODATA and the current premium base for the initial contracts. The construction of the historical "simulation" could lead to a slight understatement of the mean settlement value for a loss quarter and an overstatement of the variability. The historical "simulations" of settlement prices are presented below:

"Simulated" Futures Settlement Prices, 3Q89 - 3Q92

(Catastrophe Loss Ratio x $25,000)

Loss Quarter	Region	1989	1990	1991	1992	Mean	Standard Deviation
1st	National	-	$1,425	$1,950	$2,225	$1,867	$406
	Eastern	-	$1,175	$1,375	$4,100	$2,217	$1,634
2nd	National	-	$2,325	$4,225	$4,325	$3,625	$1,127
	Eastern	-	$1,525	$2,750	$1,925	$2,067	$625
3rd	National	$6,375	$2,800	$1,475	$24,800	$9,692	$13,100
	Eastern	$12,075	$825	$1,875	$44,725	$15,808	$25,048
4th	National	$1,800	$750	$775	-	$1,108	$599
	Eastern	$1,500	$900	$650	-	$1,017	$437

Actual settlements have been effected for the fourth loss quarter of 1992 and the 1st loss quarter of 1993.

Actual Futures Settlement Prices, 4Q92 - 1Q93

(Catastrophe Loss Ratio x $25,000)

Loss Quarter	Region	1992 *	1993 *	A Priori Statistics ** Mean	A Priori Statistics ** Standard Deviation
4th	National	$2,000	-	$1,108	$599
	Eastern	$3,575	-	$1,017	$437
1st	National	-	$3,825	$1,867	$406
	Eastern	-	$6,125	$2,217	$1,634

* From CBOT Settlement Reports

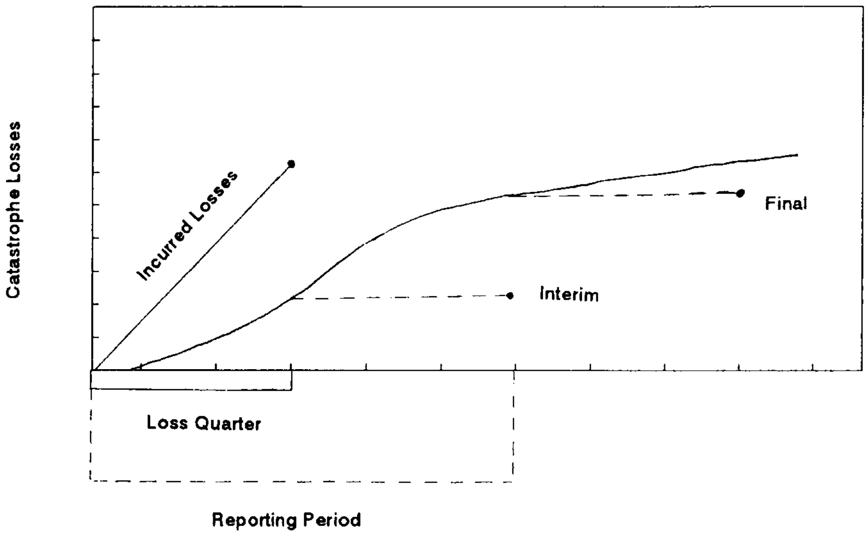
** Based on ISODATA historical simulations

From the results above, the historical simulations (which are quite limited) did not provide reliable predictive value for the first two actual settlements. However, the two actual settlements do provide further evidence of the uncertain and skewed nature of the distributions underlying the "catastrophe losses" first indicated by the statistics for the third quarter settlement prices.

PCS loss data combined with AM Best premium have also been used to illustrate historical catastrophe loss ratios (CBOT, 1993). Although of potential value in analyzing the pricing, there are several differences between the two data sets that would require careful consideration as part of any detailed analysis.

CATASTROPHIC LOSS PROCESS

Since the futures contracts are restricted to a given loss quarter, the flow of information about catastrophes within the loss quarter will likely have considerable effect on price discovery within the marketplace. An idealized graphical description of the loss process and the reporting process is shown below:



The incurred losses, although idealized, begin at zero at the beginning of the loss quarter and reach the maximum value at the end of the loss quarter. The reported losses lag the incurred losses and reach the ultimate incurred value many months after the actual settlement has taken place for a particular loss quarter. Tools for detailed analysis of the loss development process are part of the typical education of a casualty actuary in the United States. The limited time horizon and the risk of a significant catastrophe make such analysis difficult in actual applications.

Data quality issues and real time processing practicalities necessitate that the interim reported value (as of the end of the loss quarter) is only publicly announced at the end of the reporting period, and the final settlement is only publicly announced approximately three months after the end of the reporting period.

Various loss distributions can be considered for modeling the catastrophe loss distribution. Investigators have applied frequency/severity compound distributions to study United States hurricanes (Levi & Partrat, 1991) Direct modeling of the compound aggregate distribution is also a possibility.

The "catastrophic" losses included in the CBOT contract will include hurricanes, earthquakes, and other catastrophes as well as a core of non-catastrophic losses conforming to the cause of loss/line of business data definitions. Thus, any "catastrophic" loss model by component should include a basic variable of limited variability plus variables of greater variability corresponding to each significant type of natural catastrophe.

Other useful tools for analyzing the catastrophe losses are the various exposure/damage models. These models rely on distributed exposure data and simulate the effects of windstorms, earthquakes, tornados, and other natural catastrophes. The output of the model simulation exercise could then be used to construct an aggregate loss distribution for the catastrophic components of the futures contract. Coupled with the basic component described above, the total "catastrophe" aggregate loss distribution could be used to estimate futures settlement prices (and confidence intervals) and to investigate the behavior of options on the catastrophe insurance futures.

Within a given loss quarter, the level of incurred "catastrophic" losses is monotonically increasing and is dramatically affected by the occurrence or non-occurrence of major catastrophes. Accordingly models for the process need to take account of the informational value of actual catastrophes in the loss quarter relative to expected catastrophes estimated prior to the loss quarter.

EMPIRICAL MARKET OBSERVATIONS

As mentioned previously, the trading to date for futures has been very limited. Starting in July 1993, there has been some trading of options on the futures contract in the form of call option spreads synthesizing a layer of catastrophic reinsurance. Such trading activity has been concentrated in the loss quarters ending September 1993 and December 1993. From inception to settlement the future contracts that have exhibited the following price ranges:

Loss Quarter	Region	Price Range	Final Price
4th Quarter 1992	National	$2,000 - $3,000	$2,000
	Eastern	$2,175 - $4,850	$3,575
1st Quarter 1993	National	$2,025 - $4,000	$3,825
	Eastern	$1,750 - $6,775	$6,125

The daily prices for these contracts as well as volume are shown in Appendix Exhibit 2, Sheets 1 - 6.

POTENTIAL USES OF CATASTROPHE INSURANCE FUTURES AND OPTIONS ON FUTURES

Hedging with Futures

An insurer with significant exposures on the East coast is interested in protecting itself from unexpected catastrophic losses. The insurer can construct synthetic catastrophe reinsurance by purchasing September 1994 Eastern futures contracts. These contracts cover losses occurring on the East coast in the third quarter. The insurer and the industry have the following expectations:

3rd Quarter 1994	Insurer	Industry
Incurred Losses	$2 million	$2.4 billion
Earned Premiums	$5 million	$6.0 billion

The insurer assumes that its losses are perfectly correlated with the industry's. Further, it is expected that 75% of the industry's ultimate third-quarter losses will be reported to ISO DATA by December 31, 1994. With this information, the rational opening price of the September 1994 Eastern futures will be $7,500 [$25,000 x (($2.4 billion x 75%)/$6 billion)].

The insurer should purchase 267 contracts [$5 million/($25,000 x 75%)] to create a hedge against larger than expected losses. The CBOT requires a margin to be deposited; however, this margin price is substantially less than the $7,500 contract price.

The table below illustrates that the insurer establishes a hedge by "locking in" an expected loss ratio.

Loss Ratio	20%	40%	60%	80%	100%
Futures Price	$3,750	$7,500	$11,250	$15,000	$18,750
Original Futures Price	$7,500	$7,500	$7,500	$7,500	$7,500
Net Futures Gain (Loss)	($3,750)	0	$3,750	$7,500	$11,250
Number of Contracts	267	267	267	267	267
Gain (Loss) on Futures	($1,001,250)	0	$1,001,250	$2,002,500	$3,003,750
Unexpected Gain (Loss) on Insurer's Book of Business	$1,000,000	0	($1,000,000)	($2,000,000)	($3,000,000)
Net Position	($1,250)	0	$1,250	$2,500	$3,750

Hedging with Futures and Options on Futures

If an insurer wants to hedge against losses up to a specific loss ratio, it could simultaneously purchase insurance futures and options on futures. The following example uses the same assumptions in the previous example; however, we will assume that the company believes its ultimate loss ratio and the ISODATA ultimate loss ratio will not exceed 100%. The company buys 267 Eastern September futures contracts. In addition, the company sells 267 Eastern September call option contracts with a 100% loss ratio strike (X=100).

The hedge is effective up to a 100% loss ratio, and the company profits from selling the option (267 x option premium). However, if the loss ratio exceeds a 100% loss ratio, the company experiences a negative net position.

Hedging with Options on Futures

Consider again the insurer we used in the above "Hedging with Futures" example. If a company's objective is to protect itself against a loss ratio greater than 40%, it would similarly purchase 267 September 1994 Eastern call options with a strike price of 40 (i.e., 40% loss ratio). The table below illustrates the results of this hedge.

Loss Ratio	20%	40%	60%	80%	100%
Futures Price	$3,750	$7,500	$11,250	$15,000	$18,750
Gain per Options contract	0	0	$3,750	$7,500	$11,250
Number of Contracts	267	267	267	267	267
Gain on Options (before Option Premium)	0	0	$1,001,250	$2,002,500	$3,003,750
Unexpected Gain (Loss) on Insurer's Book of Business	$1,000,000	0	($1,000,000)	($2,000,000)	($3,000,000)
Net Position	$1,000,000	0	$1,250	$2,500	$3,750

Recent Market Developments

After the CBOT repositioned its insurance derivative products in July 1993, companies have been using call option spreads to hedge "layers" of insurance losses. Instead of purchasing traditional forms of reinsurance, a company could hedge its exposures above a specific amount of retained losses up to a maximum level of losses. The CBOT has referred to this strategy as constructing "synthetic reinsurance."

To create synthetic reinsurance, a company could establish the following position:

- Buy Eastern September 1994 call options with a strike of 60

  Each call has a price of 20 ($5,000)

- Sell Eastern September 1994 call options with a strike of 100

  Each call has a price of 15 ($3,750)

This position creates an initial net debit position of 5 ($1,250); therefore, the company's exposures are hedged against losses once the ISODATA loss ratio exceeds 65%. Coverage exists up to a 100% loss ratio. This assumes perfect correlation between the company's losses and the losses of the companies reporting to ISODATA. A detailed analysis should be conducted by individual companies to determine the strike prices that will hedge layers of exposure (e.g., $50 million excess of $50 million).

Speculating with Options on Futures

Individual speculators can also use call options spreads similar to the above example. They would simply take the opposite position by selling the call with a low strike and purchasing a call with a higher strike. Each point between the spread is worth \$250; therefore, the 60/100 spread would create a \$10,000 exposure.

Similarly, a reinsurer could sell layers of insurance by selling a call spread. In fact, some argue that catastrophe insurance options on futures provide effective diversification more efficiently than utilizing traditional reinsurance distribution channels (CBOT, 1993).

Arbitrage Opportunities

Given the nature of this product and the fundamental lack of market information, it is difficult to develop an accurate pricing model. Individuals and companies that can construct pricing models may be able to make arbitrage profits.

When the market matures and liquidity is sufficient in trading futures and options on futures (calls and puts), arbitrage profits will exist if the American put/call parity does not hold. The American put/call parity applies if the following relationship exists:

$$C - F0,T + (e^{-RA})K <= P <= C - (e^{-RA})F0,T + K$$

Where: C = Price of call

$F0,T$ = Spot price of futures contract

$(e^{-RA})K$ = Present value of strike price

P = Price of put

$(e^{-RA})F0,T$ = Present value of futures spot price delivered at futures maturity date (Time = A)

K = Strike price

The following table illustrates the conditions that must be met in order to avoid arbitrage opportunities:

Action	**Inflow at Time Zero**	**Inflow at Time = A** **FA,T <= K**	**Inflow at Time = A** **FA,T > K**
Buy Call	-C	0	FA,T - K
Sell Put	P	-(K - FA,T)	0
Sell Futures	0	-(FA,T - F0,T)	-(FA,T - F0,T)
Borrow (Risk Free Rate)	(e^-RA)(F0,T - K)	-F0,T + K	-F0,T + K
Column Totals	**Must equal zero**	**0**	**0**

By simultaneously selling the put, selling the futures contract and borrowing at the risk free rate, a short position in a "synthetic" call is created. Therefore, if the true call price does not equal the synthetic call price, an opportunity to make arbitrage profits exists. For example, if the call is underpriced, the position created in the table above would produce an arbitrage profit at "Time Zero." If the call is overpriced, reverse the positions (i.e., sell the call, buy the put, buy the futures contract and lend at the risk free rate).

THE FUTURE OF INSURANCE DERIVATIVES

Currently, this alternative market is providing only several million dollars of synthetic reinsurance capacity. In October 1993, the CBOT estimated this number to be approximately $6 million dollars. When this paper is presented, these insurance derivatives will have been traded for over one year. However, it is difficult to predict if the insurance industry will incorporate the contracts into their fundamental risk management strategies, as a number of barriers to success remain:

Financial Innovation - The learning curve remains steep, and many individuals and companies are reluctant to incorporate hedging activity into their business strategy.

Regulation - The National Association of Insurance Commissioners (NAIC) has not yet determined specific accounting practices and procedures for insurance derivatives. This announcement is expected in 1994. In the U.S., regulations have been implemented in Illinois and are expected to take effect in New York and California in 1994.

Liquidity - Traders face significant liquidity problems, as volume remains low in this market.

Participants - It is difficult to identify natural sellers in this market. However, reinsurers, Wall Street and institutional investors have expressed an interest in these products and may emerge as sellers.

Pricing - Given the nature of this product and the lack of information available to buyers and sellers, it is difficult to determine prices of the contract. Until an accurate pricing model is created, market trading volume will remain low.

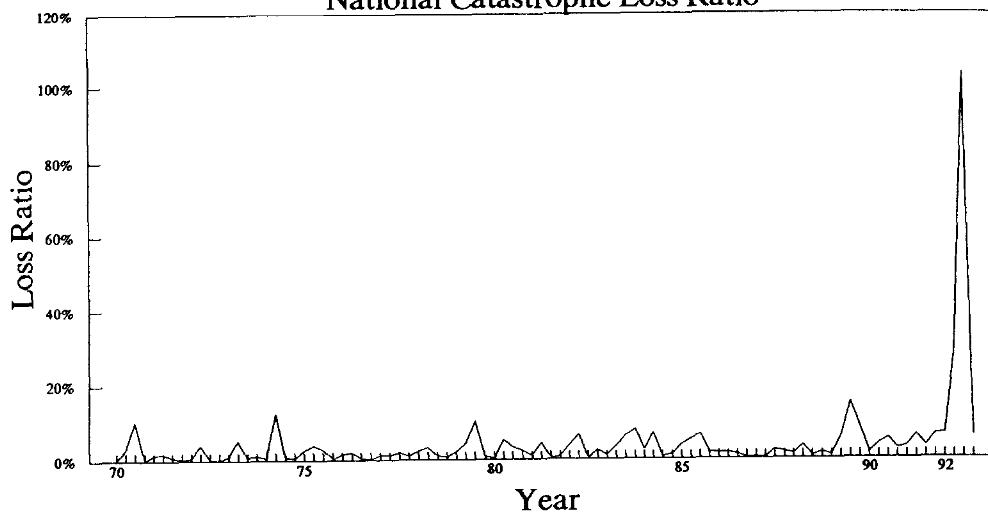
It is necessary to conduct further research to develop accurate pricing models. For example, premiums, by state and line of business, would be converted to exposure values. Subsequently, exposure values would be geographically distributed. Once this is accomplished, the model would, based on fundamental assumptions, simulate the effects of catastrophic events (hurricane, tornado, earthquake, hail, etc.). These statistics could then be used to estimate expected prices for futures and options on futures. Further, during the loss period of contracts, participants could use models to estimate the impact of catastrophes, before and after the events.

Other pricing models could be based on historical information. As the market develops, PCS and ISODATA statistics may be used to estimate expected prices. There appear to be many areas of fruitful research open to those interested in this innovative new product.

APPENDIX

Exhibit 1

National Catastrophe Loss Ratio



Source: PCS/AM Best

EXHIBIT 2
Sheet 1

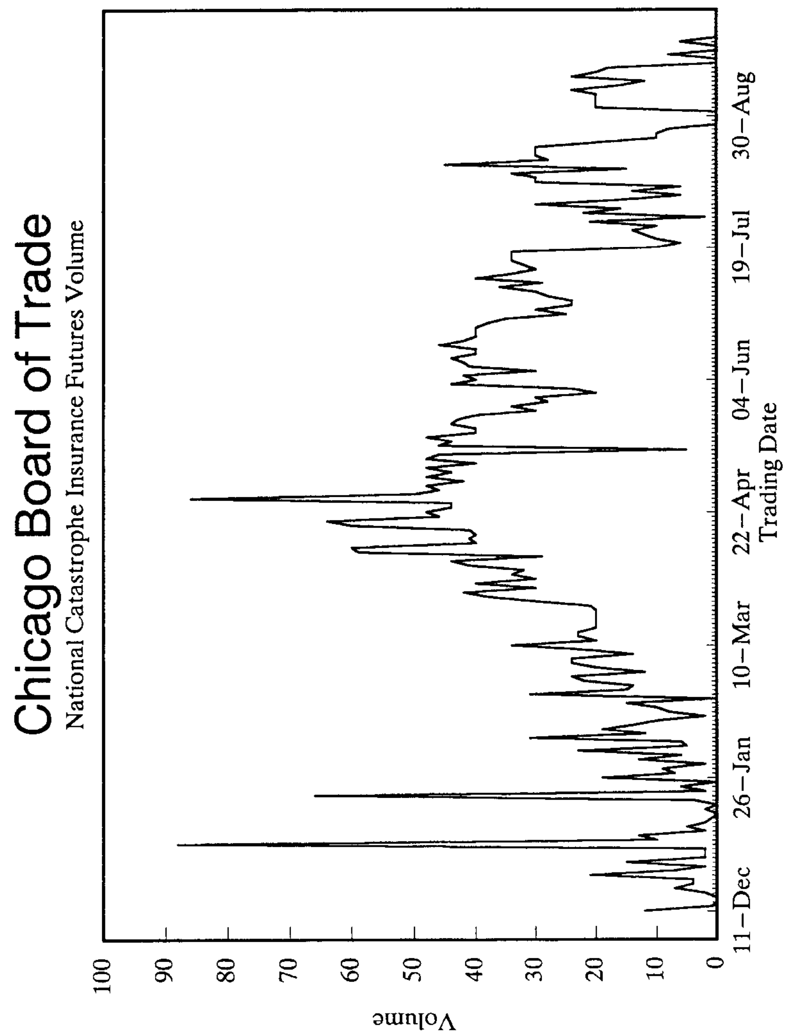


EXHIBIT 2
Sheet 2

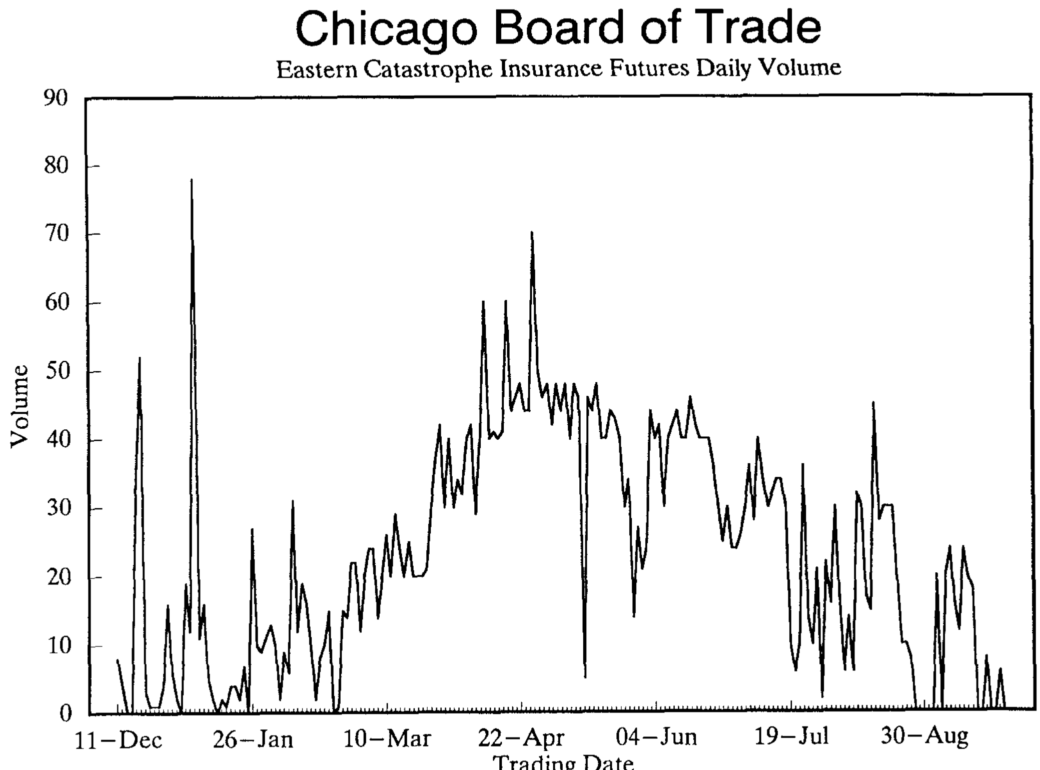


EXHIBIT 2
Sheet 3

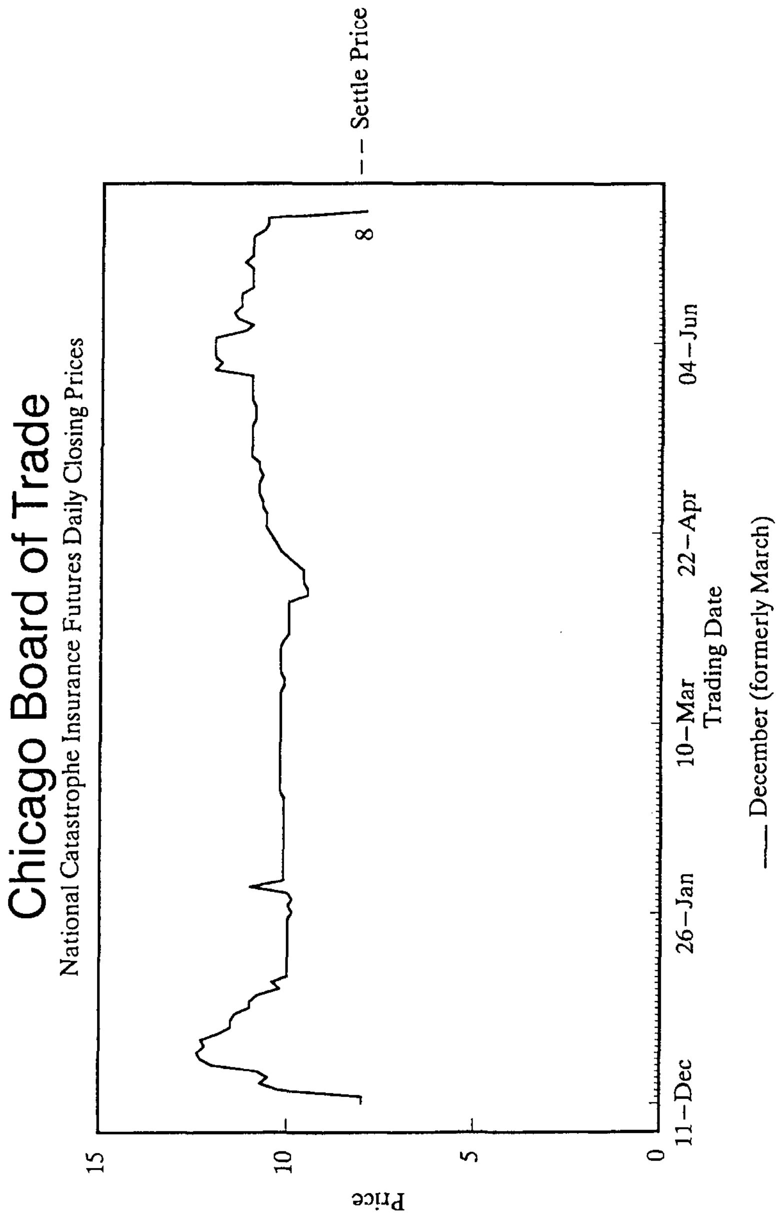


EXHIBIT 2
Sheet 4

Chicago Board of Trade

National Catastrophe Insurance Futures Daily Closing Prices

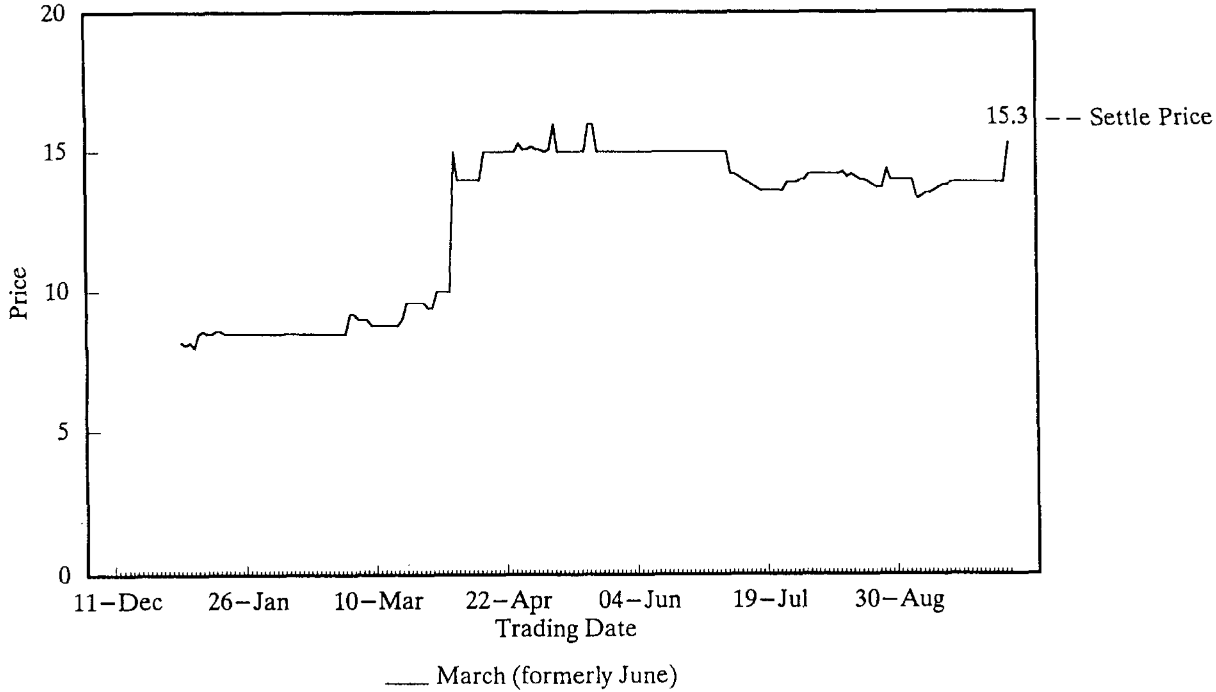


EXHIBIT 2
Sheet 5

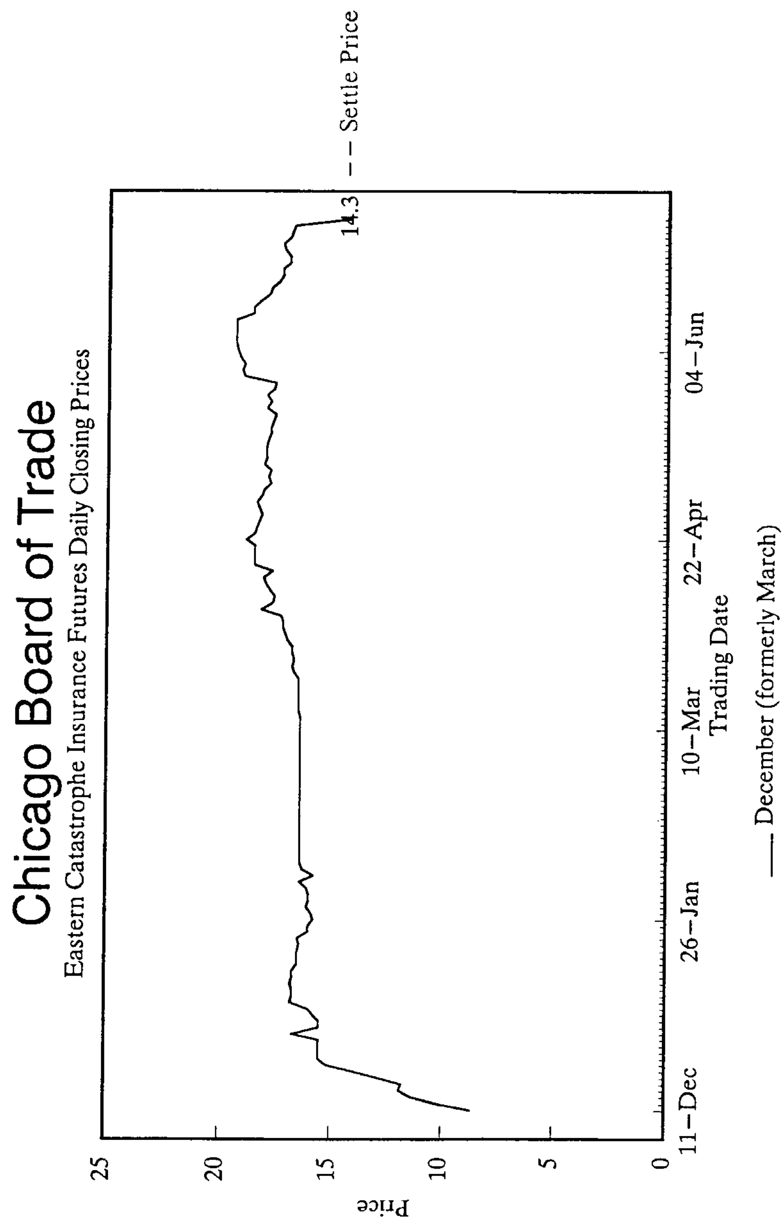
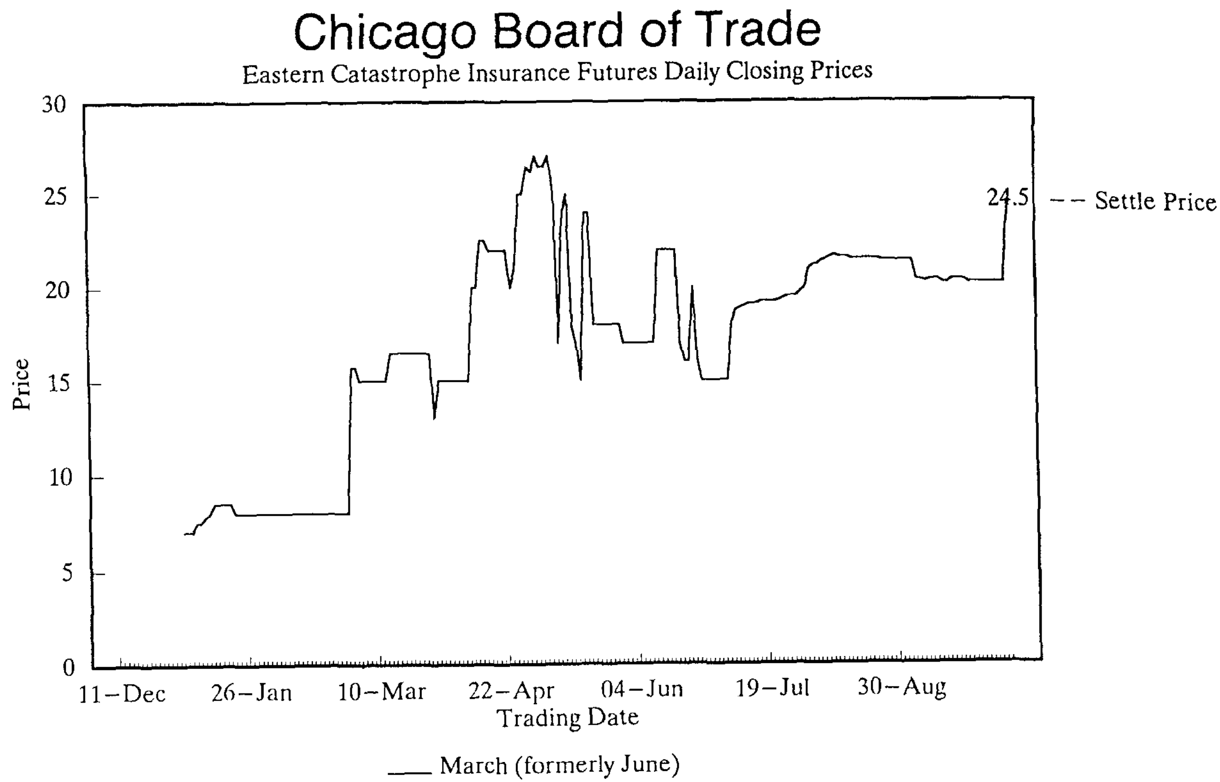


EXHIBIT 2
Sheet 6



REFERENCES

1 Chicago Board of Trade (1992) Reference Guide: Catastrophe Insurance Futures and Options. CBOT, Chicago.

2 Chicago Board of Trade (1993) Background Reports: Catastrophe Insurance Futures and Options. CBOT, Chicago.

3 Levi, C. and Partrat, C. (1991) Statistical Analysis of Natural Events in the United States. ASTIN Bulletin 21/2, 253-276.

4 Munich Reinsurance (1988) World Map of Natural Hazards. Munich Reinsurance, Munich.

5 Pickles, J.L. and Mathewson S.B. (1993) The Future of Futures. Emphasis 3, 10-13.

6 Schnieper, Rene (1993) The Insurance of Catastrophic Risks. SCOR Notes: Rewarding Risk, 11-60.

7 Swiss Reinsurance (1993) Natural Catastrophes and Major Losses in 1992. Sigma Economic Studies 2, 1-24.