THE SECURITIZATION OF CATASTROPHIC PROPERTY RISKS

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Abstract

Several reasons are suggested for the current slow emergence of a market for the securitization and derivatization of insurance risk. The principal focus of the paper is the financial engineering of securities and derivatives instruments that convey insurance risk directly to investors in the capital markets. It is shown how a special purpose reinsurer forms a bridge between conventional reinsurance and catastrophe-linked bonds. An equation is developed for the price of a pure catastrophe bond, which puts both principal and interest at risk, in terms of the probability of occurrence of the insured catastrophic event. It is then shown how to utilize a special purpose reinsurer to manufacture a principal-protected catastrophe bond as a more investor-friendly form of security that is ideal for launching the new insurance risk securitization market. Next, it is demonstrated that over-the-counter catastrophe call spread contracts are economically equivalent to excess of loss reinsurance contracts, and it is argued that such call spreads are likely to be the most efficient vehicle for transferring to investors exposure to low-probability mega-catastrophes. A stochastic simulation quantifies the value added to a portfolio of stocks and bonds from overlaying a modestly diversified portfolio of catastrophe call spreads. Finally, a cursory, qualitative treatment of various tax, accounting, and regulatory matters is presented, as well as a suggestion as to how the US federal government should become involved in the long-term financing of property catastrophe risks.

Keywords

Call spreads, catastrophic risks, excess-of-loss reinsurance, insurance derivatives, insurance risk securitization

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I. *Introduction*

It is a great honor for me to have been asked to speak to you this morning at this joint session of ASTIN and AFIR. Much has been said, and some has been written, about the convergence of insurance and financial markets, and a joint session such as today's is further testimony to the trend. At this stage in my career, I consider myself to be more a financial and investment actuary than an actuary specializing in the measurement and management of life, health, pension, property, liability, or casualty risks. Indeed, the projects on which I have been working for the past two years have provided me the opportunity to learn something about property risks and how the capital markets might be brought to bear on the financing and transfer of such risks. That is the subject which I would like to discuss with you today.

The subject of creating securities and derivative instruments that convey insurance risk directly to their holders is rather broad. It encompasses all types of insurance risk. There was a pioneering transaction in 1988, in which I had the good fortune to play a role, to securitize approximately $600 million of The Prudential of Insurance Company of America's policy loan portfolio. In 1996, some small companies providing viatical settlements of life insurance policies obtained partial funding for their operations by securitizing the viatical settlements through small private placement securities transactions. Two competing proposals to provide at least $1 billion of very high end excess of loss product liability coverage to the global pharmaceutical industry have been worked on during the past two years. Some investment banks and commercial banks have approached primary writers of motor insurance about the benefits of securitizing the relatively predictable loss distributions and paid claims emergence for both physical damage and liability.

Many conferences have been held in Europe and the US during the past two years regarding the securitization of catastrophe risk, focusing primarily on property losses due to natural catastrophes. A few small transactions were completed in 1996, the largest of which was a $100 million limit quota share-style transaction for Hannover Re transferring 50% of the risks and rewards of a designated pool of diversified property exposures to a small group of investors. This was the second securitization transaction completed by Hannover Re, the first, involving $85 million of exposure, took place in 1994 and is generally credited with being the pioneering deal in this area.

I will not attempt in this paper to review or discuss broadly the securitization of insurance risk. Rather, I will limit the presentation to the topic of catastrophic property risk, because that is where most of the marketplace's attention has been focused, and consequently where most of the effort has been spent. In the (Northern Hemisphere) spring of 1996 when I was asked to consider serving as a keynote speaker for this combined ASTIN and AFIR session, I had little doubt that by the summer of 1997, the new market of securitized insurance risk would have been well launched and that we could discuss several of the successfully completed deals as well as the future prospects for the market. Clearly, I was too optimistic. In fact, I was just plain wrong. What has happened to slow down this "inevitable" facet of the convergence of insurance and financial markets?

There are four reasons why the securitized insurance risk market is emerging so slowly.

1. Many cedents of risk, both primary writers and reinsurers, have considered securitization as an alternative to reinsurance, rather than complementary to reinsurance. The impetus for the development of the securitization market was the reinsurance capacity shortage and consequent dramatic upward shock to property catastrophe reinsurance prices following Hurricane Andrew in 1992. Both phenomena were reinforced by the occurrence of the Northridge earthquake in 1994. However, generally favorable catastrophic loss experience since those major events has restored worldwide reinsurance capacity. Reinsurance renewals for 1996, and particularly for 1997, exhibited a significant softening of prices. At the present time, most insurers and reinsurers can obtain the reinsurance they need at prices they find acceptable. The pressure to find an alternative form of risk transfer, such as securitization, is simply not very great at this point in time. Without one or more major catastrophes, the outlook is for continued excess capacity in the reinsurance markets and continued softening of prices.

2. Many of the securitization deals that were talked about or actually brought to market in 1996 were fairly judged to be complete or partial failures, or highly customized to the special needs of a particular cedent. The long-awaited and much-publicized issuance of $1 billion to $2 billion of Earthquake Risk Bonds for the start-up California Earthquake Authority ("CEA") was pre-empted by Warren Buffett of Berkshire Hathaway who provided a reinsurance contract to replace the entire capital markets securitization transaction. What could have been, and likely would have been, a defining event in the creation of the securitization market simply did not happen! The pre-empting of the CEA transaction and the difficulties experienced for other transactions that were actually brought to market have created an environment in which insurers and reinsurers who would like to utilize the capital markets to lay off catastrophe risk are understandably unwilling to be pioneers – the high development costs, both direct (legal fees in particular) and indirect (the time and efforts of senior management and other key professionals), and the risk of failure are significant hurdles.

3. The investment banking community initially underestimated the amount and intensity of education that would be required to entice investors to seriously consider the new investment opportunities in the area of securitized insurance risk. Talking about catastrophe risk as a new asset class having the desirable property of zero correlation with the risks of equity and debt instruments is simply not a good enough selling story for investors. Quite naturally and appropriately, investors want to understand the nature of the risks they assume, and thus need to become informed about the capabilities of the major catastrophe modeling firms and about matters of insurance and actuarial science. Moreover, there is a valid question about whether adequate data and analytics are available to investors for them to make decisions that are as informed as the decisions they currently make with respect to interest rate, stock market, credit, currency, and

political risks. Certainly these obstacles can be overcome, but it will take time, more time than has been spent to date.

4. There still remain unanswered questions about what form and structure of insurance-linked securities and derivatives will be viewed most favorably by investors. For example, it has been posited by some investment banks that investors will highly prefer securities or derivatives that are based on aggregate industry losses in lieu of the losses specific to a particular cedent. Industry-loss-indexed covers are felt to eliminate the moral hazard that derives from the asymmetry of information between the cedent and investors. However, what might be perceived as advantageous by investors has clearly been viewed as highly disadvantageous by many cedents. Among primary writers, cedents are virtually unanimous in their view that the level of "basis risk" posed by covers tied to industry losses is unacceptably high. Among reinsurers, the issue of such basis risk is felt to be less vexing, because reinsurers with "balanced" portfolios of risks are likely to experience losses from a given catastrophic event or set of events that are highly correlated with overall industry losses. For this reason, investment banks have been concentrating their efforts on reinsurers as likely to be in the best position to utilize securitization as a risk management tool.

Despite the slow start of insurance risk securitization, there is still considerable optimism (at least in some quarters) that the impediments described above are not permanent and that the convergence of insurance and financial markets will continue. Based on world-wide projections of probable maximum losses ("PMLs") associated with mega-catastrophes having a 100-year to 500-year expected return frequency (see Figure 1 for PMLs in the US region of the globe), it is clear that the global insurance and reinsurance industry capital that will actually be available to cover insured losses from such events is woefully inadequate. The global capital markets are vast, well over $15 trillion in terms of marketable securities. With the proper initial market conditions and the proper securities and derivative structures, there is every reason to believe that educated investors can become involved as part of a comprehensive long-term solution to dealing with global property catastrophe exposure.

The balance of this paper is organized into seven sections. Section II comments on reasons why catastrophe reinsurance pricing may be inefficient. Section III demonstrates how to engineer a high yield catastrophe bond from an excess of loss reinsurance contract. Section IV transforms the pure catastrophe bond with both principal and interest at risk into a principal-protected bond, and indicates how to deal with several important financial engineering details. Section V motivates the need for, and then describes, catastrophe call spreads, especially to permit efficient risk transfer for highly unlikely events. Section VI briefly discusses various tax, accounting, and regulatory matters. Section VII indicates a role for the US federal government to play in the financing of mega-catastrophes, and Section VIII concludes the paper.

II. Catastrophe Reinsurance Pricing

In Section V.B of this paper, I will show that reinsurance contracts are fundamentally financial derivatives, and that excess of loss reinsurance contracts are equivalent to catastrophe call spread option contracts. Thus, it should be no surprise that it has become fashionable to frame the theory for pricing of reinsurance contracts in the setting of economic equilibrium theory under uncertainty [1],[2],[3]. This paper is not about the theory for pricing catastrophe reinsurance or its associated securitization or derivatives structures. Other keynote speakers for the AFIR Colloquium, notably Professor David Cummins, who has done important work on catastrophe reinsurance pricing, will present on that topic.

Following an NBER Conference on the financing of catastrophic risk that was held in Florida in November 1996, Professor Ken Froot of Harvard University circulated a first draft of notes that summarized his conclusions from the conference [4]. In that material, Professor Froot takes as given both (i) the failure of the global catastrophe risk distribution system to spread the risks of mega-catastrophes and (ii) the high costs associated with the consequent inefficient risk sharing. He then discusses the following eight different explanations for barriers that prevent high layers of risk from being spread, many of which lead to high prices for catastrophe reinsurance:

1. Insufficiency of capital within the global reinsurance industry.
2. The market power of reinsurers.
3. Inefficiency (i.e. high costs of capital) of the corporate form for reinsurance.
4. High frictional costs of structuring and placing reinsurance.
5. Presence of moral hazard and adverse selection at the insurer level.
6. Rate regulation that constrains insurers from pricing catastrophe risk properly.
7. The existence of ex-post financing of catastrophic losses by others.
8. Behavioral factors on the part of reinsurance buyers.

Professor Froot points out that, if explanations 1, 3, and 5 above bear on the real-world problem of inadequate and inefficient spreading of catastrophe risk, then involving the capital markets via securitization or derivatization of insurance risk will ameliorate the situation. Regarding explanation 1, one need merely note the vast size of the global capital markets. As to explanation 3, catastrophe-linked instruments might provide a lower cost way for insurers and reinsurers to manage catastrophe risk than raising large amounts of equity capital. Finally, as to explanation 5, the solution entails creating sound indexes of industry losses on which securities and derivatives can be based.

In this paper, I take as given that Professor Froot's points 1, 3, and 5 enumerated above actually do explain a material portion of the overall phenomenon. My experience in the "trenches" during the past two years indicates that this is a safe assumption. Hence, I also take as given that securitization and derivatization of catastrophe risk will *ultimately* (it might take a long time, however!) develop into a meaningful market. In the remainder of the paper, we examine the early stages of the evolution of this new market.

III. Transforming Catastrophe Reinsurance into a Security

In this section, we will demonstrate how to link reinsurance pricing, and its familiar terminology, to bond pricing, with its own distinctive language. Establishing a bridge between reinsurance and securities is essential to understanding how the capital markets will view and assess insurance risks. This section is organized into three subsections. Section III.A describes a simplified fixed-indemnity reinsurance contract that pays off upon the occurrence of a defined event that occurs during the term of the contract. Section III.B then shows how that type of reinsurance contract can be thought of as a stream of contingent cash flows that is equivalent to a high yield corporate bond with zero salvage value upon default. Section III.C generalizes the fixed-indemnity reinsurance contract to a more common aggregate excess of loss agreement having a stated attachment point and a maximum indemnity limit. The material in Section III is based on my previous published work [5].

A. Utilizing a Special Purpose Reinsurer to Bridge Reinsurance and Securities

We will first consider a reinsurance contract under which an insurer pays to a reinsurer a premium P at the beginning of each period during the lifetime of the contract, which is assumed to be a total of N periods. Each period is of length T years. Thus, the total term of the reinsurance contract is NT years. The reinsurer agrees to pay the insurer a fixed *indemnity amount* L at the end of the period in which a defined event first occurs. The reinsurance contract terminates without further obligation on the part of either the insurer or the reinsurer once the payment of L is made by the reinsurer, or at the end of NT years if the defined event has not occurred by that time. The pricing of the reinsurance contract is generally quoted as a "rate on line." In this example, the rate on line is P/L. If P=$20 million and L=$100 million, the rate on line is 20%.

Examples of the defined catastrophic event, or contract "trigger," are: (i) an earthquake of magnitude at least 7.5 on the Richter Scale having an epicenter in some specified geographical zone, (ii) incurred property losses in the State of California by the property/casualty industry reaching a level of $7 billion as a result of any earthquakes occurring during any period of the contract, and (iii) the same concept as in (ii), except that the aggregate loss trigger (set at $1 billion, for example) applies to incurred losses in a particular insurer's portfolio of homeowners' policies, not to the entire industry's incurred losses.

To turn this simplified reinsurance contract into a security, we assume that an investor makes a cash contribution C in order to capitalize a special purpose reinsurance company that will underwrite the reinsurance contract with the insurer. This is illustrated in Figure 2. The investor's capital contribution C is made at the time the special purpose reinsurer is created, which is assumed to be simultaneous with the writing of the reinsurance contract. For simplicity, suppose that the yield on a U.S. Treasury bill of maturity T years (the length of each period) is a fixed rate of I per period throughout the lifetime of the reinsurance contract. Specifically, this means that a unit amount invested in a T-year U.S. Treasury bill matures for an amount 1+I. The reinsurance contract is said to be *fully collateralized* by U.S. Treasuries if L=(1+I)(P+C). This is true because the investor's capital contribution C plus the insurer's premium payment P together can be invested in a T-year Treasury bill that will mature for an amount equal to (1+I)(P+C) at the end of the T-year period, an amount exactly sufficient to make the contractual fixed-indemnity payment of L if the defined event has occurred during the period. There is zero probability that the special purpose reinsurer will have insufficient funds to make the contractual loss payment.

What happens if the defined event does not occur during a given T-year period? The investor must leave his or her initial capital contribution C invested in the special purpose reinsurer, but can withdraw from the special purpose reinsurer "excess funds" equal in amount to R=(1+I)(P+C)–C. Hence, R=L–C. The insurer will make another premium payment P at the beginning of the next T-year period. Again, an amount P+C can be invested in a T-year U.S. Treasury bill yielding I over the next T-year period. The equation L=(1+I)(P+C) remains true, and the reinsurance contract therefore remains fully collateralized.

This process of periodic insurer premium payments and periodic investor withdrawals of excess funds is repeated until the defined event occurs or until the NT-year expiration of the reinsurance contract is reached without the defined event having occurred. From the investor's viewpoint, the result of making an initial investment C is the receipt of: (i) a payment R at the end of every T-year period, so long as the defined event has not occurred since the inception of the contract, and (ii) the repayment of the initial investment C at the end of the full NT-year period, if the defined event has not occurred during the full NT-year term of the contract. At the end of any period in which the defined event first occurs, the special purpose reinsurer makes the loss payment L to the insurer, and the special purpose reinsurer is then dissolved – the insurer makes no further periodic premium payments P, the investor receives no further periodic returns R, and the investor loses his or her entire capital contribution C.

B. The Catastrophe Reinsurance Contract as a High Yield Bond

The preceding section showed that a multi-period fixed-indemnity catastrophe reinsurance contract with a defined-event trigger could be fully collateralized by creating a special purpose reinsurer to underwrite the contract. The periodic premiums from the insurer, the initial capitalization of the special purpose reinsurer, together with periodic interest earnings on those amounts, are always sufficient to pay a periodic return to the investor so long as the defined event does not occur, and to pay the insurer the fixed-indemnity amount if the defined event does occur. The insurer is party to a fully-collateralized reinsurance contract, and the investor receives a contingent stream of payments equivalent to the coupon stream and principal repayment of a "bond." Using the terminology of the preceding section, the unit bond has a maturity of NT years, makes coupon payments every T years at a rate of R/C per unit face amount of the bond, and repays the unit face amount at maturity. Bond "default" occurs when the defined event of the reinsurance contract occurs. The coupon payments and principal repayment are made only if the bond does not default. The occurrence of default causes a total loss of capital for the investor – the bond has zero salvage value upon default.

How should the fully-collateralized catastrophe reinsurance contract and its associated high yield bond be priced? Apart from special "market" factors relating to supply and demand, novelty of the bonds, etc., one would expect the pricing of the reinsurance contract and its companion bond to be driven by the probability of occurrence of the defined event, or equivalently, the probability of bond default. The higher that probability, the higher the price of the reinsurance contract (i.e. the higher the rate on line P/L), and the higher the coupon of the bond (i.e. the higher the value of R/C). We will now analyze these relationships.

Let the probability of default of the high yield bond be q per period (e.g. q=0.01 would represent a 1% chance of default each period). We assume that the N-period maturity of the bond is short enough that q can be considered to be a constant, independent of period. This assumption can easily be relaxed, but that only serves to complicate the mathematical analysis a little, without materially changing any of the conclusions drawn. We are interested in determining the per-period coupon rate c for the high yield catastrophe bond so that its fair price is equal to its unit par value (face amount). We assume that the investor sells the bond at the end of the period in which default occurs and recovers a fraction f of the sum of the coupon then due and the unit par value of the bond. In the reinsurance example presented in the previous section, f=0 because there is total loss on the occurrence of bond default. However, it is generally true that f>0 for conventional high yield corporate bonds.

Table 1 lists all the possible default and no-default payments occurring during the N-period maximum lifetime of the high yield bond, together with their associated probabilities of occurrence:

Table 1
List of All Possible Payments from a High Yield Bond

Period	No-Default Payment	Probability	Default Payment	Probability
1	c	$1-q$	$f(1+c)$	q
2	c	$(1-q)^2$	$f(1+c)$	$q(1-q)$
3	c	$(1-q)^3$	$f(1+c)$	$q(1-q)^2$
.	.	.	.	.
.	.	.	.	.
n	c	$(1-q)^n$	$f(1+c)$	$q(1-q)^{n-1}$
.	.	.	.	.
.	.	.	.	.
N	1+c	$(1-q)^N$	$f(1+c)$	$q(1-q)^{N-1}$

Let r_n denote the per-period yield of an n-period default-free U.S. Treasury "bill" – that is, an actual or hypothetical U.S. Treasury instrument that matures for a unit amount in exactly n periods (nT years) and has a price of $B_n=1/(1+r_n)^n$ today. This Treasury "bill" has no coupons, only a maturity payment. Its price B_n should be thought of as the present value today of a unit amount to be received n periods from today.

The theoretical "fair" value of the default-dependent stream of payments from the high yield bond is equal to the expected present value of the streams of payments shown in the table above, using the default-free B_n factors to perform the discounting calculations.

$$\text{Fair Price of Bond} = c \sum_{n=1}^{N} (1-q)^n B_n + (1-q)^N B_N + q\, f\,(1+c) \sum_{n=1}^{N} (1-q)^{n-1} B_n$$

The first term on the right-hand-side of the equation is the expected present value of the stream of coupons; the second term is the expected present value of the principal repayment at maturity; and the third term is the expected present value of the salvage recovered on default of the bond. Given the per-period probability of default q, one can solve the bond-pricing equation for the per-period coupon rate c that renders the fair price of the bond equal to its unit par value.

Both actuarial analysis of historical data and scientific/engineering modeling of the relevant natural disaster can be used to suggest a "theoretical" value for the per-period probability that the defined event will occur and thus trigger the indemnity payment under the reinsurance contract. The details of this type of analysis and modeling are specific to the type of event and natural disaster, and are beyond the scope of this paper. This type of analysis and modeling is the business of several firms that provide catastrophe modeling services – RMS, AIR, EQE, and Tillinghast. Before the securitization market can develop broadly, a critical mass of investors will have to delve into the details of these firms' catastrophe models because these models are the only source of analytics to underpin investors' decisions to purchase catastrophe-linked securities.

Several credit rating agencies based in the US have indicated that they will utilize the models of the principal major catastrophe modeling firms to assess the relevant probabilities of "default" for pure catastrophe bonds and thus calibrate the equivalent "credit" ratings from which investors are expected to establish fair market prices for the bonds. As pure catastrophe bond deals begin to come to market, it will be interesting to see whether investors validate or deviate from this pricing methodology. Stated differently, assuming investors utilize this methodology for pricing pure catastrophe bonds, one can deduce the market-implied probabilities of default and compare them to the associated probabilities computed by the firms that provide catastrophe modeling services.

Assuming for sake of example that the term structure of interest rates for government securities is flat at a 6% bond-equivalent yield, we can use the bond pricing equation to solve for the per-period coupon rate c applying to a 4-year pure catastrophe bond priced at par, as a function of the per-period market-implied "default" probability q. Utilizing formulas from Section III.A, we can derive the pricing relationship $P/L=(c-I)/[(1+c)(1+I)]$ for the per-period rate-on-line cost of the reinsurance cover, given the per-period coupon rate c for the pure catastrophe bond and the per-period government bond yield I. This relationship and the bond pricing equation were used to compute the results displayed in Table 2.

Table 2
4-Year Catastrophe Reinsurance Contract and Associated Pure Catastrophe Bond

Market-Implied Annual "Default" Probability	1%	2%	3%	4%	5%
Bond Coupon Rate	7.04%	8.09%	9.16%	10.25%	11.35%
Spread to Government Curve	1.04%	2.09%	3.16%	4.25%	5.35%
Reinsurance Rate on Line	1.03%	2.07%	3.11%	4.16%	5.22%

C. *Aggregate Excess of Loss Reinsurance Contracts*

While reinsurance contracts with fixed-indemnity payments triggered by the occurrence of a defined event do exist, they are not as useful to primary writers as are aggregate excess of loss contracts with maximum indemnity limits. For example, the initially proposed structure for the California Earthquake Authority identified two loss layers, one from $4 billion to $6 billion, and the other from $7 billion to $8.5 billion, for which aggregate excess of loss contracts and their associated pure catastrophe bonds are the natural vehicles for managing the risk exposure. It is not difficult to modify the analysis described in Sections III.A and III.B to accommodate the additional features of aggregate excess of loss contracts. We describe those modifications here in a qualitative manner, but view the exposition of the mathematical details as beyond the scope of this paper.

Until cumulative losses during the lifetime of an aggregate excess of loss contract reach the attachment point (i.e. the lower level of the loss layer), the investor receives the coupon payments on his or her holding of pure catastrophe bonds. When cumulative losses from all covered events reach the attachment point, the special purpose reinsurer incurs an obligation to make loss payments to the insurer under the terms of the reinsurance contract. This causes a full "default" on a portion of the investor's bond holdings. As incurred losses then mount within the loss layer, more and more of the investor's high yield bonds default. If cumulative losses reach the upper level of the loss layer (i.e. the maximum indemnity limit is attained), all of the remaining bonds default. The outstanding indemnity limit is proportionately reduced as bonds default, as are future periodic premiums payable by the insurer to the special purpose reinsurer. This scaling down of future premium payments is unusual for a traditional reinsurance contract, but it is logical for the securitized form of risk transfer.

IV. From Pure Catastrophe Bonds to Principal-Protected Catastrophe Bonds

In the preceding section we showed how an excess of loss contract could be transformed into a high yield bond in which all interest payments and the ultimate principal repayment are at risk. Investment banks which have attempted to market pure catastrophe bonds have encountered considerable resistance from investors. When bringing a new type of risk into their portfolios, investors generally prefer to limit their exposure initially and then increase it over time as they become more comfortable with the new type of risk. The evolution of investor acceptance of the sovereign credit risk of emerging market countries has followed this pattern. For example, most investors were initially comfortable with Mexican debt only in the form of so-called "Brady" bonds. The defining characteristic of a Brady bond is that the principal repayment is fully secured by a US Treasury zero-coupon bond that matches the maturity of the debt. Thus, investors' exposure to sovereign credit risk is limited to loss of interest because the principal repayment is fully secured. Once investors became comfortable with the Mexican credit story, they began to buy Mexican government bonds with both principal and interest fully exposed to risk of loss.

The Brady bond idea extends naturally to the situation of catastrophe risk. The basic approach is to segregate the funds in the special purpose reinsurer into two separate and distinct accounts: one to handle the principal repayment at maturity ("Principal Account"), and the other to handle the periodic coupon payments ("Interest Account"). The net proceeds (i.e. after underwriting fees and other upfront expenses) of the issuance of principal-protected catastrophe bonds are allocated between the two accounts on the date of issue as follows:

Principal Account:	The amount of funds necessary to purchase zero-coupon government bonds having a maturity and aggregate par amount that exactly match the maturity and aggregate par amount of the principal-protected catastrophe bonds issued.
Interest Account:	The balance of the net issuance proceeds.

For example, suppose the bond-equivalent yield of the 10-year US Treasury STRIP (i.e. zero-coupon bond) is 6%, and that the face amount of principal-protected catastrophe bonds issued is $100 million. In this case, $55,367,575.42 would be placed in the Principal Account and used to buy a $100 million face amount 10-year US Treasury STRIP. The balance of the proceeds, $44,632,424.58, assuming no underwriting fees or other upfront expenses, would be invested in the Interest Account. This amount in the Interest Account, together with the periodic reinsurance premiums received by the special purpose reinsurer, would be used to pay coupons on the principal-protected catastrophe bonds. The initial amount of indemnity limit available to the insurer under this structure is equal to the initial amount invested in the

Interest Account plus the initial reinsurance premium paid. Thus, in this situation, because the principal payment is secured, the special purpose reinsurer needs to issue a face amount of bonds somewhat in excess of double the amount of indemnity limit provided to the cedent. This is a necessary awkwardness caused by the Brady bond structure – the shorter the maturity, the greater is the ratio of the face amount of bonds issued by the special purpose reinsurer to the indemnity limit provided under the reinsurance cover.

There are several thorny financial engineering issues that must be addressed before the design of the principal-protected bond can be considered complete:

1. If the period of insurance coverage matches the lifetime of the bonds, i.e. 10 years in the example above, if one attempts to maintain a minimum indemnity limit throughout this period of coverage, and if the cover is not triggered (or if less than the maximum limit is paid out), there will be residual funds in the Interest Account on the maturity date of the bonds. Such residual funds could be paid to investors as a terminal "bonus" interest payment. However, this structure doesn't utilize funds as efficiently as possible. A solution to this inefficiency is to restrict the period of coverage to less than the full lifetime of the bonds, and to invest the funds held in the Interest Account appropriately. This solution will be described in further detail later in this section.

2. Because most investors prefer to purchase fixed-coupon bonds in lieu of variable-coupon or floating-rate bonds, it is often desirable to structure a catastrophe bond to have a level coupon throughout its life that will be paid to investors so long as the reinsurance cover does not attach. One can create a level stream of coupons for a catastrophe bond by investing the funds held in the Interest Account in an appropriate series of US Treasury zero-coupon bonds that mature on the catastrophe bond's various coupon dates. However, because the amount of indemnity limit that is available at any point in time under the reinsurance contract written by the special purpose reinsurer derives from the market value of the securities then held in the Interest Account, it is evident that the amount of indemnity limit will depend on the level and shape of the yield curve. This observation applies equally in the case of pure catastrophe bonds, but was simply ignored in the preceding section. One way to address this problem of a non-constant indemnity limit is to arrange an over-the-counter derivative contract under which the special purpose reinsurer will receive payments that are linked to both interest rate movements and incurred catastrophe losses in such manner that the interest rate dependence of the indemnity limit is fully hedged.

3. Care must be taken when dealing with items 1 and 2 immediately above in order to avoid creating a dramatically varying pattern of indemnity limit over time. Without sufficient attention to the details of engineering the catastrophe bond that is issued by the special purpose reinsurer, a highly variable pattern of indemnity limit can occur even when interest rates are not very volatile. Such a result is undesirable, especially when compared with a standard reinsurance contract which generally provides a constant limit of indemnity over the entire period of coverage, independent of the movement of interest rates. As for item 1, this matter will be discussed in further detail later in this section.

4. Although the claims development for property catastrophe covers is short tailed compared with many liability and casualty covers, one must nevertheless provide for at least one year, and preferably two to three years, of paid claims emergence. This important "detail" was ignored in the preceding section. Whether for pure catastrophe bonds or for principal-protected catastrophe bonds, the structure must tolerate an appropriate period for the emergence of paid claims. As will be described below, this can be dealt with naturally in the case of a principal-protected catastrophe bond if one solves the problem described in item 1 above by establishing a risk exposure period that is shorter than the ultimate maturity of the bond.

The four matters described above were dealt with satisfactorily in designing the principal-protected Earthquake Risk Bonds for the California Earthquake Authority [6]. A holder of an Earthquake Risk Bond would have been exposed to the loss of future interest payments in the event of a sufficiently large earthquake or earthquakes that occurred during the first four years of the life of the bond. This four-year period was termed the "risk period" of the bond. Earthquakes occurring after the four-year risk period were simply defined not to be covered events. Since the ultimate maturity of the bonds was intended to be 10 years, this left a tail of at least six years to handle claims development. In practice, one would likely truncate the development period at three years following the date of the last covered event occurring during the four-year risk period.

The choice of four years as the length of the risk period was determined as much by a financial engineering constraint as by any requirements of marketing or pricing. It is an interesting exercise in bond mathematics (solution not presented in this paper) to show that given (i) a *flat* yield curve that does not change over time, (ii) the maturity of the catastrophe bonds, and (iii) the length of risk period, there is a unique solution for the rate on line (i.e. the amount of reinsurance premium) that maintains the indemnity limit at a constant level, immediately after each coupon payment, throughout the risk period. If the yield curve is not flat, this precise result does not hold, but considerable stability in the amount of indemnity limit is generally achievable in the case that the yield curve evolves deterministically along the forward rate path implicit in the initial term structure. In the case of the 10-year maturity Earthquake Risk Bonds for the California Earthquake Authority in the interest rate and reinsurance pricing environment present during 1996, setting the reinsurance premium at the appropriate "market level" was consistent with choosing the length of the risk period to be between three and four years.

As a "hint" to those interested in working out the relationship among the rate on line, the maturity of the catastrophe bond, and the length of the risk period, one should begin by investing the initial proceeds of the Interest Account in a "stair-step" series of zero-coupon bonds, the maturities of which match the coupon dates of the principal-protected catastrophe bond. The stream of reinsurance premiums is utilized to "fill in" the stair step during the risk period, thereby creating a level coupon stream during the life of the catastrophe bond (assuming that the reinsurance cover does not attach). This cash flow engineering of the level stream of coupons for the principal-protected catastrophe bond is depicted in Figure 3. Unlike the analysis in Section III where it was assumed that periodic reinsurance premiums were paid in advance, note that Figure 3 is based on reinsurance premiums that are paid semi-annually in arrears so that they exactly match the timing of coupon payments to investors.

The mechanics of handling changes over time in the actuary's estimates of incurred losses that affect whether the reinsurance cover attaches and how much of the indemnity limit is consumed involve the creation of a third account, usefully named the "Claims Account." It serves as a "suspense" account once incurred losses have been established at a level that causes the reinsurance cover to attach, but before amounts actually need to be disbursed to settle claims. Assets are shifted from the Interest Account to the Claims Account on the basis of the actuary's estimates and re-estimates of incurred losses, but assets in the Claims Account are not actually liquidated until needed to settle claims. Money is not disbursed from the Claims Account and from the special purpose reinsurer until claims are actually settled. Ultimately, it is the total amount of claims paid that determines the total amount of interest payments made to investors, but if the early estimates of incurred losses later prove to have been too high, investors will have experienced delays in the periodic receipt of their partial interest payments.

V. Catastrophe Call Spreads

A. Derivatives versus Securities

It might seem that the principal-protected catastrophe bonds described in the previous section would be the ideal vehicle for securitizing excess of loss catastrophe covers, particularly from the viewpoint of investors who can gain comfort from knowing that their capital investment is fully protected. While this is true, it seems that the real demand for reinsurance capacity in excess of what the global reinsurance industry can or is willing to provide is for the extreme tail of an insurer's aggregate annual loss distribution. It is the mega-catastrophe having an annual probability of occurrence of less than 2% or less than 1% that requires funding directly from the capital markets. The level of reinsurance premium that insurers are willing to pay to transfer these very high layers of risk is at most three to five times the "pure premium" as measured by the various catastrophe loss models in existence. If the premium that flows into a special purpose reinsurer is not very large in relation to the indemnity limit provided, the yield spread achievable on a principal-protected catastrophe bond will likely be insufficient to attract much investor interest or appetite, especially when the market for insurance risk securitization is first developing.

It is clear from the analysis in Section III that the source of an investor's return in excess of the risk-free return (i.e. government bonds) from investing in catastrophe bonds is the reinsurance premium that is paid to the special purpose insurer. In the case of pure catastrophe bonds, this is evident from Table 2 in Section III which exhibits a near equivalence of the yield spread over the government curve and the annual rate on line for the reinsurance cover. In the case of principal-protected catastrophe bonds, however, a very substantial portion of the investor's capital is placed into the Principal Account and invested in zero-coupon government bonds. That substantially "dilutes" the yield to maturity of the principal-protected catastrophe bond. In order to securitize very high layer excess of loss reinsurance, one will either have to utilize pure catastrophe bonds or invent some other vehicle.

There are several impediments to utilizing pure catastrophe bonds for securitizing very high layer excess of loss reinsurance. First, and most important, the universe of investors who will buy bonds with maturities of one year or less is quite limited. Fixed-income investors prefer to buy bonds with maturities of at least three years, and generally five years or longer. For a pure catastrophe bond, there is no reason to distinguish (and no value gained from distinguishing) the "risk period" from the life of the bond. Thus, a five-year pure catastrophe bond naturally carries a five-year risk period. Over a five-year period, the catastrophe risk profile of the cedent's portfolio of insurance policies can change quite dramatically, a point that needs to be dealt with satisfactorily when structuring the catastrophe bond.

In the US, many primary writers of homeowners' coverage have substantially grown their exposures to losses from hurricanes and earthquakes over short periods of time by being willing to disproportionately insure coastline and faultline homes vis-à-vis homes located in less catastrophe-prone areas. Constraints must be imposed on the terms of risk transfer in the case of a multi-year catastrophe bond in order to stabilize over time the risk profile that is presented to investors. Otherwise, investors simply will not buy the bonds at any price, or will demand a conservatively high coupon. Unfortunately, such constraints have proved unpalatable to cedents, especially when compared with the more flexible approach offered by traditional reinsurance that is renewable annually. The annual renewal process is a better mechanism to permit the assumer of catastrophe risk to adjust the terms and price of the cover for material changes in the cedent's portfolio of risks.

Investors have expressed another concern with respect to catastrophe-linked securities issued by special purpose reinsurers. To satisfy the credit concerns of the cedent regarding the collectibility of the reinsurance recoverable, the assets of the special purpose reinsurer must be invested in very high quality bonds, generally government securities. Moreover, in order to be able to make the scheduled interest and principal payments to bondholders during the period that the reinsurance cover has not yet attached, the assets of the special purpose reinsurer must be cash flow matched to the cash flows of the catastrophe bonds that the special purpose reinsurer has issued. Thus, as to both credit and cash flow matching, the investment strategy of the special purpose reinsurer is highly constrained. Investors prefer more flexible investment strategies.

All of these considerations lead one to question whether there is a more efficient manner in which insurance risk can be transferred directly to investors, efficient from both the cedent's and the investor's viewpoints. The answer is yes, and the form is derivatives. The difficulty in traveling the derivatives route is that there is a much larger universe of investors who buy securities than who enter into derivatives transactions. For the past several years, the world-wide press has carried many accounts of derivatives abuses. These isolated, but not rare, abuses and the heavy publicity about them does not help the process of selling derivatives strategies to investors. However, I will present a specific catastrophe derivative idea because I believe that is a route along which the market will ultimately develop depth and breadth.

B. Derivative Characteristics of a Reinsurance Contract

The history of product innovation and product development in the financial markets has demonstrated repeatedly that successful derivatives products arise *after* the underlying cash markets have become well developed. It would have been nonsensical to develop stock options without stocks, interest rate futures without government bonds, or oil, sugar, or gold futures without oil, sugar, or gold. However, an excess of loss reinsurance contract is fundamentally an option. At inception of the contract, the cedent pays the reinsurer a premium P, in exchange for which the reinsurer must pay losses in excess of a specified attachment point X. This is economically equivalent to the purchase of a catastrophe call option by the cedent from the reinsurer. The option premium is P and the strike price of the option is X.

Most non-proportional reinsurance contracts carry only limited liability, i.e. they apply to a "layer" of risk. Such an arrangement is the superposition of two contracts: under the first contract, the cedent pays the reinsurer a premium P_L to cover all losses in excess of X_L incurred during a stated period, while, under the second contract, the reinsurer pays the cedent a premium P_U to cover all losses in excess of X_U incurred during the same stated period, where $X_U > X_L$. The reinsurance price for the catastrophe cover, expressed as a rate on line, is $(P_L - P_U)/(X_U - X_L)$. In this case, the cedent has purchased a "call spread" from the reinsurer. Specifically, the cedent has purchased for premium P_L a catastrophe call option with strike price X_L, and has written for premium P_U a catastrophe call option with strike price X_U.

Thus, it would seem obvious that the most "natural" way to structure a risk transfer arrangement directly between a cedent and an investor is via a catastrophe call spread contract. This is what the CBOT concluded in the early 1990s, and that is how the recently-revised CBOT contracts covering the entire US and various geographic zones within the US have been constructed [7]. In the case of the CBOT contracts, the strike prices are specific dollar levels of insurance industry losses arising from catastrophes as defined and measured by Property Claim Services. Of course, it is possible to create call spread contracts that have strike prices or expiration dates that differ from the standardized CBOT contracts, and to base the payoff on an insurer's actual losses in lieu of industry-wide losses. All such "customized" arrangements are referred to as over-the-counter contracts.

C. *Over-the-Counter Call Spreads*

In this section, I will describe a theoretical mechanism for establishing an over-the-counter catastrophe call spread between two parties, the cedent of risk and the assumer of the risk. In the real world, there are many obstacles to creating the mechanism in exactly the form described. In the US, for example, there are challenging constraints imposed by the insurance and securities regulators, and by the tax and accounting authorities. Far too often, these constraints are not mere nuisances, but actually drive the form in which a good product concept can be implemented. Because the regulatory, tax, and accounting treatment of a given arrangement differs from country to country, I have adopted the convenient position of exposing the general concepts without worrying about the real-world details. However, my own experiences confirm that there is considerable "devil" in the details.

During the past several years, many people have stated that the greater than $15 trillion capital markets with their greater than $100 billion daily fluctuations in market value are clearly sufficient in size to deal with the global property catastrophe problem. Of course, this is an overly simplistic argument. It ignores the difficult task of attempting to convince investors that catastrophe risk is worth putting into their asset portfolios. Also, it ignores that even under the most optimistic of situations, investors would not exceed the "optimal" asset allocation of much less than 100% of their portfolios to this risk category. Finally, it misses the point that the assets supporting the assumption of catastrophe risk must be liquid, and thus the relevant capital markets universe should be restricted to readily marketable securities. However, despite all these objections, it is constructive to find some mechanism for transferring catastrophe risk to investors that taps the vast potential of the world-wide supply of marketable securities.

The key to creating a successful over-the-counter catastrophe call spread market is to develop a standardized mechanism under which the cedent's exposure to the credit risk of the writer of the call spread contract is mitigated or eliminated by having the writer post collateral in the form of marketable securities. A special collateral account, perhaps in the form of a trust, or perhaps more simply in the form of an escrow account, is established. The writer of the call spread option deposits marketable securities into the account, and maintains a specified market value of securities in the account via adding, withdrawing, or substituting collateral daily or weekly, as appropriate. If the specified market value of the account is maintained at a level equal to the full indemnity limit provided by the call spread contract, the writer's contingent obligation is said to be fully collateralized. Many cedents are likely to require full collateralization by the call spread writer.

The writer of the call spread option maintains complete investment flexibility in his or her asset portfolio. Unlike the situation in which an investor purchases a pure or principal-protected catastrophe bond, the option writer retains full control over how the collateral will be invested. In fact, the option writer need not disturb his or her strategic or tactical asset allocation strategies at all. The catastrophe call spread writing program is merely "overlaid" on the option writer's existing asset portfolio.

Over-the-counter catastrophe call spreads also deal very well with a cedent's changing risk exposure over a multi-year period. Investors who write options against their asset holdings generally utilize options having fairly short periods until their expiration. Thus, a one-year catastrophe call spread is a "natural" contract term for both the investor who writes the call spread and for the cedent who customarily purchases reinsurance annually. Each call spread can be structured to apply to an accident year for a specific line of business. The strike prices for the call spread can be defined either as absolute (dollar) amounts, or better yet, as loss ratios. Either way, the entire program is updated annually as the current year's options near expiration and the next year's options come into existence. Of course, the newly-created options will be structured to reflect the current risk profile of the cedent's subject business.

D. Portfolio Benefits from Catastrophe-Linked Instruments

The principles of modern portfolio theory suggest that including a new asset class that has an expected holding-period return in excess of the risk-free return is beneficial to the overall portfolio if the returns from the new asset class are less than perfectly correlated with the returns from the existing portfolio into which the new asset class is introduced. How does this work in the case of catastrophe-linked instruments viewed as a new asset class?

It is intuitive that over sufficiently long holding periods, the returns from both equities and bonds should be uncorrelated with the incidence and amount of natural catastrophe losses, except perhaps for cataclysmic events that devastate entire regions of the globe and hence companies based in those regions and the economies for those regions [8]. For example, there is no evidence that the January 17, 1995 Kobe earthquake in Japan, which created property and business interruption losses well in excess of $100 billion, had more than a short-lived effect on either the Japanese equity or bond markets. The Nikkei 225 Index of Japanese stocks suffered a big drop four business days after the quake, about 7.6% from its level on the day of the quake, but largely recovered during the five days following the drop. In the bond markets, the JGB 10-year bond sold off seven basis points in yield on the day of the quake, but regained five basis points of that increase in yield within nine days. Apart from this brief period of nine days, one can discern nothing from the graphs of Japanese stock or bond market performance that would give any indication at all that a highly destructive earthquake had occurred in an important economic region of Japan.

To investigate the effect on the distribution of returns from adding property catastrophe exposure to a portfolio of stocks (equities) and bonds, I performed a simulation experiment covering a 10-year holding period. The base case situation is a portfolio for which the market value is allocated 60% to stocks and 40% to bonds at the beginning of each year during the 10-year holding period. The annual rebalancing is assumed to occur without any transaction costs. Overlaid on the base case is an over-the-counter catastrophe call option overwriting program under which an aggregate catastrophe limit equal to 10% of the market value of the underlying portfolio of stocks and bonds is written at the beginning of each year.

In order to build some diversification into the catastrophe risk play, it is assumed that four independent catastrophe risks equally comprise the aggregate limit. Suppose the market value of the portfolio is $1 billion at the beginning of a particular year, with $600 million invested in stocks and $400 million in bonds. Catastrophe call options are written against $100 million in market value, with $25 million of the total $100 million limit allocated to each of four independent catastrophe risks – for example, $25 million exposed to European floods and windstorms, $25 million to Japanese earthquakes and typhoons, $25 million to earthquakes in the US, and $25 million to hurricanes in the US. To simplify the modeling, it is assumed that the full limit for each catastrophe risk is payable at the end of the year if the cover pertaining to that risk has attached at any time during the year. Each risk is assumed to attach with a 1.5% probability annually, for which the portfolio is paid an option premium (equivalent to a reinsurance premium) at the beginning of the year equal to of 6% of the limit, i.e. a rate on line of 6% for each of the four separate covers.

Wealth accretion or diminution from investing in either stocks or bonds is assumed to follow a lognormal process. The mean annual returns for stocks and bonds are assumed to be 11% and 8%, respectively, and the probability distributions of annual stock and bond returns are assumed to have standard deviations of 15% and 10%, respectively. The coefficient of linear correlation between annual stock and bond returns is assumed to be 0.4. Annual returns for the base portfolio of 60% stocks and 40% bonds were simulated over 10,000 "paths" utilizing separate stratified samples for annual stock returns and annual bond returns. The catastrophe option overlay was simulated via 10,000 draws from a stratified sample of the binomial distribution for 0,1,2,3, or 4 attachments each year. The binomial distribution for the number of catastrophe attachments in a given year is assumed to be independent of the distribution of stock and bond returns for that year. It is assumed that there is no year-to-year correlation among any of the stochastic variables in the simulation, although incorporating stock and bond return autocorrelations would not alter the key results of the simulation that relate to the effects of the catastrophe option overlay program.

The mean and standard deviation of the probability distribution of annualized returns over the 10-year holding period for the base portfolio of 60% stocks and 40% bonds based on the 10,000 path simulation described above were 9.290% and 3.533%, respectively. The corresponding mean and standard deviation for the portfolio with the 10% catastrophe option overwrite were 9.793% and 3.557%, respectively. Figure 4 compares the cumulative distribution functions for the base portfolio and the catastrophe option overwritten portfolio.

What is most interesting about the results of the simulation is that the addition of catastrophe exposure actually increases the variance of portfolio returns very slightly. One's initial guess, based on intuitions gained from modern portfolio theory, might be that the inclusion of uncorrelated catastrophe risk should actually reduce the variance of portfolio returns. That intuition is valid, but only if some of the wealth of the base portfolio is actually reallocated to and actually "invested in" the catastrophe class – for example, if in a $1 billion portfolio consisting of $600 million stocks and $400 million bonds, one took $60 million from stocks and $40 million from bonds, and actually invested the $100 million so obtained in a catastrophe-linked instrument that contained no equity or debt components. Then one would notice a reduction in variance of the portfolio returns. But that is not how catastrophe covers work! Catastrophe covers function as options that are written against a base portfolio of cash market instruments such as stocks and bonds. This is true even for catastrophe-linked securities such as pure or principal-protected catastrophe bonds which are actually "composite" instruments consisting of catastrophe options embedded in straight bonds.

Under a catastrophe cover, or equivalently a catastrophe call option writing program, the assumer of the catastrophe risk does not make a cash investment. Instead, the writer of the cover (or option) receives a premium at the beginning of the coverage period, and makes a contingent payment at the end of the period. Because the premium is received with certainty, its receipt merely shifts upwards the mean of the period's distribution of base portfolio returns. The payment of the contingent claim at the end of the period causes the variance of the distribution of portfolio returns to increase somewhat over the base case. In our example, the 10% catastrophe option overwrite program increased the mean annualized portfolio return over the 10-year holding period by 50.3 basis points, while leaving the variance of portfolio returns essentially unchanged over the 10-year holding period. This favorable result is directly traceable to a sufficiently long holding period during which the option premiums received substantially exceed the expected losses paid.

Of course, it is not necessary to perform a stochastic simulation in order to determine the exact mean incremental portfolio return for a *one-year holding period* that derives from a 10% catastrophe option overwrite program. The incremental return can be calculated straightforwardly as follows: Accumulate the 6% rate on line premium for the catastrophe reinsurance cover at the 9.8% expected annual return for the base portfolio (computed as 60% of 11% plus 40% of 8%) from the beginning of the year when the premium is paid until the end of the year. From this result, subtract the expected annual losses of 1.5% assumed to be paid at the end of the year. This gives an incremental return of 5.088% for each $1 of the base portfolio at the beginning of the year that is exposed to the risk of catastrophe losses during the year. Since only 10% of the base portfolio is exposed in the example above, the mean incremental annual return deriving from the overwrite program is 50.88 basis points. Using the 9.290% mean annualized return for a 10-year holding period in lieu of the 9.8% mean return for a one-year holding period gives a mean incremental annualized return over the 10-year holding period of 50.57 basis points, very close to the 50.3 basis point result from the stochastic simulation. The 10,000 path simulation is indeed very accurate!

One should not be tempted by the relative locations of the two curves in Figure 2 into thinking that the catastrophe overwriting program actually produces portfolio returns that "dominate" the base case. That is not true. There are paths on which the occurrence of multiple catastrophes during the 10-year holding period causes the catastrophe overwrite program to underperform the base portfolio of stocks and bonds. In our example, a comparison of cumulative distribution functions simply does not capture this effect.

VI. Regulatory, Tax, and Accounting Matters

The creation of any new product brings with it important issues as to the regulatory, tax, and accounting treatment. These issues must be dealt with from the viewpoints of both the seller and the buyer, or, in the case of securitization/derivatization of insurance risk, from the viewpoints of both the assumer of the risk and the cedent of the risk.

The utilization of special purpose vehicles always raises critical questions of taxation. Special purpose vehicles are intended as "conduits." As such, the transactions become highly economically inefficient if both the special purpose vehicle and investors are taxed. Thus, a necessary outcome of the financial engineering exercise is the assurance that there will be absolutely no taxation at the level of the special purpose vehicle.

Insurance company cedents of risk generally prefer the accounting treatment achieved by utilizing reinsurance to the accounting treatment obtained for securities or derivatives transactions. In particular, reinsurance "recoveries" are offset directly against losses in the underwriting account, whereas "payoffs" under catastrophe spread option contracts are likely to be treated as investment income or gains that do not directly offset losses in the underwriting account. Also, since the direct issuance of insurance-linked securities by an insurance company inflates both the assets and the liabilities of the insurer, a result that generally affects adversely various financial ratios scrutinized by insurance regulatory authorities, rating agencies, and the insurer's shareholders, most transactions have sought to utilize special purpose vehicles not affiliated with the cedent.

The most vexing issue to be dealt with in the securitization/derivatization of insurance risk is whether the insurance regulatory authorities will view the insurance-linked securities or derivatives as contracts of insurance or reinsurance and thus require the investors, counterparties, and securities firms involved in the transactions to obtain licenses to operate as insurers, reinsurers, or insurance/reinsurance brokers, as the case may be. As of the time of writing this paper, this regulatory issue has been dealt with successfully in approximately 35 states for specific proposed transactions intended to be sold in the US. A few states have indicated that this issue may be difficult to resolve to the satisfaction of securities firms.

VII. Federal Government Involvement

Some people have expressed the intriguing, yet somewhat optimistic, view that what is occurring now in the development of insurance risk securitization is analogous to the early days in the development of the mortgage securitization market. However, conditions analogous to those in the US thrift industry that provided very fertile ground for the growth of mortgage-backed securities in the late 1970s and early 1980s are not necessarily to be found in the US insurance industry today. The US federal government played a pivotal role in the securitization of mortgages. By creating FNMA and GNMA, the government became the critical catalyst for, and indeed the launcher of, the mortgage securities market. It is arguable whether the market would have developed without this "seed" role of the federal government, but it is not arguable that the pace of growth would have been much, much slower without the federal government's "leadership."

Before leaving the topic of federal government involvement, I would like to point out on purely mathematical and financial grounds (as opposed to public policy grounds) why I think that the federal government is needed to achieve a "complete" solution to the financing of losses caused by mega-catastrophes. The reason is that property catastrophe risk is not "insurable" in the classic sense of probability theory's law of large numbers. Even on a global basis, mega-catastrophes must be viewed as statistically infrequent. Worse than that, these events are, by definition, extremely severe. For very low frequency, very high severity events, the law of large numbers can be made to apply only by playing the mathematical "game" of insurance over a very, very long time period, at least decades, and perhaps centuries. The only institution with sufficient resources to deal with such a problem, and the only institution that is "guaranteed" to survive over the long run, is the federal government.

Any system for dealing with catastrophes must be based on actuarially-sound premium rates. Without adequate premium rates, no insurance or reinsurance enterprise is viable over the long run. However, adequate premium rates alone do not assure financial viability in the case of insurance against natural catastrophes. The high-severity aspect can strike at any time and cause an insurer to plunge into serious financial difficulty or technical insolvency. A funding mechanism or "bridge" is needed to permit the insurance enterprise to continue for a long enough period to recover its financial health after being battered by a mega-catastrophe. With such a funding bridge in place, the insurance enterprise can succeed because its actuarially-adequate premium rates create sufficient profits on average that the enterprise can pull itself out of the financial stress created by the occurrence of a rare major catastrophic event. The federal government is the only entity that can step in to backstop this required funding bridge. In my opinion, the backstop should be in the form of a "lending window" to financially-troubled insurers and reinsurers that are judged by state and federal regulators to be capable of rehabilitation.

My paper on dealing with the US crisis in the availability and pricing of homeowners' insurance discusses more completely than is possible here the respective roles of homeowners, property insurers, state regulators, the capital markets, and the federal government in helping solve the problem [9]. An alternative role for the federal government is presented in a paper by Christopher Lewis and Kevin Murdock [10].

VIII. Conclusion

I began this paper by reflecting on the reasons for the current slow emergence of a market for the securitization and derivatization of insurance risk. The principal focus of the paper was on financial engineering, i.e. how to manufacture instruments that convey insurance risk directly to investors in the capital markets. First introduced was the simple concept of a special purpose reinsurer linking reinsurance to pure catastrophe bonds. We then examined principal-protected catastrophe bonds as a more investor-friendly form of security ideal for launching this new market.

It was pointed out that the *incremental* catastrophe risk management needs of cedents, both currently and over the long run, and whether applying to insurers or their reinsurers, seem to lie at the very high end of the risk spectrum. Exposure to rare mega-catastrophes is what the capital markets are being asked to deal with. It was shown that over-the-counter catastrophe call spread contracts are ideal for this purpose. A stochastic simulation was presented to demonstrate the value added to a portfolio of stocks and bonds from overlaying a modestly diversified portfolio of catastrophe call spreads. Finally, a cursory, qualitative treatment of various tax, accounting, and regulatory matters was given, as well as a suggestion as to how the US federal government should become involved in the long-term financing of property catastrophe risks.

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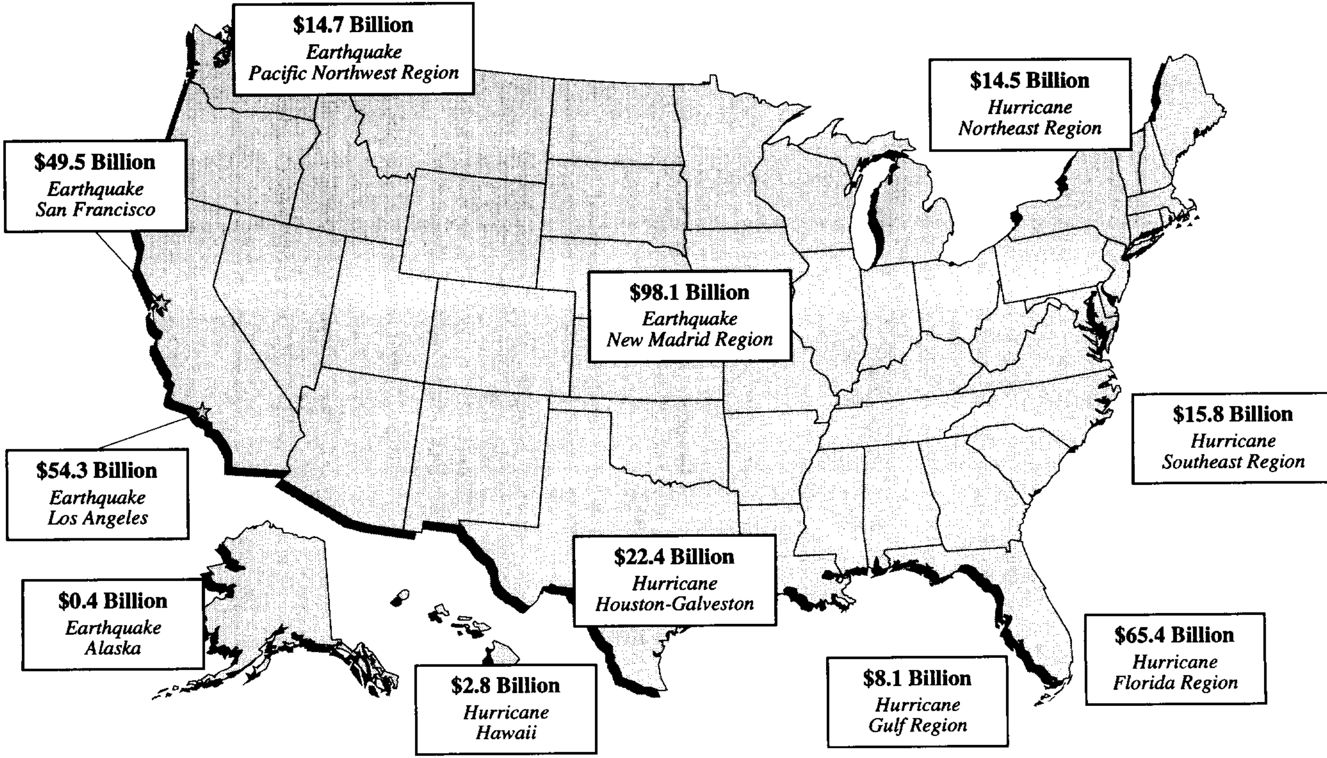
Figure 1

Potential Insured Losses From Natural Disasters



Note: Probable Maximum Loss represents the 500-year loss level, where applicable, for insured losses only.

Source: Risk Management Solutions, Inc., Insurance Services Office, Inc.

Figure 2

Special Purpose Reinsurer Bridges Reinsurance and Securities

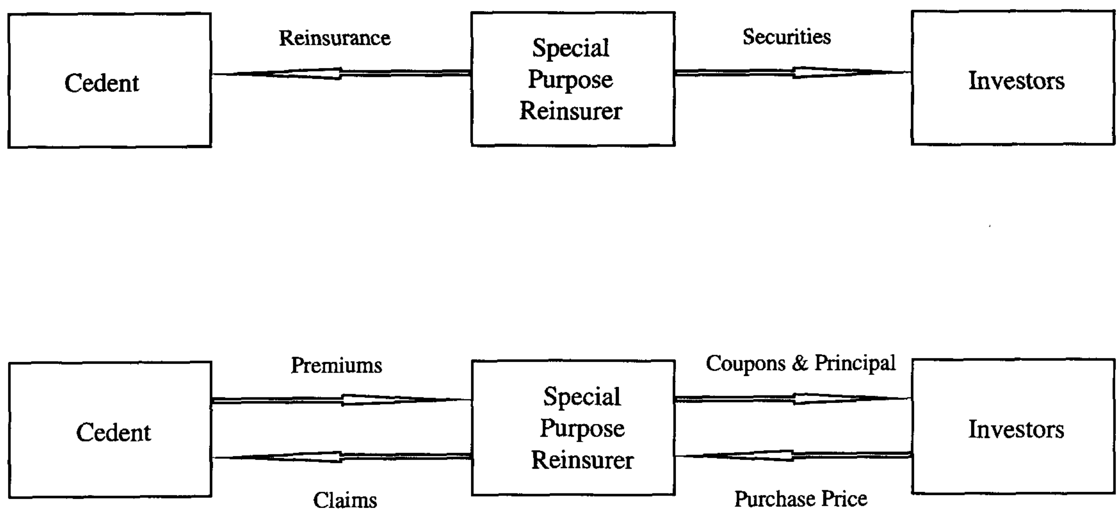


Figure 3

10-Year Catastrophe Bond With 4-Year Risk Period
Composition of Semi-Annual Level-Coupon Stream

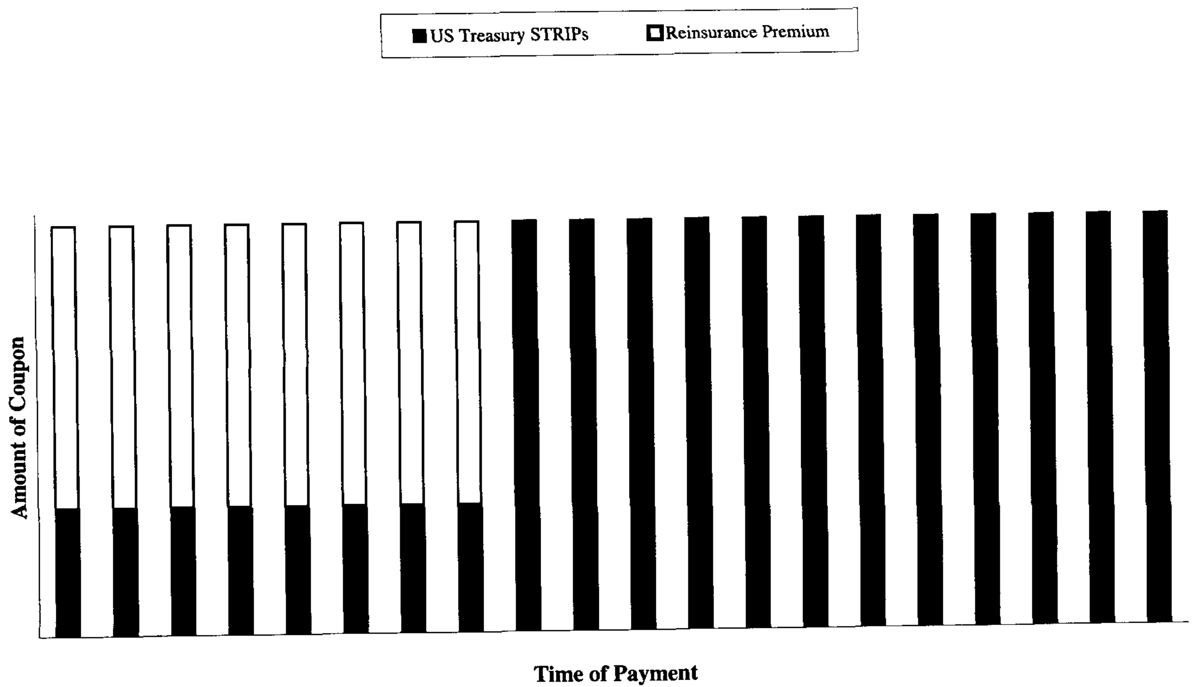
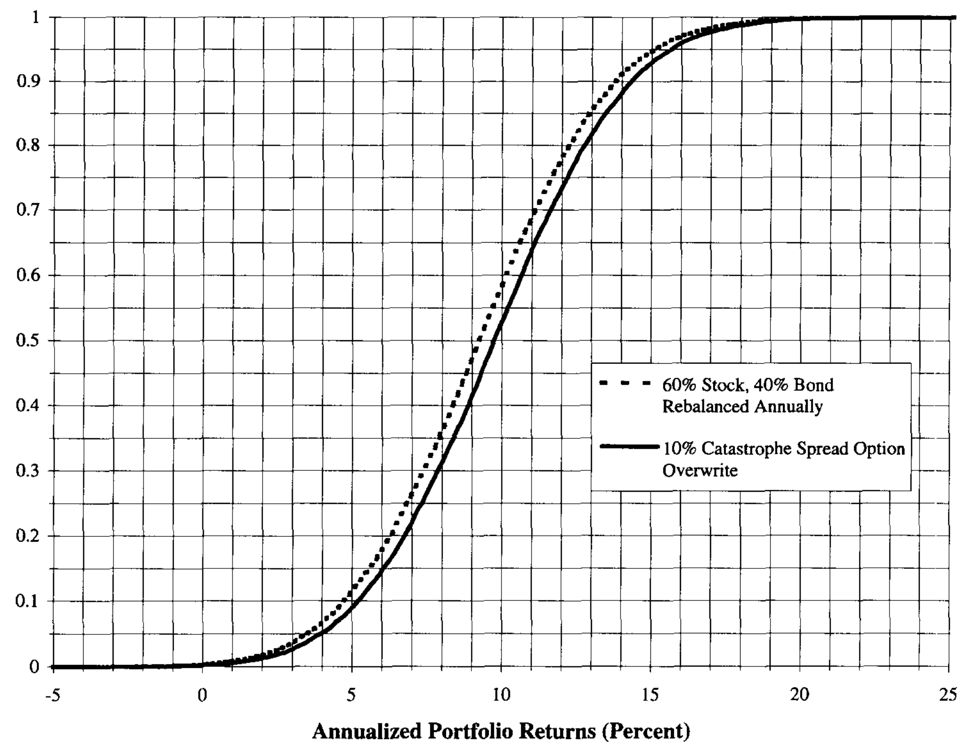


Figure 4

Cumulative Distribution Functions for Portfolio Returns (10-Year Horizon)



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