AMERICAN ACADEMY of ACTUARIES

# Evaluating the Effectiveness of Index-Based Insurance Derivatives in Hedging Property/Casualty Insurance Transactions

## By

## American Academy of Actuaries
## Index Securitization Task Force

## With Research and Input From

## Casualty Actuarial Society
## Valuation, Finance and Investments Committee

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# Evaluating the Effectiveness of Index-Based Insurance Derivatives in Hedging Property/Casualty Insurance Transactions

## *Purpose*

In October 1998, the NAIC formed the Securitization Working Group (Working Group) to evaluate regulatory changes to support capital market alternatives. The Working Group asked the American Academy of Actuaries (Academy) to provide technical assistance in understanding and measuring the effectiveness of index-based insurance derivatives in hedging insurance transactions. The purpose of this white paper is to provide the Working Group with information on evaluating the effectiveness of index-based insurance derivatives in hedging property/casualty insurance transactions for companies. This paper will discuss the following items:

- reasons for insurance companies to enter into insurance derivative transactions
- indices and index-based insurance derivative products
- risk elements associated with index derivative instruments – basis risk, credit risk, model risk and timing risk
- characteristics of a good index
- pre- and post-event measurement and reliance on models
- framework for evaluating hedge effectiveness

This paper only addresses the pre-event measurement of hedge effectiveness for companies transferring risk to counterparties through index-based derivative transactions. It does not deal with measuring the risk/return relationship of the transaction for the investor or counterparty, nor does it compare the transfer of risk to counterparties through index-based derivative transactions to the transfer of insurance risk under traditional insurance and reinsurance transactions.

The paper includes an appendix that summarizes the current indices and standard derivative products for property catastrophe exposures that are available through exchanges. It also includes an appendix on weather derivatives offered in the capital markets and a glossary of terms used in this paper.

## *Introduction*

Hurricane Andrew and the Northridge earthquake caused the insurance industry to realize the impact that a mega-catastrophe could have on the industry's solvency. Prior to those catastrophes, the largest catastrophic event as reported by Property Claim Services (PCS) was Hurricane Hugo with insured losses of $4.2 billion. While Hurricane Hugo was significant, it did not represent an event that could impair the solvency of one or more major insurers. Andrew and Northridge have caused the industry to reevaluate its exposure to loss from a single event, or multiple major events in a short period of time, and to look toward additional sources of capital to finance or spread the risk. One such source is capital markets. Mega-catastrophic events that might seriously impair the capital base of the worldwide insurance industry may cause only a ripple if spread through the global capital markets.

Several products have been developed that transfer insurance risk to investors. These products can be categorized into loss- or indemnity-based transactions and index-based transactions. Indemnity-based transactions, whose settlement is directly related to the loss experience of the company issuing the securities, include catastrophe bonds and contingent capital facilities (e.g., surplus notes, CatEputs™). Index-based transactions, whose settlement is triggered or derived from the value of an independent index, include exchange-traded index options, over-the-counter options or other derivatives that rely on an index for triggering or establishing the value of the instrument. To date, investors have shown an interest in property catastrophe insurance based securities and have also expressed an interest in investing in other insurance related securities, including casualty and life insurance exposures. This paper deals with index-based transactions for the property/casualty insurance industry.

Insurance-based securities are attractive to some investors. As interest rate spreads have narrowed, investors have become interested in securities that offer high rates of return while providing additional diversification benefits to a portfolio. Mortgage-backed securities and other asset-backed investments were the first examples of this trend. Because catastrophe insurance risk is viewed as uncorrelated with other financial market risks, securities whose value is subject only to catastrophe risks may improve the risk/return tradeoff available to investment portfolio managers.

The majority of transactions that have occurred have been catastrophe bonds sold by offshore special purpose reinsurers—reinsurers whose sole purpose is to transform a traditional reinsurance transaction into an insurance-linked security for investors. Use of the special purpose reinsurer allows the ceding company to account for the transaction as reinsurance. So far, the cost of these transactions has been viewed as greater than the cost of purchasing comparable reinsurance.

Index-based insurance derivatives represent a relatively new means of transferring risk for insurers. Although index-based insurance derivatives have been in existence since 1992—initially Chicago Board of Trade (CBOT) futures and, more recently, CBOT and Bermuda Commodities Exchange (BCOE) options—they have had limited use by insurers and investors. For insurers, this lack of interest may be due to their statutory accounting treatment, insurers' inexperience in managing basis risk and the availability of reinsurance at attractive costs with no basis risk.

While these derivatives represent a new category of investment, history has shown that it takes time and experience to educate investors and create a sufficient level of comfort with a new type of security. Currently successful classes of investments, such as credit card securitizations and mortgage-backed securities, have taken a number of years to develop a liquid market.

The NAIC formed the Securitization Working Group (Working Group) in October 1998 to evaluate regulatory changes to support capital market alternatives. The Working Group separated its review into 1.) developing legislation to support fully funded indemnity-based transactions such as catastrophe bonds, thus reducing the need for offshore special purpose reinsurers, and 2.) investigating whether it is appropriate to permit the underwriting accounting treatment of index-based insurance derivatives.

While, to date, virtually all securitization transactions have been property catastrophe related, the Working Group is not limiting the development of legislation to only property-related exposures. At the current time the NAIC is finalizing the legislation and supporting underwriting accounting treatment for fully funded transactions. This model legislation is known as the "Protected Cell Company Model Act."

With respect to index-based insurance derivatives, the Working Group will consider industry proposals to change statutory accounting treatment (i.e. underwriting rather than investment accounting) for index-based insurance derivatives if the transaction can be shown to be effective in hedging the exposure of the insurer. The Working Group asked the American Academy of Actuaries (Academy) to provide technical assistance in understanding and measuring the effectiveness of index-based insurance derivatives in hedging insurance transactions. The Academy, supported with research and input provided by the Valuation, Finance and Investments Committee (VFIC) of the Casualty Actuarial Society, has prepared this paper to assist the regulators in developing the regulatory framework.

### *Insurer Interest in Index-Based Insurance Derivatives*

Insurers traditionally transfer insurance risk through the purchase of reinsurance. Insurers have expressed an interest in insurance derivative transactions for a variety of reasons. These reasons include:

- supplemental capacity – Index-based insurance derivatives represent a viable alternative in supplementing an existing reinsurance program - either filling incomplete layers or perhaps providing capacity beyond that which the reinsurance market is willing to offer. Index-based insurance derivatives are likely to be used to provide supplemental capacity rather than as the only form of risk transfer. A mature and liquid capital market in insurance derivatives could eventually offer significantly more risk bearing capacity than is available in the reinsurance market. In addition, some insurers and reinsurers may wish to diversify their portfolio by assuming risk through derivative products, thus expanding the use of existing insurer capital.

- capital markets' participation – The reinsurance industry has a finite capacity available to deal with the mega-catastrophes. Major carriers, if they were to choose to purchase, could not purchase enough reinsurance to cover the mega-catastrophic event, and the surplus of these carriers is exposed in the event of a mega-catastrophe or a series of moderate-sized events within a short period. Even if reinsurance could be purchased to cover the mega-catastrophe, the aggregation of exposure to the reinsurers could be such that several reinsurers could become insolvent. The capital available in the capital markets to spread risk is multiples of the total capital of the insurance industry. A mega-catastrophe would have far less impact proportionally on a diversified investment portfolio than on the aggregate surplus of the insurance industry.

- transparency and potential transaction cost reduction – Compared to the traditional reinsurance submission, minimal submission requirements, if any, ease the transferring of risk to investors. The use of an independent index reduces the potential for adverse selection and the burden on the investor in evaluating company data. The burden is still on the company to evaluate the effectiveness of the hedge. In a developed market, the risk transfer of insurance exposures through the capital markets will be no different than the sale of a debt or equity security. Exchange-traded products have the added advantage of publicly available valuations. The purchase may also reduce intermediary costs. Additional cost savings may result from increased competition from the new source of capital.

- integrated risk products – The evolution of broad balance sheet and income statement risk management techniques has introduced financial risks, e.g.,

> foreign exchange risk, commodity price risk, credit risk, etc., into the insurance product offerings of insurance companies. There is an increased demand for including such exposures in traditional insurance contracts and rating approaches. In assuming such risk, insurers may wish to hedge these exposures to the financial markets along with the traditional insurance risk. The current accounting treatment disadvantages carriers providing integrated risk covers when they hedge non-insurance exposures in the financial markets.

The first insurance derivatives were developed by the CBOT in 1992. Even after the introduction of index-based insurance derivatives, the acceptance of option products was low for several fundamental reasons.

First, and most significant, is basis risk. Basis risk is the risk that the financial instrument will not exactly cover the losses it is intended to hedge. Index-based insurance derivatives purchased through the exchanges or over the counter inherently have basis risk due to the broad nature of the underlying indices. The purchase of reinsurance, on the other hand, generally does not expose the ceding company to basis risk. Even with supportive regulatory treatment, it is unlikely that index-based insurance derivatives will gain broad acceptance until companies become confident in their ability to measure and manage basis risk on a pre-event basis.

Second, the ability to measure and manage basis risk is a function of being able to model the index and the insurer's exposures given potential loss events. In general, companies have not significantly developed the internal capabilities to measure and model indices and basis risk. As a result they have viewed the purchase of an index-based insurance derivative more as an educational investment to prepare for future use than an effective hedge of existing exposures.

Third, index-based insurance derivatives represent a new form of risk transfer. With such an innovation comes new products, new terminology and methodologies that must be learned by insurers in order to successfully integrate those products into a reinsurance/risk transfer program. An interesting contrast between reinsurance and index-based insurance derivatives is the allocation of work. A significant effort is involved in the preparation of the submission to the reinsurer. In the purchase of index-based derivatives this effort is replaced by the effort involved in modeling, measuring and evaluating basis risk associated with the transaction.

Finally, the statutory accounting treatment of these products affects their acceptance as hedging tools. Property/casualty insurance companies are measured and benchmarked by various performance ratios—most notably the loss ratio and combined ratio. These ratios are calculated from premiums, losses and expenses as defined by statutory accounting principles. Investment income is not directly considered in any underwriting calculations or ratios. The purchase of reinsurance directly affects these values, and the impact of the reinsurance transaction is reflected in the net underwriting results.

On the other hand, the purchase of an insurance-linked derivative is currently treated as an investment transaction. For example, in the case of an option, under current statutory accounting the derivative is treated as 1.) an asset during the life of the option, 2.) an investment expense if the option expires unexercised, and 3.) miscellaneous other investment income if the option ends "in the money." Underwriting profits and ratios are not affected by the purchase of the option.

Consider two identical insurers with identical experience - one purchasing reinsurance and the other purchasing an index-based derivative with identical cash flows as the reinsurance contract. If a loss occurs, then the insurer who purchased the derivative would post higher net underwriting losses and combined ratio than the company that bought the reinsurance contract; if no loss occurs, the impact on underwriting results is the opposite. Assuming no difference in taxation, the ending surplus position would be identical, but, when evaluated according to statutory ratios, the insurer that transferred risk through the purchase of the derivative may be viewed as a poorer underwriter. While cosmetic in nature, the current accounting treatment is a factor in the use of index-based insurance derivatives as a risk transfer mechanism.

It should be noted that under GAAP accounting, it is widely interpreted that profit or loss from an index-based insurance derivative, which is determined to be a highly effective hedge, would offset underwriting income (i.e., underwriting ratios in GAAP are impacted). The GAAP treatment of index-based insurance derivative contracts will follow FAS 133 once effective. The proposed effective date of this standard has been extended to June 15, 2000.

## *Indices and Index-Based Insurance Derivatives*

To date, the market for index-based insurance derivatives has been limited to property catastrophe exposures due to a lack of non-property historical indices and standardized derivative products as well as the greater uncertainty regarding timing of loss payments for "longer tailed" lines of insurance. The discussion in this section will focus on property catastrophe derivative products but can be extended to other lines as well. It should be noted that there are a variety of index-based derivative products. The following discussion will illustrate the index option transaction.

In seeking to transfer catastrophe risk through insurance options, an insurer would seek to purchase a catastrophe option through one of the exchanges or over-the-counter (directly from a principal otherwise known as a counterparty). The insurer is purchasing a security, which is known as a call option. A call option gives the buyer/insurer the right, but not the obligation, to receive funds from the seller/investor if the value of the index exceeds a specified level (strike price) during the specified exercise period (which could be the life of the option, or just on the expiration date). When triggered, the settlement value of the derivative is based on the contractual terms of the agreement. The investor, or counterparty, has sold a call option and receives a premium for the exposure to the risk assumed by selling the option. A more detailed description of options and exchange-traded option products is contained in the appendix.

Generically, the index-based insurance derivative product has the following characteristics:

- one or more underlyings
- one or more notional amounts or payment provisions or both
- cash settlement

The term *underlying* refers to the variable within the derivative that, along with the contractual provision, determines the payout of the option. For example, a property catastrophe option may be written to provide a fixed payout in the event of occurrence of an earthquake exceeding a specific value on the Richter scale during the agreed exposure period. In this case the underlying would be the Richter scale and the notional amount/payment provision would be the fixed payout of the contract. Other examples of underlyings include the PCS index, GCCI, SIGMA index, RMS index, wind speed, temperature, statewide loss ratio for a line of business or inches of rain. The PCS Index and GCCI are indices used for the standardized catastrophe option products sold on the exchanges.

The price paid for the option is 1.) based on the market price for such instruments if purchased on an exchange or 2.) negotiated between the buyer and seller in an over-the-counter transaction. Generally, index-based insurance derivatives are settled in cash if they are "in the money" (i.e., the value of the underlying exceeds the strike price), or expire worthless if the value of the underlying does not exceed the agreed strike price of the option.

Catastrophe options can be purchased in the form of standardized options from the CBOT or BCOE[1]. The options sold on the CBOT are based on the PCS index and their settlement value is a function of the PCS index. The BCOE options are based on the GCCI and are fixed amount contracts. In both cases the standardized products can be purchased on selected state, regional and national index bases.

In addition to exchange-based products, insurers can purchase over-the-counter options contracts. In this case the underlying, settlement formula, price and other contract details are negotiated between the insurer and counterparty.

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[1] Recently the BCOE suspended the trading of GCCI options. This document assumes that the BCOE will resume trading GCCI options at some time in the future. The BCOE options, as described in this paper and appendix, are based on information provided by the BCOE through its web site.

## *Risk Elements*

Index-based insurance derivatives introduce a number of risk elements to the buyer or insurer that differ, in degree, from the risk elements associated with traditional reinsurance. These risk elements include the following:

- basis risk
- credit risk
- model risk
- timing risk

These risk elements need to be addressed by the company entering into derivative transactions. In a traditional reinsurance transaction, the buyer and regulator are primarily concerned with the credit risk. The other risk elements are generally not present or present to a lesser extent. The following section further describes each of these risk elements.

### Basis Risk

Basis risk is the risk that there may be a difference between the performance of the hedge and the losses sustained from the hedged exposure. It is the risk that the value of the underlying or index used and/or structure of the settlement of the derivative may not provide the desired offset to the insurer’s loss. For most reinsurance contracts, basis risk is eliminated since the reinsurance contract’s terms and conditions specify the subject losses that are to be covered by the contract. Basis risk may exist in reinsurance contracts containing industry loss warranties—a class of reinsurance contracts that use industry or parametric indices to trigger coverage. With this type of contract no payment is made, for a given occurrence, unless the industry index or the parametric value exceeds a specific value.

Basis risk can produce losses or gains for a company. For example, in the case of catastrophe options, an insurer may suffer significant insured losses from an event, but the catastrophe loss index underlying the derivative may not recognize the same relative level of losses. As such, the derivative may provide a reduced or potentially zero payout. Alternatively, the insurer could experience relatively light losses while the derivative produces a gain relative to the losses incurred by the insurer.

A hedge is said to be effective when the derivative and hedged exposure are closely related such that the payoff of the derivative is consistent with the losses associated with the hedged exposure and reduces risk to the company. A perfect hedge has no basis risk; that is, the settlement value of the derivative is equal to the losses from the exposures that were hedged. Basis risk arises in index-based catastrophe derivatives (or any index-based derivative) due to differences between the nature of the index used in the derivative and the insurer's exposure.

Indices that are used in derivatives may take many forms. They include published indices such as the GCCI and PCS index; parametric values such as Richter scale values, hurricane intensity, inches of rain, etc.; industry aggregate (or region or state) loss values/loss ratios; or commodity prices.

Indices underlying the standard exchange-traded index-based insurance derivative products are constructed from a broad compilation of insurance related data. A company's portfolio of risks may be different than the portfolio of risks comprising the index. Unless the index is comprised solely of the company's actual loss experience, an element of basis risk will always be present in index-based derivative transactions. Basis risk is reduced as the company's portfolio better matches the portfolio of the index. Better matching can often be achieved by using a more refined set of indices, e.g., using state vs. regional indices or ZIP code vs. state indices, in the construction of the underlying in an over-the-counter derivative. Appendix A provides a brief description of the various property catastrophe indices.

There are many sources of basis risk. The sources can be categorized in the following groupings:

- individual company operating differences from the company(ies)/industry comprising the index
- differences between the company's portfolio and portfolio comprising the index
- construction of the index
- changes in the company's portfolio during the exposure period
- nature, intensity and geographic spread of the catastrophe
- structure of the derivative

*Individual Company Operating Differences*

Each company is unique in the way it operates. Among the many variations are the company's appetite for risk, its underwriting and approach to risk selection and its claims handling. Thus, a company's results may naturally differ from that of an index of comparable exposures. Significant differences can exist in the way the company underwrites relative to the aggregate industry exposure underlying the index. Some examples of areas of differences include dispersion or concentration of risks; exposure characteristics such as occupancy and construction; coverage variations such as deductibles, limits and attachment points; and company mitigation efforts. The company's claim practices also will affect its experience. In addition secondary costs, such as increases in residual markets costs and guaranty fund assessments related to carriers that become insolvent due to the event, need to be considered.

### *Portfolio and Index Portfolio Differences*

The location of the company's risks relative to the aggregate portfolio exposure distribution may impact the company's recovery if the company's exposures are distributed differently than the aggregate portfolio. Even if there is high correlation between exposure distributions, there can be significant shortfall or gain in the recovery depending on the specific location of the catastrophe.

### *Construction of the Index*

The construction of the index used in the derivative will affect the effectiveness of a hedge based on the index. Factors that will impact basis risk include whether the company's experience is included in the index, the way the data is weighted (dollar vs. unit), volume of data (particularly in small cells), and granularity of the index (to what level of detail does the index exist – national, regional, ZIP code). The construction of the index is important in the ability to model pre-event effectiveness of the hedge. An index that can be easily modeled relative to a company's exposures will be more readily accepted in hedging insurance exposures.

### *Changes in the Company's Portfolio during the Exposure Period*

At the time the company enters into the hedge, its evaluation of basis risk is based on the exposures in force at the time of the transaction. As the company writes new business and some risks are cancelled or not renewed, the composition of the book may change from the exposure base underlying the hedge. This exposure base change may introduce an exposure mismatch between the exposure and hedge and may reduce the effectiveness of the hedge.

### *Nature, Intensity and Geographic Spread of the Catastrophe*

The catastrophic event may occur in an area with a heavier or lighter concentration of exposures than the index, resulting in significantly different results between the insurer and index. The degree of intensity of the catastrophe will impact the basis risk. It is far easier to achieve an effective hedge for a large area that is affected by an event such as a hurricane, earthquake, or multi-state storm than for a specific localized event such as a tornado. Various academic studies have found that the broader the event and the greater the devastation, the lower the basis risk.

### *Structure of the Derivative*

The structure of the derivative is an important factor in improving the effectiveness of the hedge. Just as the overall construction of the index is important, the construction of the derivative product through selection of the index and notional value is critical in reducing basis risk. The closer a company comes to matching its experience with that of the index, the lower the basis risk. For example, using a number of detailed indices instead of one broadly based index, a company can significantly improve the effectiveness of the hedge. Other factors that might be considered include time periods for index observation and time period for valuation at expiration.

The company may also be able to reduce the under-performance of a derivative by increasing the recovery from the derivative. Increased recovery could be achieved by structuring the derivative to produce a higher notional or settlement amount or purchasing additional options on the exchange. Note that this strategy will not reduce the basis risk but will result in shifting the distribution of recovery such that the probability of loss is reduced and probability of gain is increased.

## Credit Risk

The need to evaluate credit risk is associated with the purchase of derivatives and reinsurance. The reinsurer or counterparty must fulfill its contractual obligations if the insurer is to achieve the desired risk transfer. In entering a reinsurance transaction/derivative transaction, the company must evaluate the creditworthiness of the reinsurer/counterparty.

With respect to reinsurance, regulators oversee the operations of domestic reinsurers and have established rules requiring appropriate collateral to support balances with unauthorized or late paying reinsurers. No similar regulatory protection exists when entering uncollateralized derivative transactions, although most exchanges provide a similar form of oversight to secure recoveries from exchange-traded products. The NAIC is currently reviewing industry proposed counterparty credit requirements which, if accepted, would permit derivative transactions to be treated as underwriting transactions.

## Model Risk

Model risk is the risk that the model used to evaluate the effectiveness of the hedge does not accurately predict the index and/or company results. Model risk can also enter into the purchase of reinsurance. For the purchase of property catastrophe reinsurance, the results of modeling are often relied upon in the pricing of coverage, the decision to purchase reinsurance and the determination of the amount of coverage to be purchased.

With respect to derivatives, the management of basis risk by a company relies on the company's ability to evaluate, on a pre-event basis, the expected recovery and distribution of recoveries of the derivative transaction. The determination of the expected effectiveness of the hedge relies on the evaluation of differences in the notional/settlement values of the derivative and company loss experience using simulated events or historical experience. Models are approximations based on empirical data and analysts' expectations regarding future or unobserved behavior and will not perfectly predict the behavior of complex systems.

The model itself, unless used as the underlying in the derivative product, will not produce the basis risk, but, to the extent it is relied upon by the insurer, it may cause the insurer to structure a derivative that does not achieve the desired hedge.

### Timing Risk

Timing risk is the risk associated with estimation errors in interim financial reporting and the timing of cash settlement of the derivative between the event and the settlement of the derivative. Liquidating the derivative may eliminate timing risk, but liquidation may introduce additional risks. Timing risk can also be present in reinsurance transactions since the estimation of ceded balances and the recovery of funds from the reinsurer may be uncertain.

For index-based transactions, the index is based on aggregate company or industry loss statistics. The timing of settlement of the derivative may be delayed because losses are not recorded immediately after they occur. For example, a company hedging 1999 Atlantic hurricane losses may not be able to determine the ultimate value of the hedge until sometime in 2000 – too late to benefit its 12/31/1999 financial statements. In the case of derivatives whose settlement relies on an index that develops over time, the ultimate value of the derivative may not be known for months after the event. During this period the insurer will prepare financial statements based on estimates of the future recovery under the derivative. This estimate may change between financial reports until the index has achieved its ultimate value. Modeled results may be used as a proxy in the interim or, alternatively, the valuation could be based on investors' estimates of losses for the full period.

Timing risk is also associated with the delayed receipt of funds to pay claims between the date of catastrophe and the settlement date of the derivative. This could result in the insurer having to borrow funds until the final cash settlement is received.

## *Characteristics of a Good Index*

Index-based insurance derivatives can be purchased either as hedges or as investments. The effectiveness of a derivative in any given situation is related to the context in which the derivative is traded, since hedging and investing involve different objectives. Furthermore, the ability to measure the effectiveness of an index-based hedge is related to the nature of the hedge and the specific type of derivative being employed. Conceptually, there are both qualitative and quantitative characteristics that can affect a hedge's effectiveness. This section discusses the *qualitative* characteristics of insurance derivative indices for use as hedges. In particular, the characteristics of a "good" index are examined within the context of a "good" hedge. The following qualitative characteristics of indices can potentially enhance the effectiveness of an index-based insurance derivative as a hedge.

- The index is relatively ***easy to understand*** and conceptually straightforward.

- The index, and thus the payoff of the derivative, is ***related to the loss process***. Beyond purely statistical measures, the index and the underlying loss process should exhibit reasonably common causation. In other words, the level of losses and the value of the index should have common causal factors. For example, a lumber price index and hurricane catastrophe loss, although not directly related, would be affected by many of the same factors. On the other hand, although it may be possible to show statistical correlation between hurricane losses and an unrelated index, such as a gold index or hog futures, the lack of common causal factors may preclude derivatives based on these indices from being effective hedges.

- The timing of changes in the index's value is ***consistent with the emergence of the loss process***. In other words, and more generally, the value of the index should not appreciably lag the emergence of losses; instead, the index should be responsive to losses essentially as they emerge. Such a characteristic has two positive implications:

    - The value of the hedge can be quickly determined if the derivative is marked to market.
    - Loss and offsetting hedge cash flows can be reasonably well matched if, for example, the derivative value is marked to market and the derivative can be traded in an efficient and mature market.

- The index does not create ***moral hazard potential***. Moral hazard refers to the possibility of a company's increasing its reported losses to enhance the payoff of the contract. There is potential for moral hazard in indemnity-based contracts. For example, in an indemnity-based catastrophe bond, the issuing company has the ability to inflate its reported losses to receive debt forgiveness under the provisions of the bond issue if the trigger is based on reported losses. This potential does not exist if the trigger is based on paid losses, since the benefit of any debt forgiveness would be offset by additional loss payments. On the other hand, there may be little potential for moral hazard in index-based contracts. In fact, the more broad based the index, the lower the moral hazard problem. Thus, from the standpoint of reducing moral hazard, it is desirable that the index be as broad-based as possible.

- The index is ***capable of being modeled***. Preferably, the index would be capable of being modeled on an ***exposure*** basis or based on a ***historical database***. Note that an extensive history may not be available for a newly developed index, but an index that proves useful will encourage modelers to accumulate relevant information. This modeling capability would:

  - Provide for the testing and evaluation of the effectiveness of the index.
  - Enhance the ability to project the performance and responsiveness of derivatives under a variety of future scenarios.
  - Provide a basis for more informed market trading of insurance derivatives, which would serve to make the markets in which the contracts are traded more active and efficient. The more liquid and efficient the market is, the more likely it will be that the market value of an insurance derivative will reflect its inherent value.

- The data required to construct the index ***are not subject to manipulation***. To the extent that an index is comprised of data from several companies or sources, the manipulation of a single source of data should not result in significant manipulation of the overall index. To the extent possible, the data comprising the index should be verifiable. Note that a single-company index may require greater due diligence on the part of the parties entering into the derivative hedge to protect against potential manipulation.

- The index is “***flexible***” enough to allow parties to an index-based derivative to customize their transactions. This customization can increase the effectiveness of the hedge position. This flexibility typically means that subsidiary indices may be calculated based on subsets of the data underlying the original index. For example, an index should be flexible with respect to some or all of the following factors:

  - geographic distribution
  - line of business
  - demographics
  - inflation and/or other economic variables
  - level of attachment

There are potential conflicts between these desirable qualitative characteristics. It is doubtful that any index will fulfill each characteristic to a comparable degree. Therefore, a good index often involves tradeoffs between one characteristic and another.

## *Pre- and Post-Event Measurement and Reliance on Models*

Before discussing the framework for evaluating hedge effectiveness it is important to briefly comment on the difference between the pre-event and post-event measurement of hedge effectiveness and reliance on models.

Pre-event measurement of effectiveness refers to the company's ability to estimate the expected effectiveness of the hedge prior to the event. Pre-event measurement requires the use of models or judgement to estimate the 1.) settlement values of the derivative, 2.) company's projected loss experience and 3.) relationship between these two variables. The statistics described later utilize, as input, the output of such a model and generate measures of the expected relationships between company results and results of the hedging transaction. In evaluating the effectiveness of a hedge the company and regulator should understand the inherent model risk and uncertainty associated with any estimation of effectiveness. A hedge may be determined to be effective on a pre-event basis, but then turn out to be ineffective at final settlement.

Post-event measurement of effectiveness can be objectively determined by comparing the settlement value of the derivative against the losses arising from the hedged exposures. While such measurement requires no estimation at final settlement, it may require the company to estimate the fair value of the recovery or model the expected settlement value to support its claim that the derivative was effective and establish a financial statement recovery. Model risk, where modeling is used, will also be inherent in such estimates.

Any measurement or statistic that uses the output of a model is only as good as the model itself. That is, if the model accurately measures the modeled event, then users may place greater reliance on the resultant measurement or statistic. If there are questions about the predictive value of a model and the model's output is used in a subsequent calculation, the resultant measurement or statistic, while being mathematically accurate, may not produce reliable values.

## *Framework for Evaluating Hedge Effectiveness*

In evaluating the effectiveness of index-based insurance derivatives as hedging mechanisms, both qualitative and quantitative factors should be considered. Desirable qualitative characteristics of an index are discussed in a previous section. This section discusses a four-step process for evaluating hedge effectiveness, including both qualitative and quantitative considerations. It also suggests measurement statistics that may prove useful for evaluating hedge effectiveness. These quantitative measures are closely related to many of the qualitative considerations and, in some cases, can be interpreted as mathematical assessments of the degree to which an index-based derivative fulfills those desired qualitative characteristics. Comments regarding implementation and illustrations of the quantitative tests complete this section.

In any particular situation, evaluation of hedge effectiveness has the following four steps:

- Define the risk exposure to be hedged.
- Identify the index-based derivative structure to be used to hedge the exposure.
- Develop a viable economic argument that identifies a causal relationship between the exposure to be hedged and the index or indices underlying the hedging instrument (the qualitative criterion).
- Demonstrate mathematically that the hedge is effective (the quantitative criterion).

An effective hedging transaction satisfies both the qualitative and quantitative criteria. These criteria are the same regardless of whether or not historical data or a formal model exists. Taken together, these four steps serve to define the hedging transaction and test the transaction for effectiveness.

Each step in the evaluation process is described in more detail below. The exposures to be hedged and the derivative's expected relationship to those exposures should be established prior to the time of purchase of the derivative.

### Define the Exposure to be Hedged

The first step in showing that an index-based insurance derivative transaction or set of transactions is an effective hedge of underwriting exposures is to define the exposure being hedged. This step is analogous to defining the portion of an insurer's loss experience that is to be covered by a reinsurance agreement.

The definition of the exposure to be hedged is central to the establishment and monitoring of the derivative hedging transaction. The definition of the exposure needs to be specific enough to allow the expected and actual effectiveness to be measured unambiguously.  The definition of the exposure to be hedged may include, but is not limited to, the following elements:

- lines of business, coverages, and/or products
- statutory companies, geographic territories, and/or marketing channels
- underwriting categories and/or classifications
- perils and/or causes of loss
- retentions, limits, and/or pro rata share of losses
- exposure period and/or calendar period of losses

In defining the exposure to be hedged, it is important that the exposure is not otherwise transferred, such as through reinsurance or another hedging transaction.  In other words, the same exposure should not be hedged or transferred in more than one transaction.

### Identify the Structure of the Derivative Transaction

The second step is to identify the structure of the derivative transaction that is to be used to hedge the exposure.  In practice an insurer, in the process of managing the risks inherent in its business, may return iteratively to this step (and even to step one) as the analysis proceeds and as information about what derivatives are available in the market (and their pricing) becomes available.

This identification is also central to the analysis of whether the transaction can be expected to be an effective hedge of the exposure.  To perform such an analysis, the insurer must specify the following elements:

- the type or types of derivatives to be purchased (e.g., call option spreads, insurance futures)
- the indices that are used as underlyings by the derivatives, along with the relevant strike prices and payoff functions
- the numbers of units of such derivatives to be purchased

It is anticipated that a derivative program will be part of a broader risk management program for the insurer. It therefore may be necessary to consider portions of the insurer’s reinsurance program or other risk management program in evaluating hedge effectiveness.  To the extent that such broader consideration is necessary, these additional components of the insurer’s risk management program need to be specified as well.

## The Qualitative Criterion

The qualitative criterion requires that an economic or physical rationale be identified to provide a logical basis for expecting that the indices underlying the selected derivatives will display the desired relationship to the losses emanating from the exposure to be hedged during the relevant time period. When analyzing an insurer's historical loss experience for the exposure being hedged, it is possible to find indices with extremely close relationships to those historical losses, but for which there is no basis for expecting such relationships to continue during the relevant time period. In order to have a reasonable expectation that the historical relationship will persist, the insurer needs to establish that specific known or plausible factors can be expected to cause the selected indices and the selected underwriting exposures to display the desired relationship during the relevant time period.

As an example, suppose an insurer has ten years of historical data concerning the underwriting exposure that has been specified. Consider the set of professional teams in all sports that have played for the same period. It is quite possible that one could find a team whose win-loss record—or some other statistic—over that period varies very closely with the specified underwriting exposure. However, there is no reason to expect that an index based on that team's win-loss record this year will effectively hedge the underwriting exposure this year.

## The Quantitative Criterion

Establishing an economic or physical argument for common causation is a necessary step but not a sufficient condition for establishing that the derivative transaction is an effective hedge. It is possible that the index has common causation with the selected exposure but that the relationship between their two movements is still weak. In that case, a derivative based on such an index would not be an effective hedge of this exposure. Therefore, once the insurer has established common causation, it must continue its analysis to show that the subject losses are expected to be reasonably related to the recoveries anticipated from the hedging transaction.

Based on our initial research, we have identified the statistics listed below as being possible measures of hedge effectiveness:

- change in expected policyholder deficit
- change in value at risk
- change in standard deviation
- coverage ratio
- correlation

These measures can be separated into two categories: 1.) those that measure reduction in risk and 2.) those that measure the relationship between the exposure to be hedged and the hedging transaction directly.

The primary benefit of a hedging transaction is that it reduces the risk to the insurer. The first three measures above measure this reduction in risk directly. The last two measures address the relative movement of the hedge and the exposure. (Depending on the specific definitions selected, the latter may be stricter in that risk can be reduced without the hedge and exposure moving together in a way that produces high coverage ratios or correlation statistics.) The risk reduction tests may be more relevant from a regulatory standpoint though, since they include both the benefits of the hedging transaction, i.e., the recoveries, and the cost, i.e., the hedge premium and any borrowing cost emanating from timing differences.

It is evident that the amount of risk reduction will depend in part on the relationship between the recovery and the underlying loss. When the recovery is less than the subject loss but closely related to it, downside risk has been protected and risk has been reduced. What may be less clear is that a hedge that often results in a recovery in excess of the underlying loss may actually increase risk because of the cost of the hedge.

In the following discussion, we explain each of these statistics and identify advantages and disadvantages of each measure. The Valuation, Finance and Investments Committee of the Casualty Actuarial Society intends to perform additional research to further evaluate each measure for use in evaluating hedge effectiveness.

### *Change in Expected Policyholder Deficit (EPD)*

EPD provides a framework for measuring the reduction in risk provided by the hedge transaction. The policyholder deficit for a single scenario represents the amount (if any) by which losses exceed the amount available to fund them. Over a wide range of scenarios, the individual policyholder deficits are weighted by their respective probabilities to determine the EPD.

EPD considers the full probability distribution of subject losses and recoveries. One example of EPD that might be applicable in this context is the ratio of the expected value[2] of losses in excess of a threshold to expected hedged loss (or surplus, if lower).

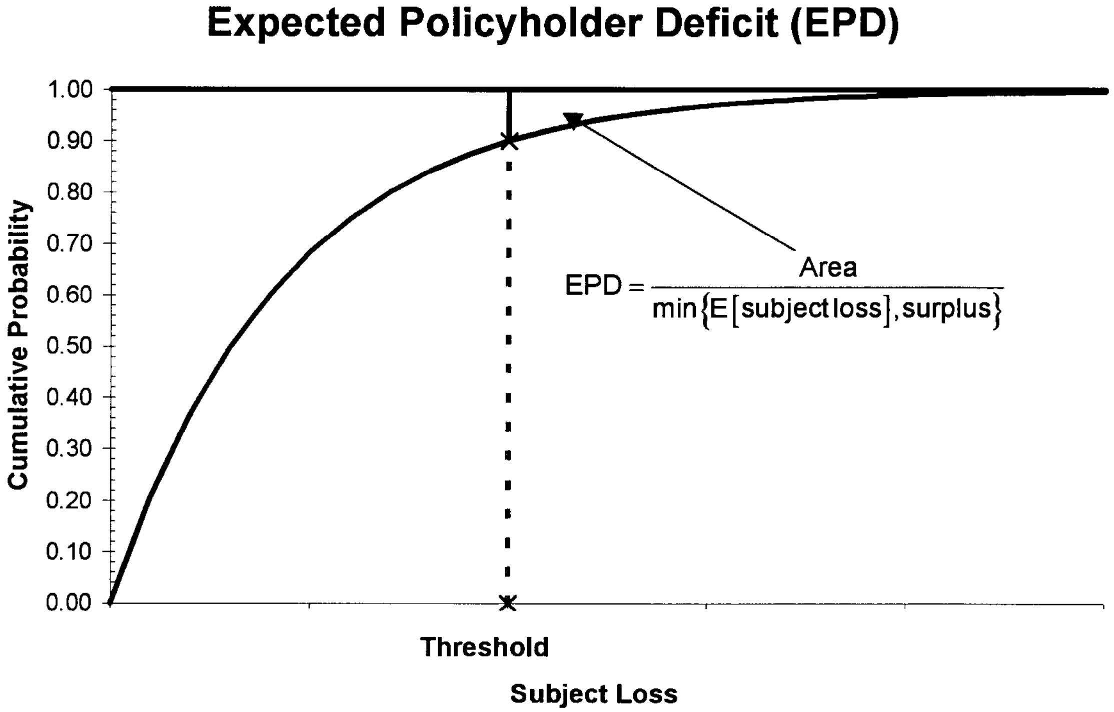
---

[2] The notation, E[x], is used to represent the expected value of x. The expected value of x is calculated as the sum over all possible values of x of the product of each value and its corresponding probability. For a set of events with equal probability, the expected value is equal to the average of the amounts.

$$\text{EPD(pre-hedge)} = \frac{\text{E}\left[\max\{0, \text{subject loss} - \text{threshold}\}\right]}{\min(\text{E[subject loss], surplus})}$$

We suggest comparing the EPD to the minimum of expected loss and surplus. In some situations, the EPD could be small relative to expected losses but large relative to surplus. Because solvency is an important consideration in evaluating insurance company transactions, we suggest comparing EPD to surplus in these cases. EPD is illustrated graphically in Figure 1.

*Figure 1*



We suggest that the threshold reflect the amount available or allocated to fund losses related to the exposure for hedge calculations with the amount held constant. We can measure the EPD both before and after the hedge transaction and determine the reduction in EPD afforded by the transaction. The EPD after the transaction would be defined as follows:

$$\text{EPD(post-hedge)} = \frac{\text{E}\left[\max\{0, \text{subject loss} + \text{hedge premium} + \text{borrowing cost} - \text{recovery} - \text{threshold}\}\right]}{\min\{\text{E}[\text{subject loss}], \text{surplus}\}}$$

where recovery is the amount recovered from the hedge.

Transactions with recoveries that are often considerably in excess of the subject loss may serve to increase rather than decrease EPD. In these situations, the price of the transaction would reflect the costs associated with providing these excessive recoveries.

An EPD-based measure of risk reduction would then be

$$\Delta\text{EPD} = \text{EPD (post-hedge)} - \text{EPD (pre-hedge)}$$

According to this measure, risk reduction would be indicated by a value of $\Delta$EPD less than zero. While a value less than zero may indicate risk reduction, regulators may wish to establish greater reductions as target values that the derivative should achieve to be considered effective. Further research is required to determine the target.

*Change in Value at Risk (VaR)*

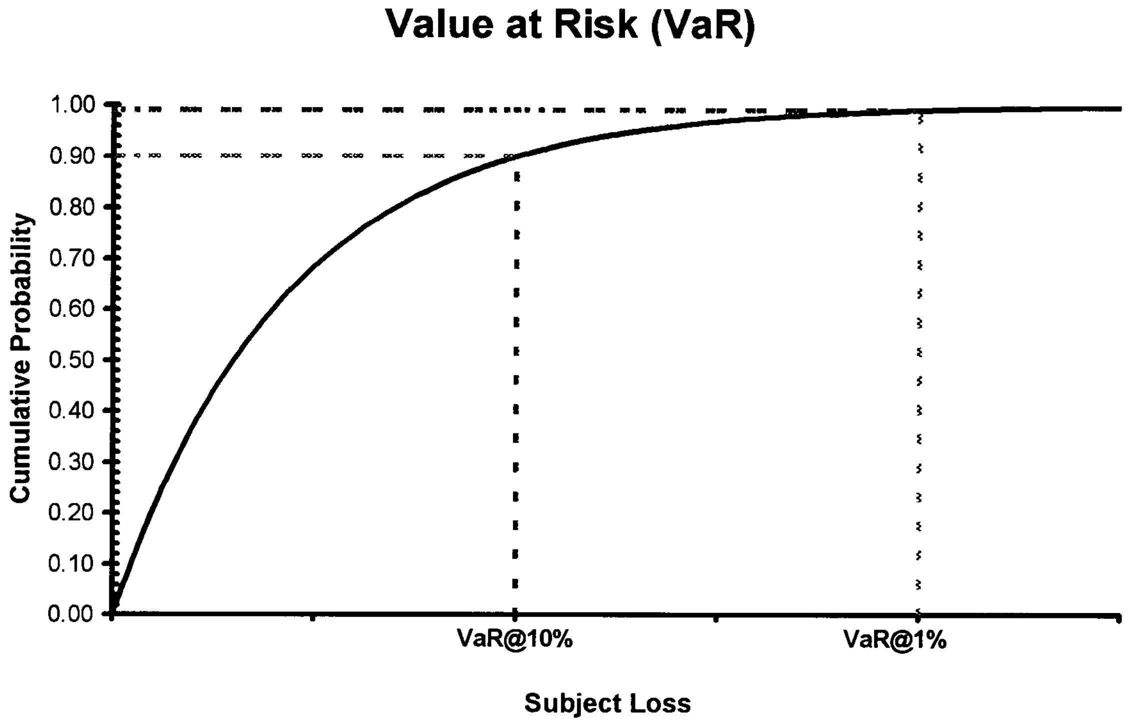
For evaluating hedge effectiveness, VaR is the insurer's net loss from the exposure at a given probability level during a specific time period. VaR is generally stated relative to a particular probability that identifies a particular scenario from a probability distribution. For example, the probability that losses will exceed the $\text{VaR}_{@1\%}$ is equal to 1%. The 1% probability level represents the loss in the scenario for which 99% of the scenarios produce more favorable results and 1% of the scenarios produce more adverse results.

A simple formula for $\text{VaR}_{@1\%}$ would be:

$$\text{VaR}_{@1\%} \text{ (pre-hedge)} = \text{subject loss}_{@1\%}$$

Subject losses are not a single amount but rather can be represented by a probability distribution. Therefore, VaR can be evaluated at any probability level. VaR can be illustrated graphically as shown in Figure 2.

*Figure 2*


Value at Risk (VaR)

As an example, a 5% VaR of $30 million on a Florida homeowners book of business indicates that there is a 95% chance that the portfolio will not generate more than $30 million of subject losses during the specific time period. Equivalently, in this example, there is a 5% probability that the portfolio will experience of subject losses more than $30 million during the time period under consideration.

With the hedge, the above formula for VaR would be modified to include the hedge premium and any borrowing costs needed to fund losses between the payment of losses and collection of the hedge recovery. The hedge recovery is the amount of money that the insurer receives on the settlement date as a result of having purchased the derivatives. The formula for $\text{VaR}_{@1\%}$ with the hedge would be:

$\text{VAR}_{@1\%}$ (post-hedge)
= (subject $\text{loss}_{@1\%}$ + hedge premium + borrowing $\text{cost}_{@1\%}$ – hedge $\text{recovery}_{@1\%}$)

The VaR with the hedge would be calculated at the same probability levels as the VaR without the hedge. A VaR-based measure of risk reduction would then be:

$$\Delta\text{VaR} = \text{VaR (post-hedge)} - \text{VaR (pre-hedge)}$$

If there is a consistent reduction across the probability levels tested the transaction would pass the quantitative criterion.

VaR is popular in the financial services sector, particularly banking. VaR is similar to the "probability of ruin" measure in the sense that it is used as an indicator of how likely a very bad result is. The statistic is an interesting and potentially useful one. However, it is deficient as a thorough risk measure, since each VaR measure provides no information about the overall distribution of losses and probabilities of losses of other sizes. It does not reflect the severity of a loss in excess of the VaR. The EPD reflects the severity distribution of the losses in excess of the threshold.

*Change in Standard Deviation (StD)*

A very basic measure of risk is the standard deviation. The standard deviation statistic provides a framework for measuring the reduction in risk provided by the hedge transaction. The standard deviation of a random variable X is given by:

$$\sigma[X] = \sqrt{E\left[X - E[X]\right]^2}\ .$$

The StD before the transaction would be defined as:

$$\text{StD (pre-hedge)} = \sigma[\text{subject loss}]$$

The StD after the transaction would be defined as:

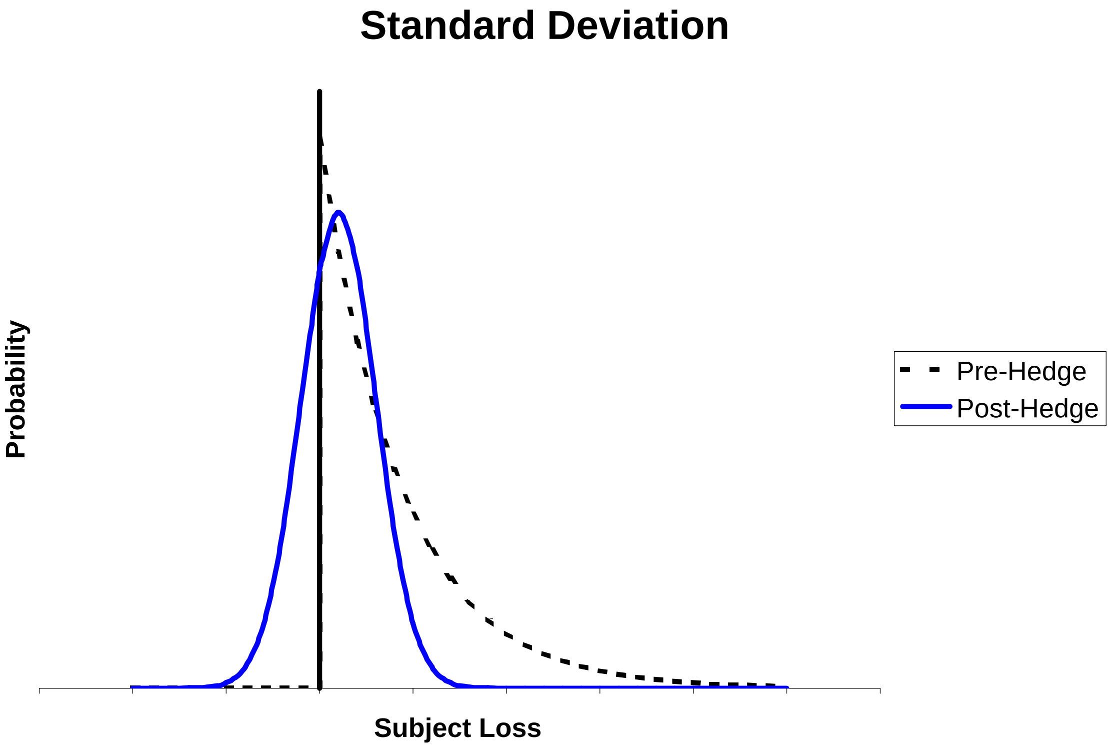
StD (post-hedge)
= σ[subject loss + hedge premium + borrowing cost – hedge recovery]

A StD-based measure of risk reduction would then be:

$$\Delta\text{StD} = \text{StD (post-hedge)} - \text{StD (pre-hedge)}$$

StD can be illustrated graphically as shown in Figure 3.

*Figure 3*



The StD measure reflects the upside variation as well as the downside variation. In contrast, both the EPD and VaR measures reflect only the downside variation.

*Coverage Ratio*

One measure that can be used to test the relationship of the hedged loss to recovery is the coverage ratio. The coverage ratio is defined as the amount recovered from the derivative transaction divided by the subject loss. This test could be stated as:

$$\text{Prob } \{a<\text{coverage ratio}<b\}>p_1 \text{ and Prob } \{c<\text{coverage ratio}<d\}>p_2$$
$$\text{given that the subject loss } \geq e*E \text{ [subject loss] or } e*E \text{ [surplus]}$$

This measure requires that the coverage ratio be within some range, a through b, with more than probability $p_1$, and within another range, c through d, with more than probability $p_2$. If appropriate, the test could also be limited by looking at only subject loss amounts greater than some multiple e of the expected hedged loss or surplus, whichever is less. The purpose of such a limitation is to prevent small events from heavily influencing the results. Small events, such as those with subject losses of less than 25% of the expected loss related to the hedged exposure, generally have very little impact on the financial results of the insurer.

The range endpoints of a, b, c, and d can be chosen to minimize the likelihood that the derivative will be used as an investment rather than as a hedge.

An illustration of this type of test might be:

$$\text{Prob}\,\{0.80<\text{coverage ratio}<1.20\}>0.80 \text{ and Prob}\,\{0.50<\text{coverage ratio}<1.50\}>0.95$$
$$\text{given subject loss } \geq 0.25 * E\,[\text{subject loss}]$$

If only the first half of the test were used, the amount of the recovery could be less than 80% of the hedged loss in as many as 20% of the possible results. Alternately, the recovery could be 2 or 3 times the hedged loss in as many as 20% of the possible results. The former situation could leave the insurer without a sufficient recovery, whereas the latter situation could provide the insurer with an excessive recovery. We, therefore, suggest adding the second half of the test to put additional bounds on the ratio of the recovery to the hedged loss.

The concept of coverage ratio can be illustrated graphically. In Figure 4, the vertical axis represents the insurer’s recovery; the horizontal axis represents the insurer’s loss from the exposure being hedged. Each possible event can be represented by a point on a graph. If the axes are scaled identically, which they are in all the illustrations herein, the points will fall along a diagonal line, which is shown in Figure 4. Events, such as A, B and C, whose points on the graph are close to the solid line, would have a coverage ratio close to 1. Events, such as D, whose points on the graph are well above the solid line, have a recovery that greatly exceeds the loss. Events, such as E, whose points on the graph are well below the solid line, have a recovery that is significantly less than the loss.

## *Figure 4*

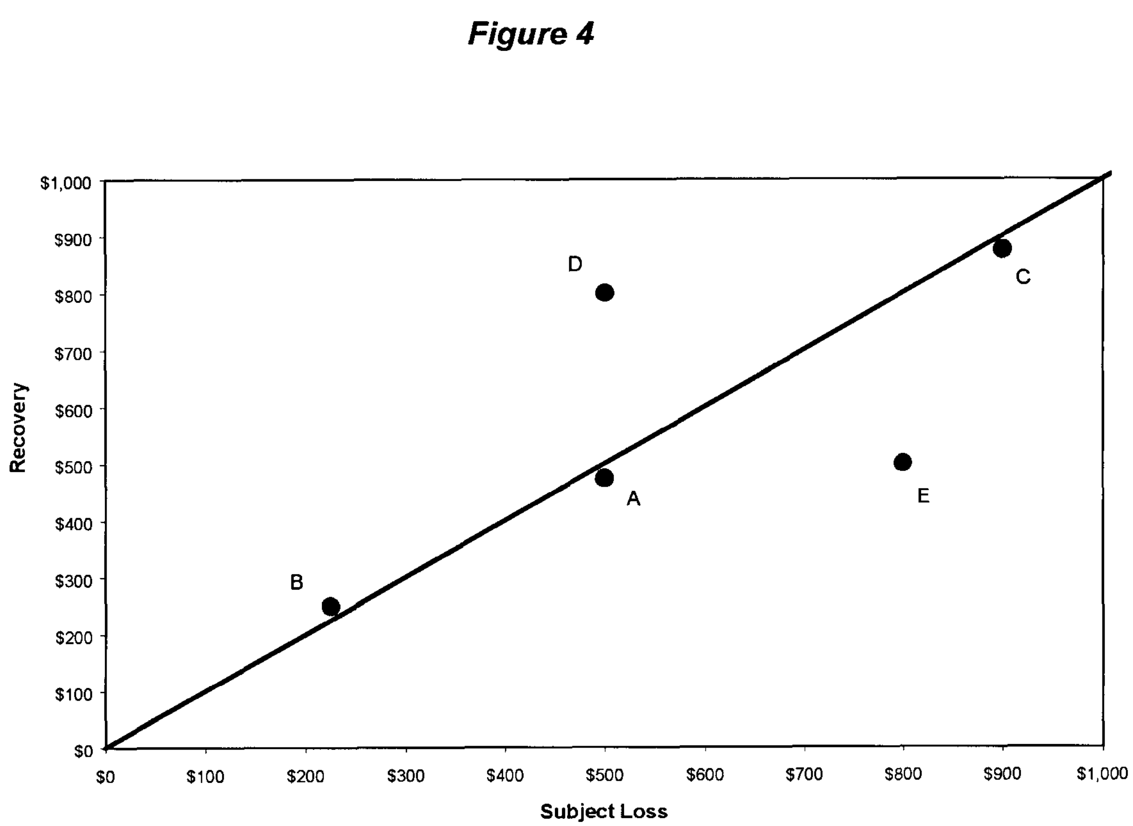
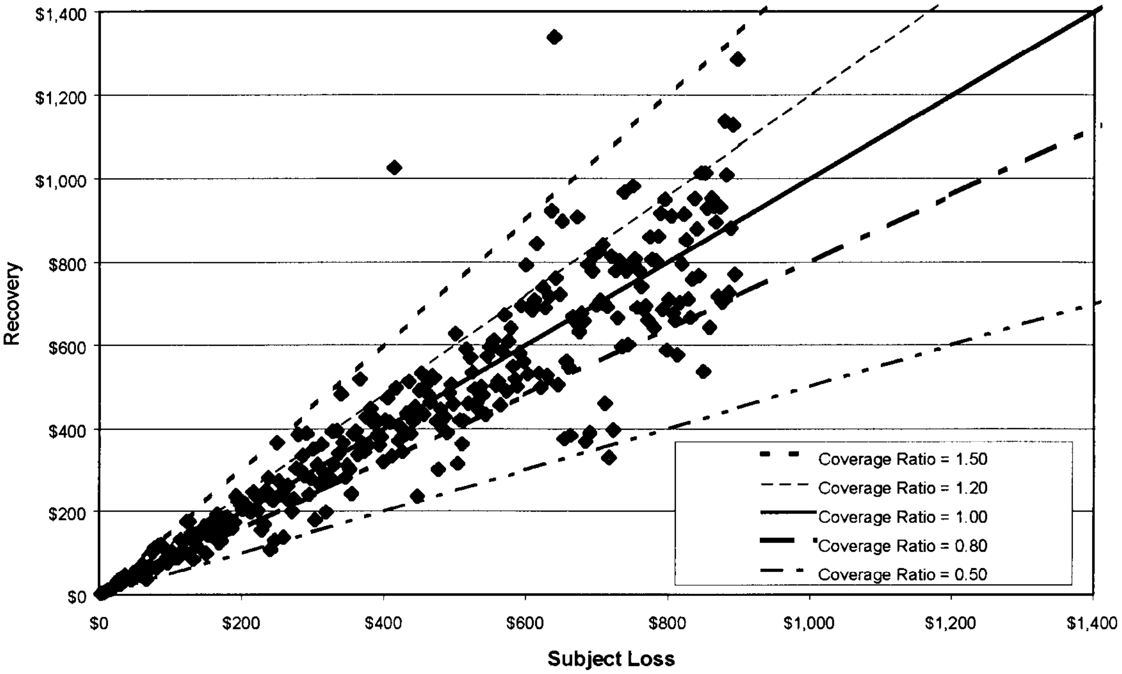


Figure 5 presents an illustration of a situation that passes the test above. In addition to the diagonal line, there are also lines representing coverage ratios of 50%, 80%, 120% and 150%. As can be seen, most of the points fall between the 80% and 120% lines and almost all of the points fall between the 50% and 150% lines.

*Figure 5*



As specified in the above illustration, this test would require that, for losses at least one-fourth the size of the expected loss (in other words, the smaller loss possibilities are being excluded),

- more than 80% of the scenarios involve a coverage ratio between 0.80 and 1.20

and

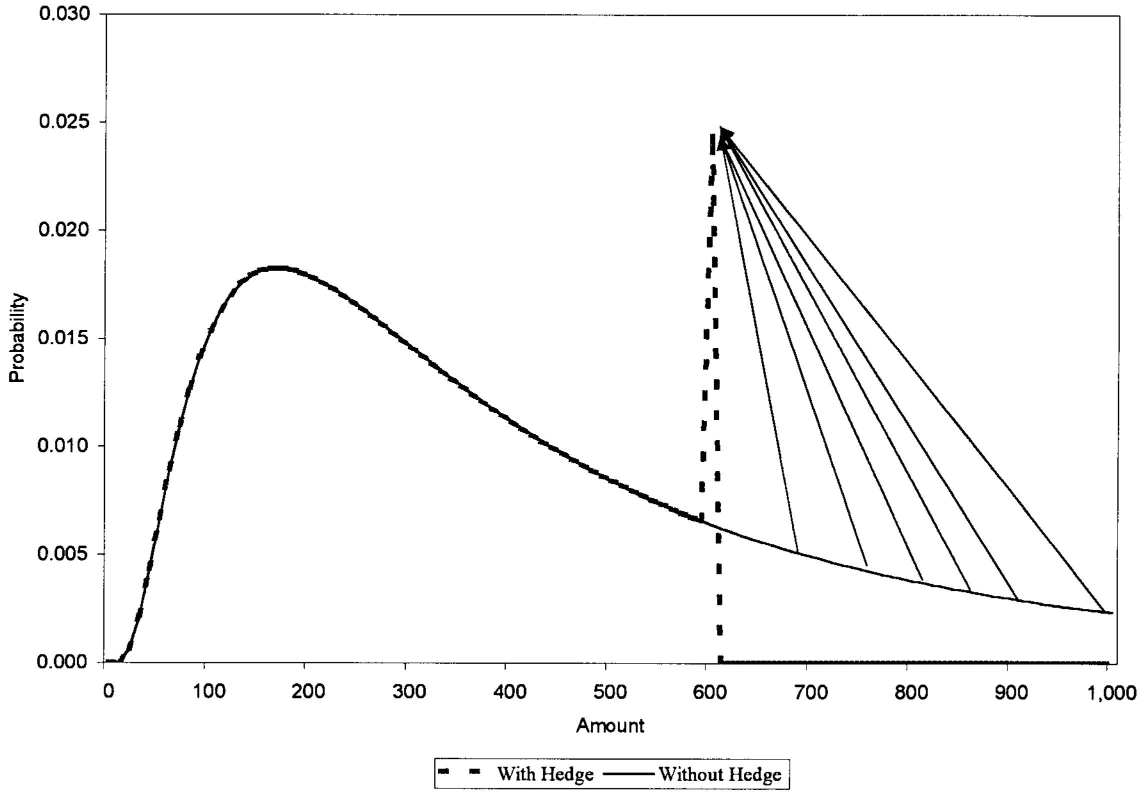
- more than 95% of the scenarios involve a coverage ratio between 0.50 and 1.50

This sample test attempts to ensure that there is, in the vast majority of possible scenarios, a close relationship between the underlying hedged loss and the recovery from the hedging transaction.

This measure has the benefit of being intuitively appealing. It directly measures the extent to which the subject losses are offset by hedge recoveries. If the focus of testing is to determine whether the hedge will act like reinsurance by providing recoveries that are closely related to the subject losses, this measure is appropriate. If, however, the focus of testing is to determine whether risk has been reduced, this measure is too strict. That is, there does not need to be a one-to-one correspondence between subject losses and hedge recoveries for the insurer's risk to be reduced.

To explain further, we use some graphical illustrations. Figure 6 shows a sample probability distribution of net losses by size before and after a hedging transaction. The lines show how individual points in the distribution change when the hedge is introduced. In this illustration, the hedge acts like reinsurance in that most large losses are reduced to the same amount.

***Figure 6***



The above illustration shows that the hedge caps the losses at 600. All points beyond 600 are limited to 600. This hedge is similar to a reinsurance contract providing coverage excess of 600.

Hedges, however, can reduce risk without this consistent reduction in losses, as is illustrated in Figure 7.

## *Figure 7*

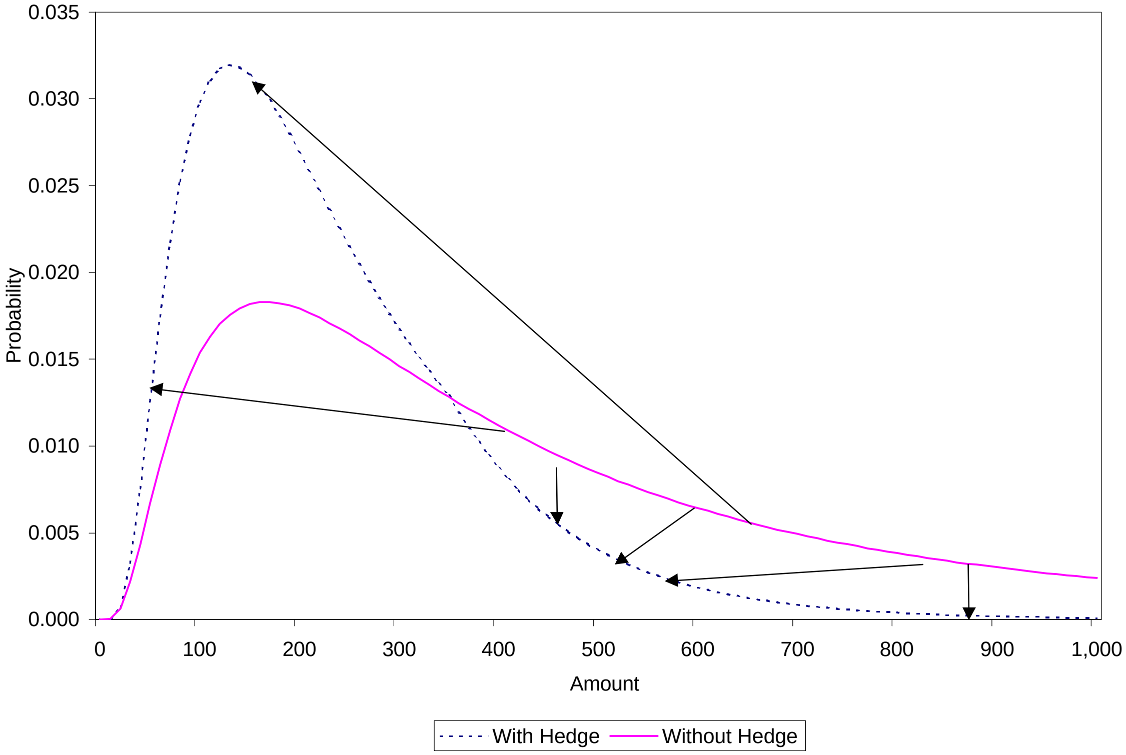
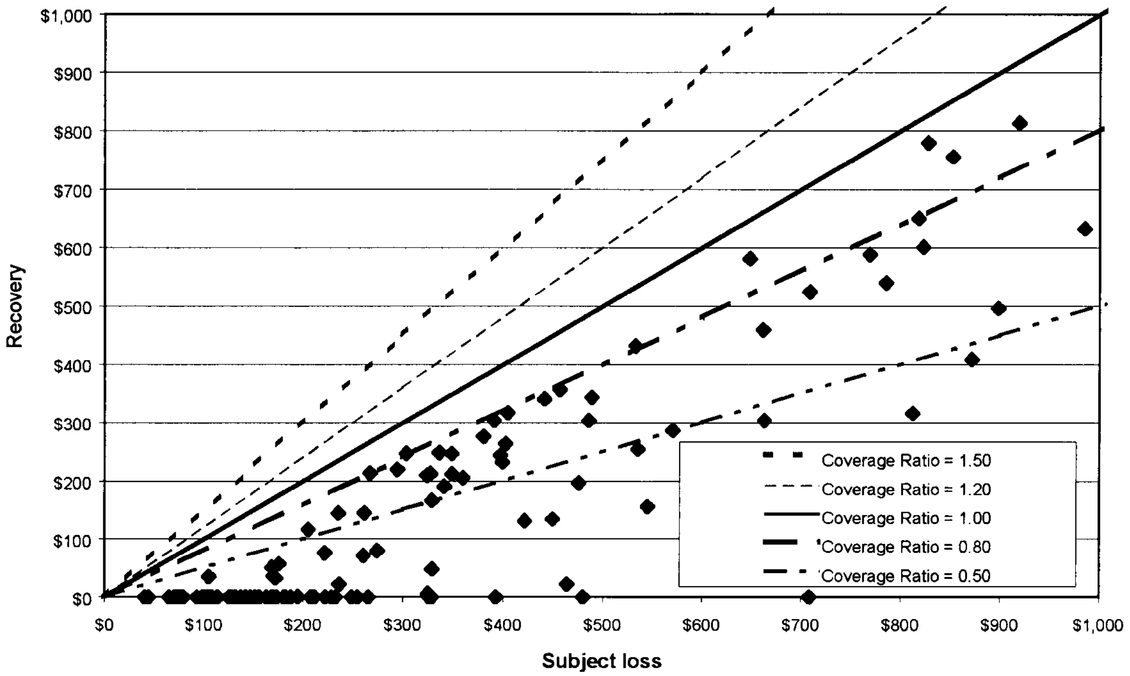


Figure 7 shows that the hedge reduces risk by lowering the tail of the distribution. That is, the probability distribution of net losses with the hedge is much tighter than the probability distribution of losses without the hedge. It should also be noted that movements from gross (without the hedge) to net (with the hedge) are not consistent throughout the distribution as they might be with a reinsurance contract.

For example, in the above figure, one arrow shows a gross loss of approximately 850 before the hedge that becomes approximately 550 after the hedge. Similarly another point at approximately 870 before shows no benefit after the hedge. (Under the previous figure, which could be viewed as a reinsurance transaction, these losses would have both been capped at 600.) This phenomenon can be observed in the data supporting the later illustrations included as Appendix D. The above hedge could be considered effective at reducing risk.

The coverage ratios corresponding to Figure 7 are shown in Figure 8. As can be seen, very few of the points fall within either of the ranges discussed above. Nonetheless, the transaction is effective at reducing risk. Figures 7 and 8 illustrate that hedges can be effective at reducing risk even when few of the coverage ratios fall within a range that might be considered appropriate.

***Figure 8***



*Correlation*

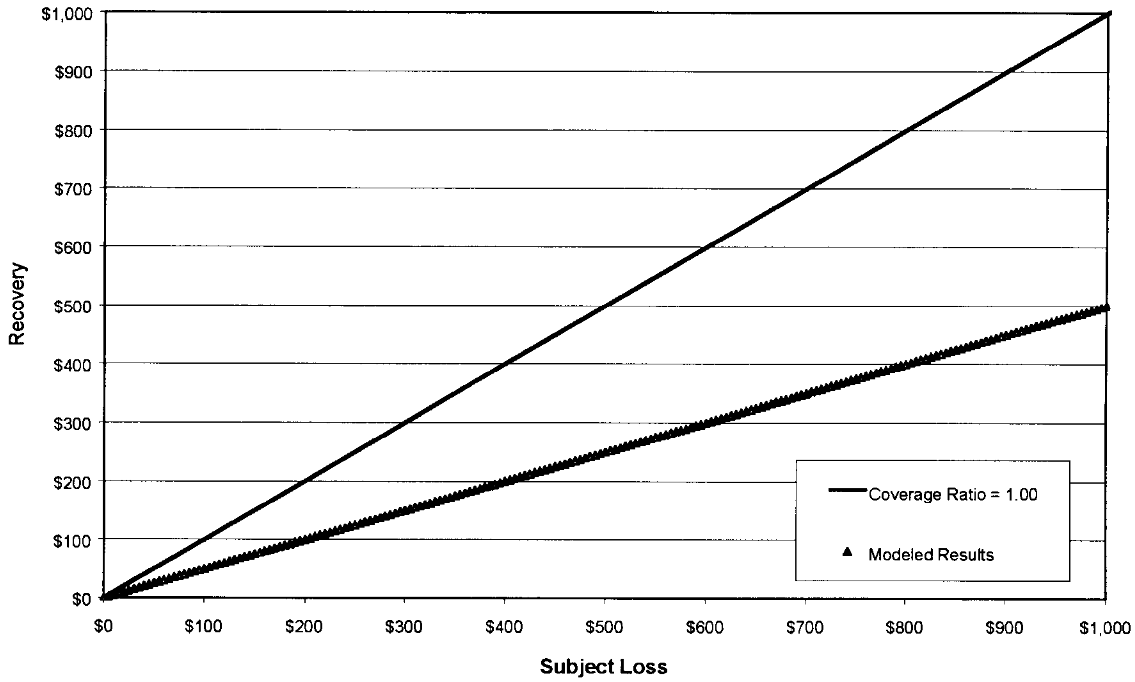
A statistical measure commonly thought to measure hedge effectiveness is the correlation coefficient. In layman's terms, correlation measures the degree to which two variables are linearly related. Mathematically, the formula for correlation is:

$$\text{Correlation} = \frac{\text{E}\big[(\text{hedged loss} - \text{E[hedged loss]}) \times (\text{recovery} - \text{E[recovery]})\big]}{\sigma\left[\text{hedged loss}\right] \times \sigma\left[\text{recovery}\right]}$$

While a high correlation can indicate a close relationship, it can also be misleading. Simple correlation does not consider the relative magnitudes of movements between two variables. Thus, a high correlation statistic means that the variables move together, in a consistent pattern, but not necessarily in a one-to-one relationship. For example, if recoveries from a derivative were always exactly twice the level of the subject losses, the correlation between subject losses and recoveries would be equal to 1 (or 100%). Similarly, if recoveries were always one-half of subject losses, the correlation would also be 1.

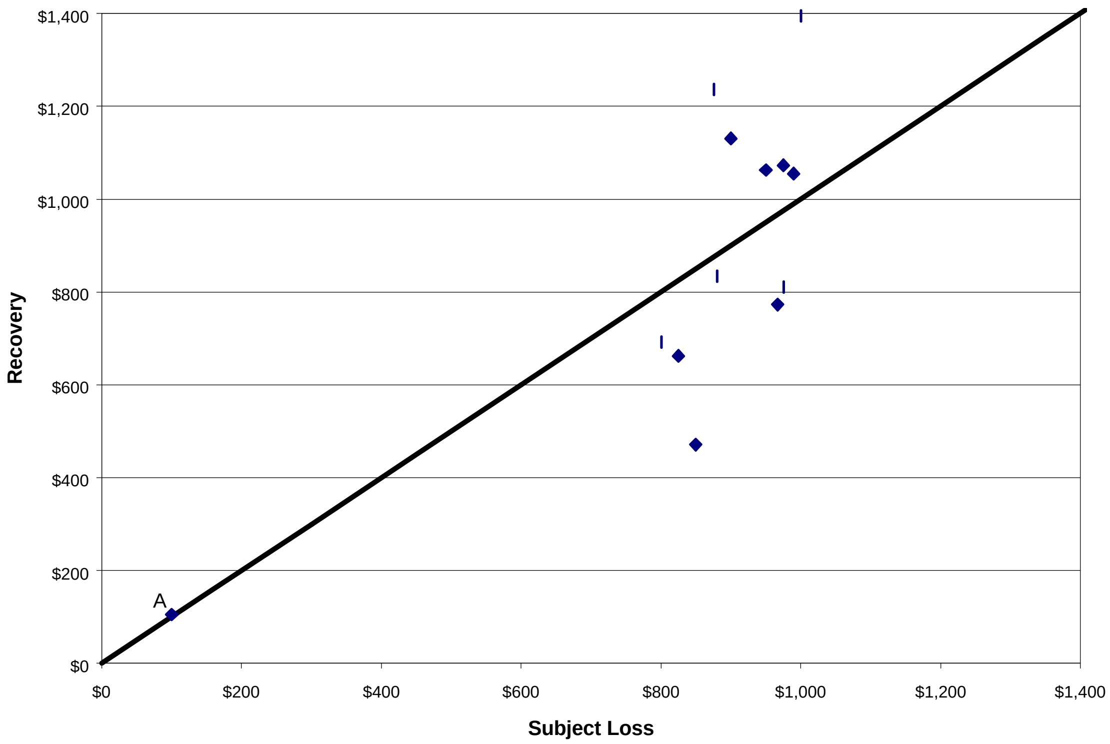
The latter example is illustrated in Figure 9. The lower line represents the recoveries and insurer's losses from each event. As can be seen, except for very small events, it is never close to the diagonal line as is desired. Of course, if the exposure to be hedged were restated as a 50% participation in the previously defined layer or if twice as many derivatives were purchased, this hedge would be perfect. However, it does illustrate one of the inadequacies of using correlation as a sole measure of hedge effectiveness.

***Figure 9***



Another concern with using correlation is shown in Figure 10. In this illustration, the correlation is 76%, a value considered relatively high. However, this high correlation is driven by the single point, A, which is an extreme value at which both the recovery and insurer's loss are low. This illustration also demonstrates the benefit of eliminating small losses from consideration of hedge effectiveness, such as those smaller than 25% of the expected loss. In this illustration, the hedged loss at point A is $105, whereas the expected value of the hedged loss is $870. Therefore, the limitation eliminates this point. The correlation excluding this single point is only 57%.

*Figure 10*



Correlation is a statistic commonly used to test relationships between two variables. The above examples have demonstrated a number of the weaknesses of correlation and why it may be inappropriate to be used as a sole measure of hedge effectiveness. It may have merit as part of an effectiveness test when used in conjunction with the other measurements above.

## Implementation of Quantitative Tests

There is a common set of variables needed to calculate all of these measures. These variables are:

- a probability distribution of events that define the exposure
- the amount of subject loss for each event
- the amount of hedge recovery for each event
- the hedge premium
- the timing of payment of the subject loss
- the timing of receipt of the hedge recovery
- the cost of borrowing

The last four of these variables are generally known or can be reasonably estimated at the time the transaction's effectiveness is being evaluated. The first three variables, though, are unknown and therefore must be modeled.

There are at least three ways to model the probability distribution, related losses and hedge recovery.

First, an exposure-based model may be available. Examples of exposure-based models are the catastrophe models used by many insurers to quantify their catastrophe exposure. These models produce estimates of losses under the index and insurer losses under a wide range of scenarios regarding possible catastrophe events. In most hedging situations, the estimated index values for each event will allow the modeler to estimate the hedge recovery, whereas the company losses can be used to determine the subject losses.

Second, models may be built utilizing historical information to develop a probability distribution. For example, if the events leading to the subject losses are sufficiently frequent, the insurer may be able to reference its own historical database to determine the probability and sizes of its subject losses. External information would likely be needed to estimate the hedge recovery related to each scenario in the probability distribution.

Third, the insurer may need to apply judgment in selecting a wide range of possible scenarios and estimating their probabilities, related subject losses and hedge recovery. For example, if an insurer were to develop a new product, it would not have historical experience from which to estimate a probability distribution. Through informed judgment, though, the insurer could estimate the probability distribution of subject losses in a manner similar to that used to estimate expected losses under a new product in the pricing process. Again, external information would likely be needed to estimate the hedge recovery related to each scenario.

In summary, the first three variables in the list above require the insurer to identify a range of scenarios regarding the amounts of subject losses and hedge recoveries and their probabilities.

## Illustrations of Quantitative Tests

The following two examples illustrate these calculations for two sample insurance companies. Appendix D provides the supporting data for the illustrations.

### *ABC Insurance Company*

The ABC Insurance Company is exposed to the risk of a catastrophic loss. ABC wishes to hedge a part of its risk to the capital markets by buying options on the Insurer Loss Index (ILI). Options that pay $1 if the ILI exceeds the option’s strike price are traded on the Insurance Loss Exchange.

Ordinarily, an insurer will purchase options at several strike prices. For example, if it purchased a single option at each strike price over $20 ($21, $22, 23, etc), it would receive ($X – strike price; $0 if $X $\leq$ strike price) whenever the ILI had a value of $X on the settlement date. The timing of hedge recoveries is the same as the timing of loss payment, so there are no borrowing costs.

To hedge its losses, ABC has to decide how many options to buy at each available strike price. Because neither historical data nor a model was available, ABC's management constructed 100 loss scenarios. For each scenario, the following information was developed:

- the probability of the scenario
- the value of the index (I)
- ABC's incurred losses (L)

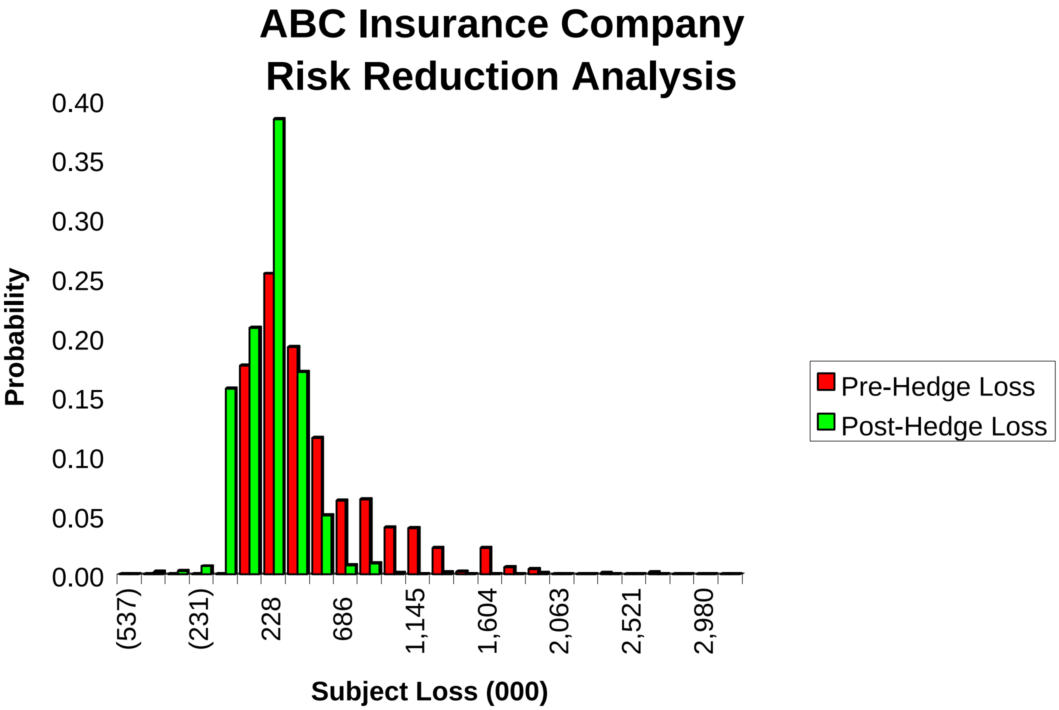
ABC's management decided to hedge its losses in excess of $500,000. That is, its Pre-hedge loss, HL, will be the excess of its loss over $500,000. ABC decided to buy an equal number of contracts at each strike price over $20.

The next step is to calculate the number, N, of options to purchase. Using the scenario information on Exhibit I, management obtained a value of N = 20,070.

For each scenario, the pre-hedge loss and the recovery are given in Appendix D -Exhibit I. ABC incurs a loss in excess of $500,000 in some scenarios when the index values are below $20. Note that the post-hedge net loss (the hedged loss less the recovery) can be both positive and negative. The hedge is not perfect.

To evaluate the effectiveness of the hedge, ABC's management sorted the losses into 25 intervals and calculated the probability of both the direct and net losses falling into each interval. The results are shown in Figure 11.

*Figure 11*



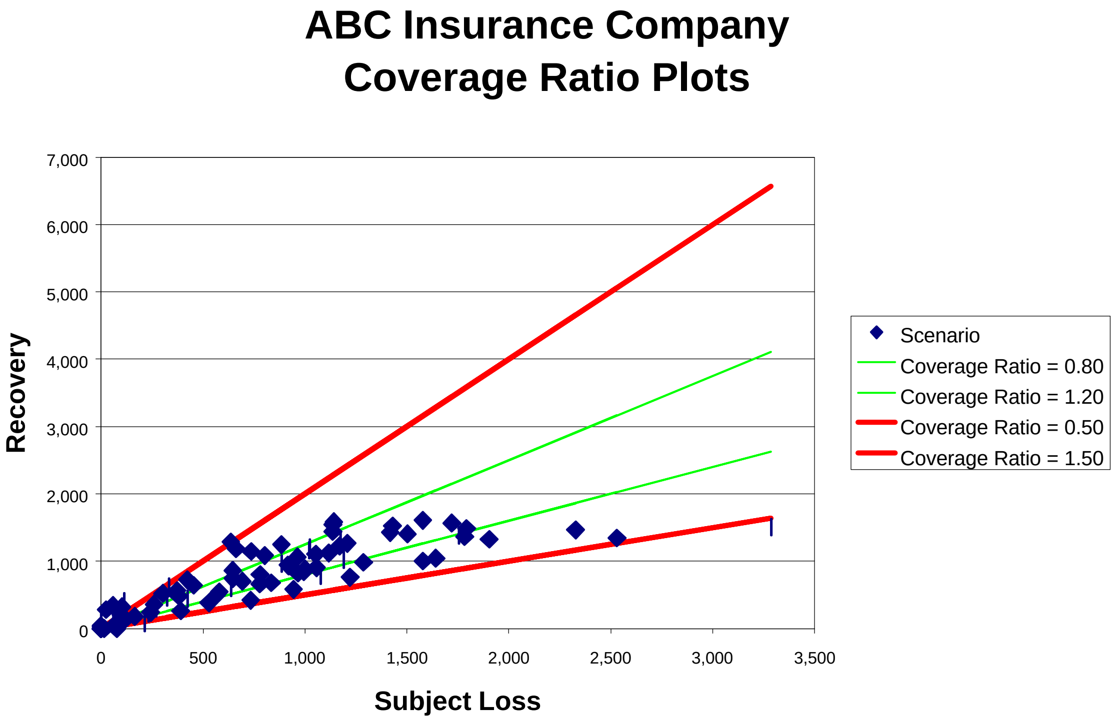
The post-hedge net losses are far less likely to fall in the higher ranges than are the pre-hedge losses. Because graphical representations are not sufficient to evaluate hedge effectiveness, ABC then calculated the values of the hedge effectiveness measures described above. It chose a threshold (Th) of \$1,000,000 for the EPD calculation and a probability level of 1% for the VaR calculation. The results are in Table 1 below.

### *Table 1*
### Risk Reduction Tests

| | |
|---|---|
| **Expected Policyholder Deficit** | |
| EPD with Hedge = | 0.00353 |
| EPD without Hedge = | 0.08413 |
| Difference = | (0.08061) |
| **Value at Risk @1.0%** | |
| VaR with Hedge = | 423,246 |
| VaR without Hedge = | 1,188,799 |
| Difference = | (765,553) |
| **Standard Deviation** | |
| StD with Hedge = | 82,704 |
| StD without Hedge = | 232,153 |
| Difference = | (149,449) |
| **Coverage Ratio (CR) Test** | |
| Pr{0.80<CR<1.20} | 0.821 |
| Pr{0.50<CR<1.50} | 0.859 |
| **Correlation Test** | |
| Corr[HL,R] = | 0.934 |

The significant reductions in EPD, VaR and StD show that risk is reduced. The coverage ratio comparisons have relatively high values. The correlation statistic also shows high correlation for the transaction. Figure 12 shows a scatter plot of the pre-hedge loss and hedge recoveries and graphical presentation of the coverage ratio test.

*Figure 12*

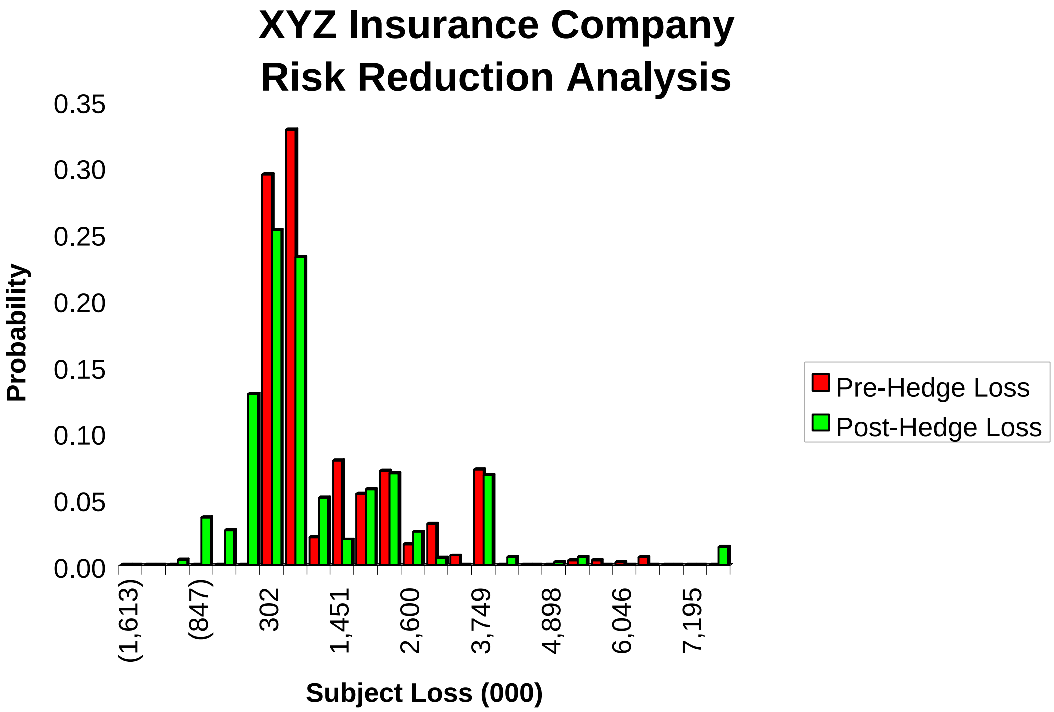


For ABC Insurance Company the variability of the post-hedge loss is less than that of the pre-hedge loss. The hedge effectiveness measures show favorable results. Thus we may be justified in concluding that the ABC Insurance has bought an effective hedge.

*XYZ Insurance Company*

The XYZ Insurance Company is also exposed to the risk of a catastrophic loss. XYZ wishes to hedge a part of its risk to the capital markets by buying options on the ILI. Like ABC, XYZ decided to hedge the losses above $500,000 by purchasing options at strike prices over $20. Its management performed an analysis similar to that done by the ABC Insurance Company. XYZ's management determined they needed to buy 23,325 options. XYZ's scenarios are included in Exhibit II. The comparisons of pre-hedge loss and post-hedge loss are shown in Figure 13.

***Figure 13***



The results of the quantitative tests are shown in Table 2.

***Table 2***

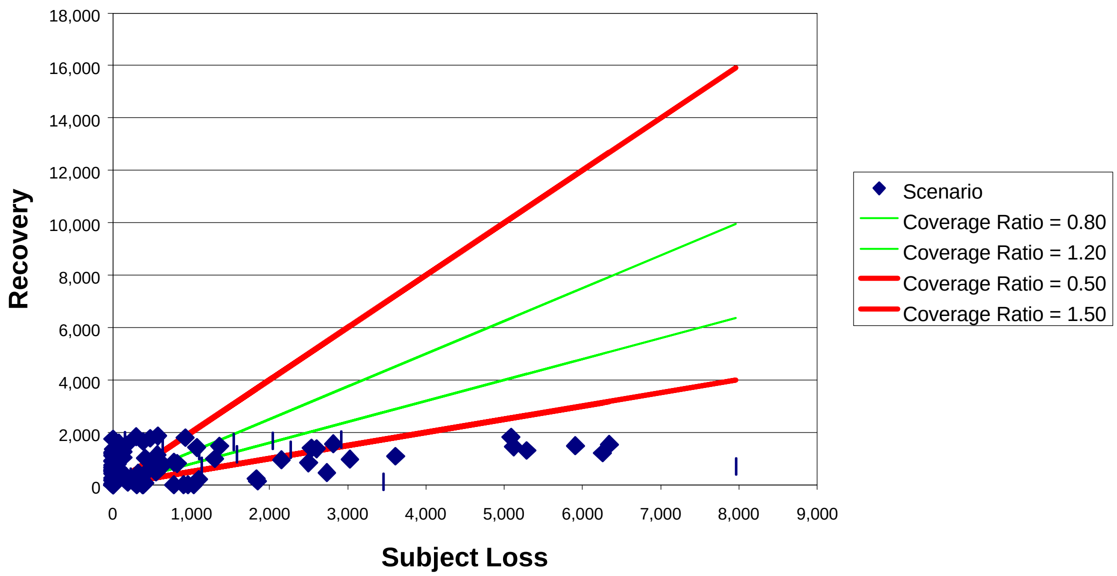
**Risk Reduction Tests**

| | |
|---|---|
| **Expected Policyholder Deficit** | |
| EPD with Hedge = | 0.27493 |
| EPD without Hedge = | 0.30798 |
| Difference = | (0.03305) |
| **Value at Risk @1.0%** | |
| VaR with Hedge = | 3,465,480 |
| VaR without Hedge = | 3,452,326 |
| Difference = | 13,154 |
| **Standard Deviation** | |
| StD with Hedge = | 674,871 |
| StD without Hedge = | 720,081 |
| Difference = | (45,210) |
| **Coverage Ratio (CR) Test** | |
| Pr{0.80<CR<1.20} | 0.624 |
| Pr{0.50<CR<1.50} | 0.649 |
| **Correlation Test** | |
| Corr[HL,R] = | 0.349 |

The above table shows minimal risk reduction as measured by the changes in EPD, VaR and the StD. The coverage ratio and correlation statistics have low values. Figure 14 shows a scatter plot of the pre-hedge loss and hedge recoveries and graphical presentation of the coverage ratio test.

*Figure 14*

**XYZ Insurance Company**
**Coverage Ratio Plots**



For XYZ Insurance Company the variability of the pre-hedge loss is not significantly less than that of the post-hedge loss. The hedge effectiveness measures show less favorable results. Thus we might conclude that XYZ Insurance did not buy an effective hedge.

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# Appendices

# Appendix A

## Indices

The indices are used to determine the trigger and payout of index-based insurance derivatives. This section will discuss indices that have been used or could be used in writing property catastrophe index-based insurance derivatives. The indices have been categorized as either Property Catastrophe Insurance Indices or Parametric Indices.

### *Property Catastrophe Insurance Indices*

Property Catastrophe Insurance Indices are based on losses from property catastrophic events. Below, a brief description is given of the Property Claim Service (PCS) Index, Guy Carpenter Catastrophe Index (GCCI), Risk Management Solutions (RMS) Index, Sigma Index and Sedgwick Global Underwriting Index.

#### Property Claim Service (PCS) Index

This index, which is traded at the Chicago Board of Trade (CBOT), is provided by ISO's Property Claim Services (PCS). This index tracks PCS's estimated insurance industry aggregate direct property losses (in dollars) as a result of catastrophes that occur in the United States. As shown below, there are nine loss indices: a national index, five regional and three state indices.

**PCS Indices**

| **National** | **Regional** | **State** |
|---|---|---|
| US | Eastern | Florida |
| | Northeastern | Texas |
| | Southeastern | California |
| | Midwestern | |
| | Western | |

PCS has a record of insurance catastrophe losses for over 40 years. By definition, a catastrophe is an event that causes more than $25 million of insured property damage and affects a number of policyholders. PCS's estimate is its best judgment of total insurance payments for personal and commercial property lines of insurance covering personal property, time-element losses, vehicles, boats and related property items. Losses due to uninsured publicly owned property and utilities, agriculture, aircraft and property insured under the National Flood Program Write-Your-Own policies and all loss adjustment expenses are not included.

PCS data collection includes a general survey of companies, agents and adjusters; its National Insurance Risk Profile (NIRP); and its own on-the-ground survey. The survey includes about 70% of the market and leads to the development of a composite of individual loss and claim estimates reported by these sources. PCS uses these numbers to extrapolate to total industry losses using market share information. Losses from large or unique catastrophes may continue to develop after the initial estimate. PCS will re-survey these large or unique catastrophes every 60 days until it believes the full insured loss has been determined.

The indices are valued in points; each point is worth $100 million of aggregate industry losses. The index is calculated simply by taking the PCS estimate for insured catastrophic losses in the specified area and time period and dividing by $100 million. The index is rounded to the first decimal point.

## Guy Carpenter Catastrophe Index (GCCI)

The GCCI, which is traded on the Bermuda Commodities Exchange (BCOE), was developed by Guy Carpenter and is calculated by its affiliate IndexCo. ISO provides to IndexCo the exposure data used for the 30 or more companies included in the index.

The index is designed to measure the amount of insured damage to homes in the U.S. from atmospheric perils such as hurricanes, tornadoes, windstorms, hail and freezing. The GCCI is reported in loss-to-value ratios (ratios of insured losses to insured values). The index is published for all 50 states and the District of Columbia; the index for Texas is published using a separate process. The index can be customized to almost any area within the United States.

The GCCI is calculated on two bases: 1) on a per event basis and 2) on an aggregate basis. For “the event,” GCCI measures the damage from the largest event during a given time period. For “the aggregate,” GCCI measures the total catastrophe damage during a given time period.

The line of business covered is homeowners property insurance (direct business under multi-peril policies that are on owner-occupied dwellings only). It excludes claims under condominium or tenants policies, mobile homes, FAIR Plans or Pools and home business coverage. Losses under other perils such as flood, fire, lightning, earthquake and riot are also excluded. For a company’s data to be eligible to be included in the GCCI, it must have at least 2.0% of the homeowners market in at least one state or in the District of Columbia. Unlike the PCS index, there is no minimum catastrophe threshold.

The most detailed reporting unit for the index is at the ZIP-code level or through a group of ZIP codes brought together to form a larger credible geographic area. The index can then be aggregated at any other higher level. For a ZIP code to qualify as a reporting unit, it must have at least 1,000 owner-occupied housing units and at least four participating companies, each providing data on at least ten homes with a minimum of $700,000 of insured housing value, in aggregate, in that ZIP code. If a ZIP code does not qualify as a reporting unit, it is grouped together with other ZIP codes until qualifying as a reporting unit.

The index can be calculated as follows:

- In each reporting unit, calculate the admitted company loss-to-value ratio (atmospheric losses under coverage A, B, C and D, divided by the company's exposure or coverage A insurance amount).
- Add, without weight, all participating companies' loss-to-value ratios within the reporting unit. Divide the sum by the number of participating companies.
- To aggregate the index for larger geographic areas, the reporting unit indices are aggregated using the housing values as weights.

The index is published for the following two 6-month periods: January 1 through June 30 and July 1 through December 31. During the development period, the GCCI index is published six times. The chart below summarizes the development and publication dates.

**Development and Publication Dates**

| Name of Publication Date | Publication Date | Losses Incurred and Paid as of Date |
|---|---|---|
| Partial Period | 1 month after period | 1st 3 months into period |
| Full Period | 4 months after period | End of period |
| First Update | 7 months after period | 3 months after period |
| Second Update | 10 months after period | 6 months after period |
| Third Update | 13 months after period | 9 months after period |
| Fourth Update | 16 months after period | 12 months after period |

## Risk Management Solutions (RMS) Index

The RMS index was created for over-the-counter products. In order to produce a model-generated loss estimate, it runs a catastrophe model against an industry exposure base. When all parameters of a catastrophic event are known after a catastrophe, such as central pressure, forward speed and radius of the maximum wind, they are input into a catastrophe model to determine the model-generated loss. Model-generated losses for perils such as hurricanes, typhoons, cyclones and earthquakes can be calculated for events occurring worldwide. Model-generated losses are divided by $100 million and rounded to the nearest integer to obtain the index value. The index is available on both an event and aggregate basis.

The event threshold (Richter scales) for earthquakes varies from 5.0 to 7.0 by region. The event threshold for hurricanes is Saffir-Simpson category 1 or higher. The model-generated losses can be reported at the ZIP-code level for various periods. Final index values are available 28 days following an event.

### Sigma Index

The “Sigma Index” was initially not designed to be an index, but it could be used as such in derivative transactions. Each year, Swiss Reinsurance Company publishes an issue of “Sigma” on both natural catastrophes and man-made disasters that are included as events. Natural catastrophes include floods, storms, earthquakes (including seaquakes and tsunamis), droughts, brush fires (including heat waves), cold, frost and others (including hail and avalanches). Man-made disasters include major fires, explosions, aviation disasters, shipping disasters, road/rail disasters, mining accidents, collapses of building/bridges and miscellaneous (including terrorism). The index is used for international securitizations.

Losses are defined as all insurance losses worldwide, with the exclusion of third-party liability. If insurance is not available, estimates of total loss are used. Sigma has published tables listing major losses since 1970. Minimum catastrophe limits are inflation adjusted from year to year. Limits for insurance losses are set for shipping, aviation, other losses and total losses. Minimum limits for personal injury are also set for persons dead and/or missing, injured and homeless.

The sources of data are daily newspapers, Property Claims Service (PCS), primary insurance and reinsurance periodicals, specialist publications, as well as reports from primary insurance and reinsurance companies.

### Sedgwick Global Underwriting Index

This index is based on Lloyd’s Global Results. An underwriting ratio is the basis for the index and is defined as Lloyd’s net claims divided by net premium for the underwriting year. A Sedgwick Global Underwriting Index point is equal to a 1% loss ratio. Therefore, an index value of 100.00 indicates a loss ratio of 100%. The index can be used to hedge a company’s underwriting risk, provided the company’s existing portfolio is correlated with the Lloyd’s global result.

## *Parametric Indices*

Parametric indices use a set of parameters to define an event.  Examples of parametric indices include the Saffir-Simpson Scale, the Richter Scale and the Fujita Scale.

Other parametric indices may include abnormal weather conditions such as the number of days with a predefined temperature (too hot or too cold), amount of rain (too much or too little), or amount of snow (too much or too little).  These other parametric indices are used in weather derivatives, which are described in Appendix C.

# Key Characteristics of Property Catastrophe Insurance Indices

| | **PCS** | **Guy Carpenter** | **RMS** | **Sigma** | **Sedgwick** |
|---|---|---|---|---|---|
| Area Covered | USA | USA | Worldwide | Worldwide | Worldwide |
| Reporting Units | Individual states | ZIP codes or collection of ZIP codes | ZIP codes | Country/state | Worldwide |
| Insured Exposure | Property | HO | Single-family dwelling, renters, condos, mobile homes | All excluding third-party liability | Lloyd's Global Results |
| Perils | Hurricanes, tornadoes, hail, windstorms, winter freezes, earthquakes riots, fires, floods and explosions | Hurricanes, tornadoes, hail, windstorms and winter freezes | Hurricanes, typhoons, cyclones, earthquakes | Natural catastrophes (floods, storms, EQ, drought and brush fires, cold/frost, other), man-made disasters (major fires and explosions, aviation, shipping, road/rail, mining accidents, collapse of buildings/bridges, misc.) | Lloyd's Global Results |
| Index Basis | Dollars | Loss to value ratios | Dollars | Dollars, persons dead/missing injured or homeless | Underwriting Ratio |
| Source of Data | ISO's Property Claim Services Unit | Insurers reporting to ISO with at least 2% of one state's market | IRAS catastrophe model | Daily newspapers, primary insurance and reinsurance periodicals, specialist publications | Lloyd's Global Results |
| Event Thresholds | $25 million insured property losses | None | Richter Scale of 5-7 depending on region, Saffir-Simpson Category 1 or higher | *Insurance Losses in 1998:*<br>Shipping - $12.8M<br>Aviation - $25.7M<br>Other losses - $32.3 M<br>Total losses - $64.6 M<br>*Personal injury:*<br>Dead/missing - 20<br>Injured - 50<br>Homeless - 2,000 | N/A |
| Where Index Traded | CBOT | BCOE | OTC | OTC | OTC |

# Appendix B

# Exchange Traded Catastrophe Options

Catastrophe Options can be traded in over-the-counter type transactions or traded on an exchange. Currently, there are two exchanges that trade catastrophe options: the Chicago Board of Trade (CBOT) and the Bermuda Commodities Exchange[1] (BCOE). A brief description of the options traded on each of these exchanges is given below.

## *PCS Options on the CBOT*

The CBOT started trading the PCS catastrophe insurance options in 1995. The options are traded based on the PCS indices, which are available for nine areas, a national index, five regional indices and three state indices, as shown below.

**PCS Indices**

| **National** | **Regional** | **State** |
|---|---|---|
| US | Eastern | Florida |
| | Northeastern | Texas |
| | Southeastern | California |
| | Midwestern | |
| | Western | |

Contracts are available for the following periods:

| **Contract Month** | **Loss Period** |
|---|---|
| March | January-March |
| June | April-June |
| September | July-September |
| December | October-December |
| Annual | January-December |

The PCS Options have a 12-month development period. During this development period, PCS may re-estimate the catastrophe losses for the loss period. The exercise style is European, which means the options can be exercised at expiration only.

---

[1] Recently the BCOE suspended the trading of GCCI options. This document assumes that the BCOE will resume trading GCCI options at some time in the future. The BCOE options, as described in this paper and appendix, are based on information provided by the BCOE through its web site.

The premiums or prices for the CBOT options are quoted in points and tenths of a point. Each point is worth $200 and each tenth of a point is worth $20. As mentioned in Appendix A, each point also represents $100 million in industry aggregate losses. Suppose a call option with a strike price of 20 were purchased. This equates to industry losses of 20 X $100 million or $2 billion. At the end of the relevant period, the PCS index is reported as 40. This equates to industry losses of the amount of 40 X $100 million or $4 billion. The value of the option is calculated as the difference between the index and the strike price times $200. The option would be worth $200 x (40-20) or $4,000.

The above example would give the buyer of the call option unlimited protection in case the industry losses were above $2 billion. A layer of losses can also be hedged by simultaneously buying an option at one strike price and selling a call option at a higher strike price. This can be accomplished by buying a CBOT option spread. Suppose a 20/40 PCS call option spread were purchased. This option spread would pay off if industry losses were greater than $2 billion. If losses were in excess of $2 billion, the option payment would be equal to the difference between the index and the strike price (20) times $200. The maximum payment would be (40-20) X $200, or $4,000.

## *Catastrophe Options on the BCOE*

The Bermuda Commodities Exchange was incorporated on July 22, 1996 pursuant to the Bermuda Commodities Exchange Act, 1996 for the purpose of listing for trading, futures contracts and options. This index has been temporarily suspended at the time of writing this paper. The options trading is based on the GCCI indices, which are published for six areas as shown below:

**GCCI Indices**

| National | Regional | State |
|---|---|---|
| United States | Northeast | Florida |
| | Southeast | |
| | Gulf States | |
| | West & Midwest | |

The BCOE contract is binary, which means that if the option is greater than or equal to the designated strike price of the option, the entire cash value of the option is paid. Each BCOE option contract pays $5000 if the contract strike price is obtained. If the strike price is not obtained, the buyer of the option receives no payments. The strike prices are based on GCCI indices. GCCI indices are loss-to-value ratios. Appendix A gives more information on the calculation of the GCCI indices. One may take the strike price and divide by 10,000 to obtain the GCCI index.

Suppose an option with a strike price of $300 for a specified region is purchased, and this region had an owner-occupied housing unit insured value of $500 billion. The GCCI index equivalent to the strike price is 300/10,000, or .03. Industry losses equivalent to this strike price are .03 X 500 billion or $15 billion. If industry losses exceed $15 billion, a cash payment of $5,000 is received. If industry losses are less than $15 billion, no payment is received. More specifics on exercising an option are given in the table on the following page.

Contracts are available for the following two 6 month periods: January 1 through June 30 and July 1 through December 31. See Appendix A for a description of publication dates and development of the index. The option will be automatically exercised at the first publication date where certain conditions are met, as described in the following table:

**Automatic Execution of BCOE Options**

| **Name of Publication Date** | **$5000 Settlement Made** | **No Settlement Made** |
|---|---|---|
| Partial Period | Index value is greater than or equal to 110% of the strike price | N/A |
| Full Period | Index value is greater than or equal to 110% of the strike price | N/A |
| First Update | Index value is greater than or equal to 110% of the strike price | Index value is less than 25% of the strike price |
| Second Update | Index value is greater than or equal to 110% of the strike price | Index value is less than 50% of the strike price |
| Third Update | Index value is greater than or equal to 100% of the strike Price | Index value is less than 100% of the strike price |

Three types of option contracts are available: 1) Single Loss Catastrophe Option that covers homeowners losses as a result of the largest atmospheric loss event, 2) Secondary Loss Catastrophe Option that covers homeowners losses as a result of the 2nd largest atmospheric loss event, 3) Aggregate Catastrophe Option that covers total homeowners losses as a result of all atmospheric loss events.

## Key Characteristics of Property Catastrophe Option Products

| Exchange | CBOT | BCOE | OTC |
|---|---|---|---|
| Contract Types | Aggregate loss | Single loss, second loss, aggregate loss | Negotiated |
| Locations traded | USA, Northeast, Southeast, East, Midwest, West, CA, FL, TX | USA, Northeast, Southeast, Gulf States, West and Midwest, FL | Negotiated |
| Nature of Option | European | Binary | Negotiated |
| Period Covered | Quarter, Annual | Semi-annual | Various |
| Development Period | 12 Months | Maximum is 9 months (Reported at 13 months) | N/A |

## Appendix C

# Weather Derivatives

The information below was obtained from Worldwide Weather Trading Company, LLC (“WWTC”), a New York-based trading company offering weather hedges covering specified worldwide weather conditions including temperature, rainfall and snowfall.

### *General*

A weather hedge can help protect gross margins of companies whose sales revenues are at risk because of adverse weather conditions. While most traditional hedges have focused on minimizing supply side fluctuations in price, the weather hedge is one of the first products that can hedge the demand variable.

Through traditional Wall Street products such as swaps and options, companies can help hedge against the negative financial impact of most weather perils. These perils include:

- temperature (too hot or too cold)
- rain (too much or too little)
- snow (too much or too little)

Weather hedges reflect weather conditions at a:

- specific location
- group of locations (basket)

Transactions include:

- duration (monthly, seasonal, annual)
- payouts (maximum amount, weather event increments)

WWTC buys and sells put options, call options and swaps for three types of weather perils:

- Temperature: The most common representation of a temperature contract involves heating and cooling degrees, which are described below. WWTC will also write contracts for average, maximum and minimum temperature over a determined time period.

- ➢ Heating degree days are a measure of how much energy is required to heat a dwelling to 65 degrees Fahrenheit. It is calculated by taking the average daily temperature for a location and subtracting this value from 65. Negative values are treated as zero. The more heating degree days, the colder the weather.
- ➢ Cooling degree days measure the amount of energy required to cool a dwelling to 65 degrees. Subtract 65 from the average daily temperature, with negative values treated as zero. The more cooling degree days, the warmer the weather.
- ➢ Typically, the heating degree season is winter, and the cooling degree season is summer.

- Precipitation: The amount of rainfall, or melted equivalent of snow, over a determined period. WWTC will also write contracts for pure rainfall (sans melted equivalent of snow) where possible.

- Snowfall: The amount of snow measured over a determined period of time.

Three examples of trades are provided: a heating degree call, a cooling degree put and an average-temperature swap.

1) Example of a snowfall call:

   An airline estimates that it will lose $10,000 for every inch of snow greater than 45.0 between November 1 and March 31. Flights get cancelled, passengers get bumped and routes get changed. The station of interest (reference station) is Philadelphia International Airport, where the airline has a major hub.

   The transaction:

   The airline (counterparty) purchases a snowfall call option for Philadelphia International Airport for the period November 1 to March 31. For every inch of snow in excess of 45.0, WWTC pays the counterparty $10,000 with a cumulative amount not to exceed $1,000,000. For the service of hedging its risk, the airline pays WWTC a premium of $22,000[*].

   March 31 comes and goes, and National Climatic Data Center reports that at Philadelphia International Airport, 60.0 inches of snow fell between November 1 and March 31. WWTC pays the airline (60.0 - 45.0 inches) x $10,000 = $150,000. WWTC retains the premium; the airline's cost of hedging its risk. The airline has diminished its $150,000 adverse weather operational expense into a $22,000 cost incursion.

---

[*] Example only - Premium will vary by trade.

Heating and cooling degree calls may also be purchased and sold through WWTC (and are most common), as may precipitation calls.

2) Example of a cooling day degree put:

A large energy company in Northern Illinois estimates it loses $50,000 for every cooling degree day (CDD) less than 600 over the period June 1 to August 31. The colder the summer, the less electricity the company will sell to customers who use air conditioners. It is interested in hedging its exposure to a cool summer in the Chicago area.

The transaction:

The energy company (counterparty) takes out a CDD put option with a strike level of 600. For every CDD below 600 over the period June 1 to August 31, WWTC will pay the counterparty $50,000 with a cumulative amount not to exceed $5,000,000. The reference station is Chicago O'Hare International Airport. For hedging its risk, the counterparty pays WWTC a premium in the amount of $600,000[*].

On September 1, the National Climatic Data Center reports that between June 1 and August 31 there were 550 cooling degree days at Chicago O'Hare International Airport. Because this is a put option, WWTC pays the energy counterpart an amount of (600 - 550 CDD) x 50,000 = $2,500,000. WWTC retains the $600,000 premium. With an outlay of $600,000, the energy company has saved $1,900,000 in potential loss through purchasing the derivative instrument.

WWTC also buys and sells put option contracts for heating degree days, rain, precipitation and snowfall.

3) Example of Average Temperature Swap

An amusement park's revenues fall sharply when the average daily temperature rises above 96 degrees. The park (counterparty) is located near Phoenix, Arizona and wants to have consistent revenue. Consequently, it is willing to pay for the privilege of protecting itself from a hot summer, which depresses attendance.

---

[*] Example only - Premium will vary by trade.

At the same time, a large area ice cream chain benefits from the same hot summer. It sells a lot of ice cream to customers seeking relief from the summer heat. It estimates that its profits fall sharply when average daily temperatures fall below 96 degrees in Phoenix. The ice cream counterparty makes a natural swap for the amusement park because it has opposite risk hedging interests for the same peril (a hot summer).

The transaction:

The amusement park buys a swap from WWTC at Phoenix Sky Harbor International Airport. The strike level is 15 days, in which the average daily temperature exceeds 96 degrees during June through August. For every day in excess of 15, WWTC pays out $50,000/day with a cumulative amount not to exceed $1,000,000 (the maximum payout is realized if 35 days exceed 96 degrees).

Should the number of days over 96 degrees fall below 15, the counterparty pays WWTC under the negotiated terms of the swap. These terms are usually the same ones they are receiving from WWTC (in other words, $50,000 per day below 15 with the same maximum payout of $1,000,000).

In turn, the ice cream company sells a swap to WWTC, in which WWTC collects if the number of summer days greater than 96 degrees exceeds 15. The ice cream company receives payment from WWTC if the number of days falls below 15. WWTC has, in effect, matched up the amusement park and the ice cream company because their risks are the flip sides of the same coin.

WWTC will swap risks in temperature (including heating and cooling degree days), rainfall, precipitation and snow.

## Appendix D

### *Explanation of Exhibits I and II*

Exhibits I and II give details for the scenarios for the ABC Insurance Company and the XYZ Insurance Company. An explanation of the data elements associated with each scenario follows.

1. Probability of the Scenario
2. Ground Up Loss (L)

   The loss incurred by the insurance company in each scenario.
3. Index Value (I)

   The value of the Insurance Loss Index (ILI) that is associated with each scenario.
4. Purchased Index

   The amount of money received by ABC or XYZ if they had purchased one contract at each strike price above 20 when the final index value is I. In these cases it is I – 20.
5. Pre-Hedged Loss (HL)

   HL = Max (L-500000, 0). Both ABC and XYZ decided to hedge the excess portion of their ground up losses over $500,000. The $\text{VaR}_{@1\%}$ (pre-hedge) is the smallest HL for which the sum of the probabilities of all scenarios with larger HL's is less than 1%.
6. Number of Options Purchased (N)

   The number of options purchased by ABC and XYZ to hedge their loss.
7. Index Recovery (R)

   R = N times the Purchased Index. R represents the amount the insurer would recover if the index hit I.
8. Coverage Ratio (CR)

   CR = R/HL. If both R and HL are zero, RR = 1.000 because the result is deemed favorable. If exactly one of R or HL is zero, CR = 0.000 because the result is deemed unfavorable.

9. Post-Hedge Net Loss (NL)

   NL = HL – R. NL is the net insurer loss after purchasing N options. The $\text{VaR}_{@1\%}$ (post-hedge) is the smallest NL for which the sum of the probabilities of all scenarios with larger NL's is less than 1%.

10. Direct Policyholder Deficit

    Direct policyholder deficit = Max (HL – EPD Threshold, 0). ABC and XYZ used $1,000,000 as the EPD Threshold. The EPD without a hedge is the probability weighted average of the direct policyholder deficits for each scenario, found at the bottom of the exhibit.

11. Net Policyholder Deficit

    Net policyholder deficit =Max (NL + Expected HL/0.700 – EPD Threshold, 0). The Expected HL/0.700 is assumed to be the hedge premium. ABC and XYZ used $1,000,000 as its EPD Threshold. The EPD with a hedge is the probability weighted average of the net policyholder deficits for each scenario, found at the bottom of the exhibit.

Calculation of Number of Options Purchased - ABC

ABC's management found the value of N that minimized the Var[Pre-Hedge loss – recovery], where the recovery, R, is $N \times (I - 20)$ for $I > 20$ and zero for $I \leq 20$. N = Cov[R, Pre-Hedge Loss]/Var[R]. Using the scenario information on Exhibit I, management obtained a value of N = 20,070.

Calculation of Number of Options Purchased – XYZ

XYZ's management found the value of N that minimized the Var[Pre-Hedge loss – recovery], where the recovery, R, is $N \times (I - 20)$ for $I > 20$ and zero for $I \leq 20$. N = Cov[R, Pre-Hedge Loss]/Var[R]. Using the scenario information on Exhibit II, management obtained a value of N = 23,235.

## *Exhibit I – ABC Insurance Company Scenarios*

| Pr{Scenario} | Ground Up Loss (L) | Index Values (I) | Purchased Index | Pre-Hedge Loss Loss (HL) | Number of Options (N) | Index Recovery(R) | Coverage Ratio (RR) | Post-Hedge Net Loss (NL) | Direct PD | Net PD |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.075000 | 0 | 0 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.068750 | 18,837 | 1 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.063063 | 35,018 | 2 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.057884 | 56,210 | 3 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.053168 | 111,519 | 4 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.048869 | 85,855 | 5 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.044949 | 141,620 | 6 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.041373 | 174,181 | 7 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.038109 | 165,982 | 8 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.035127 | 174,975 | 9 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.032402 | 188,221 | 10 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.029911 | 267,603 | 11 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.027630 | 201,260 | 12 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.025543 | 288,813 | 13 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.023630 | 374,361 | 14 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.021877 | 366,804 | 15 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.020268 | 515,852 | 16 | 0 | 15,852 | 0 | 0 | 0.000 | 15,852 | 0 | 0 |
| 0.018792 | 347,740 | 17 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.017435 | 372,554 | 18 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.016188 | 576,252 | 19 | 0 | 76,252 | 0 | 0 | 0.000 | 76,252 | 0 | 0 |
| 0.015041 | 390,658 | 20 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.013985 | 415,635 | 21 | 1 | 0 | 20,070 | 20,070 | 0.000 | (20,070) | 0 | 0 |
| 0.013012 | 382,116 | 22 | 2 | 0 | 20,070 | 40,140 | 0.000 | (40,140) | 0 | 0 |
| 0.012115 | 569,436 | 23 | 3 | 69,436 | 20,070 | 60,210 | 0.867 | 9,226 | 0 | 0 |
| 0.011288 | 712,471 | 24 | 4 | 212,471 | 20,070 | 80,280 | 0.378 | 132,191 | 0 | 0 |
| 0.010524 | 437,281 | 25 | 5 | 0 | 20,070 | 100,350 | 0.000 | (100,350) | 0 | 0 |

## Exhibit I (Continued) – ABC Insurance Company Scenarios

| Pr{Scenario} | Ground Up Loss (L) | Index Values (I) | Purchased Index | Pre-Hedge Loss Loss (HL) | Number of Options (N) | Index Recovery(R) | Coverage Ratio (RR) | Post-Hedge Net Loss (NL) | Direct PD | Net PD |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.009819 | 412,251 | 26 | 6 | 0 | 20,070 | 120,420 | 0.000 | (120,420) | 0 | 0 |
| 0.009166 | 620,025 | 27 | 7 | 120,025 | 20,070 | 140,490 | 1.171 | (20,465) | 0 | 0 |
| 0.008562 | 559,314 | 28 | 8 | 59,314 | 20,070 | 160,560 | 2.707 | (101,246) | 0 | 0 |
| 0.008003 | 664,739 | 29 | 9 | 164,739 | 20,070 | 180,630 | 1.096 | (15,891) | 0 | 0 |
| 0.007486 | 597,506 | 30 | 10 | 97,506 | 20,070 | 200,700 | 2.058 | (103,195) | 0 | 0 |
| 0.007005 | 732,572 | 31 | 11 | 232,572 | 20,070 | 220,770 | 0.949 | 11,802 | 0 | 0 |
| 0.006560 | 742,932 | 32 | 12 | 242,932 | 20,070 | 240,840 | 0.991 | 2,092 | 0 | 0 |
| 0.006146 | 891,205 | 33 | 13 | 391,205 | 20,070 | 260,910 | 0.667 | 130,295 | 0 | 0 |
| 0.005761 | 526,084 | 34 | 14 | 26,084 | 20,070 | 280,980 | 10.772 | (254,896) | 0 | 0 |
| 0.005404 | 769,526 | 35 | 15 | 269,526 | 20,070 | 301,050 | 1.117 | (31,525) | 0 | 0 |
| 0.005071 | 603,195 | 36 | 16 | 103,195 | 20,070 | 321,120 | 3.112 | (217,926) | 0 | 0 |
| 0.004761 | 557,520 | 37 | 17 | 57,520 | 20,070 | 341,191 | 5.932 | (283,671) | 0 | 0 |
| 0.004472 | 760,388 | 38 | 18 | 260,388 | 20,070 | 361,261 | 1.387 | (100,873) | 0 | 0 |
| 0.004203 | 1,029,117 | 39 | 19 | 529,117 | 20,070 | 381,331 | 0.721 | 147,786 | 0 | 0 |
| 0.003952 | 611,761 | 40 | 20 | 111,761 | 20,070 | 401,401 | 3.592 | (289,639) | 0 | 0 |
| 0.003717 | 1,233,003 | 41 | 21 | 733,003 | 20,070 | 421,471 | 0.575 | 311,532 | 0 | 0 |
| 0.003498 | 923,391 | 42 | 22 | 423,391 | 20,070 | 441,541 | 1.043 | (18,150) | 0 | 0 |
| 0.003293 | 822,099 | 43 | 23 | 322,099 | 20,070 | 461,611 | 1.433 | (139,511) | 0 | 0 |
| 0.003102 | 881,297 | 44 | 24 | 381,297 | 20,070 | 481,681 | 1.263 | (100,383) | 0 | 0 |
| 0.002922 | 1,067,856 | 45 | 25 | 567,856 | 20,070 | 501,751 | 0.884 | 66,105 | 0 | 0 |
| 0.002754 | 802,148 | 46 | 26 | 302,148 | 20,070 | 521,821 | 1.727 | (219,673) | 0 | 0 |
| 0.002597 | 1,080,478 | 47 | 27 | 580,478 | 20,070 | 541,891 | 0.934 | 38,587 | 0 | 0 |
| 0.002450 | 872,756 | 48 | 28 | 372,756 | 20,070 | 561,961 | 1.508 | (189,204) | 0 | 0 |
| 0.002311 | 1,444,624 | 49 | 29 | 944,624 | 20,070 | 582,031 | 0.616 | 362,593 | 0 | 0 |
| 0.002181 | 1,137,261 | 50 | 30 | 637,261 | 20,070 | 602,101 | 0.945 | 35,160 | 0 | 0 |

## Exhibit I (Continued) – ABC Insurance Company Scenarios

| Pr{Scenario} | Ground Up Loss (L) | Index Values (I) | Purchased Index | Pre-Hedge Loss Loss (HL) | Number of Options (N) | Index Recovery(R) | Coverage Ratio (RR) | Post-Hedge Net Loss (NL) | Direct PD | Net PD |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.002059 | 832,701 | 51 | 31 | 332,701 | 20,070 | 622,171 | 1.870 | (289,470) | 0 | 0 |
| 0.001945 | 952,924 | 52 | 32 | 452,924 | 20,070 | 642,241 | 1.418 | (189,317) | 0 | 0 |
| 0.001837 | 1,279,051 | 53 | 33 | 779,051 | 20,070 | 662,311 | 0.850 | 116,740 | 0 | 0 |
| 0.001736 | 1,334,881 | 54 | 34 | 834,881 | 20,070 | 682,381 | 0.817 | 152,500 | 0 | 0 |
| 0.001641 | 1,193,660 | 55 | 35 | 693,660 | 20,070 | 702,451 | 1.013 | (8,791) | 0 | 0 |
| 0.001551 | 923,774 | 56 | 36 | 423,774 | 20,070 | 722,521 | 1.705 | (298,747) | 0 | 0 |
| 0.001467 | 1,146,708 | 57 | 37 | 646,708 | 20,070 | 742,591 | 1.148 | (95,883) | 0 | 0 |
| 0.001387 | 1,721,460 | 58 | 38 | 1,221,460 | 20,070 | 762,661 | 0.624 | 458,799 | 221,460 | 0 |
| 0.001312 | 1,575,833 | 59 | 39 | 1,075,833 | 20,070 | 782,731 | 0.728 | 293,102 | 75,833 | 0 |
| 0.001242 | 1,280,044 | 60 | 40 | 780,044 | 20,070 | 802,801 | 1.029 | (22,757) | 0 | 0 |
| 0.001175 | 1,465,160 | 61 | 41 | 965,160 | 20,070 | 822,871 | 0.853 | 142,288 | 0 | 0 |
| 0.001112 | 1,493,667 | 62 | 42 | 993,667 | 20,070 | 842,941 | 0.848 | 150,725 | 0 | 0 |
| 0.001053 | 1,145,372 | 63 | 43 | 645,372 | 20,070 | 863,011 | 1.337 | (217,639) | 0 | 0 |
| 0.000997 | 1,500,146 | 64 | 44 | 1,000,146 | 20,070 | 883,081 | 0.883 | 117,065 | 146 | 0 |
| 0.000944 | 1,555,300 | 65 | 45 | 1,055,300 | 20,070 | 903,151 | 0.856 | 152,149 | 55,300 | 0 |
| 0.000894 | 1,418,597 | 66 | 46 | 918,597 | 20,070 | 923,221 | 1.005 | (4,625) | 0 | 0 |
| 0.000847 | 1,416,212 | 67 | 47 | 916,212 | 20,070 | 943,291 | 1.030 | (27,079) | 0 | 0 |
| 0.000803 | 1,383,521 | 68 | 48 | 883,521 | 20,070 | 963,361 | 1.090 | (79,841) | 0 | 0 |
| 0.000761 | 1,787,866 | 69 | 49 | 1,287,866 | 20,070 | 983,431 | 0.764 | 304,434 | 287,866 | 0 |
| 0.000721 | 2,079,182 | 70 | 50 | 1,579,182 | 20,070 | 1,003,502 | 0.635 | 575,681 | 579,182 | 0 |
| 0.000683 | 1,688,799 | 71 | 51 | 1,188,799 | 20,070 | 1,023,572 | 0.861 | 165,227 | 188,799 | 0 |
| 0.000648 | 2,141,834 | 72 | 52 | 1,641,834 | 20,070 | 1,043,642 | 0.636 | 598,193 | 641,834 | 0 |
| 0.000614 | 1,462,276 | 73 | 53 | 962,276 | 20,070 | 1,063,712 | 1.105 | (101,435) | 0 | 0 |
| 0.000582 | 1,302,365 | 74 | 54 | 802,365 | 20,070 | 1,083,782 | 1.351 | (281,416) | 0 | 0 |
| 0.000552 | 1,552,433 | 75 | 55 | 1,052,433 | 20,070 | 1,103,852 | 1.049 | (51,418) | 52,433 | 0 |

## Exhibit I (Continued) – ABC Insurance Company Scenarios

| Pr{Scenario} | Ground Up Loss (L) | Index Values (I) | Purchased Index | Pre-Hedge Loss Loss (HL) | Number of Options (N) | Index Recovery(R) | Coverage Ratio (RR) | Post-Hedge Net Loss (NL) | Direct PD | Net PD |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.000524 | 1,617,986 | 76 | 56 | 1,117,986 | 20,070 | 1,123,922 | 1.005 | (5,936) | 117,986 | 0 |
| 0.000497 | 1,236,455 | 77 | 57 | 736,455 | 20,070 | 1,143,992 | 1.553 | (407,537) | 0 | 0 |
| 0.000471 | 1,518,776 | 78 | 58 | 1,018,776 | 20,070 | 1,164,062 | 1.143 | (145,286) | 18,776 | 0 |
| 0.000447 | 1,162,665 | 79 | 59 | 662,665 | 20,070 | 1,184,132 | 1.787 | (521,467) | 0 | 0 |
| 0.000424 | 1,522,733 | 80 | 60 | 1,022,733 | 20,070 | 1,204,202 | 1.177 | (181,469) | 22,733 | 0 |
| 0.000402 | 1,669,132 | 81 | 61 | 1,169,132 | 20,070 | 1,224,272 | 1.047 | (55,139) | 169,132 | 0 |
| 0.000381 | 1,383,460 | 82 | 62 | 883,460 | 20,070 | 1,244,342 | 1.408 | (360,882) | 0 | 0 |
| 0.000362 | 1,708,030 | 83 | 63 | 1,208,030 | 20,070 | 1,264,412 | 1.047 | (56,382) | 208,030 | 0 |
| 0.000343 | 1,135,709 | 84 | 64 | 635,709 | 20,070 | 1,284,482 | 2.021 | (648,773) | 0 | 0 |
| 0.000326 | 1,672,351 | 85 | 65 | 1,172,351 | 20,070 | 1,304,552 | 1.113 | (132,201) | 172,351 | 0 |
| 0.000309 | 2,403,550 | 86 | 66 | 1,903,550 | 20,070 | 1,324,622 | 0.696 | 578,928 | 903,550 | 0 |
| 0.000294 | 3,031,031 | 87 | 67 | 2,531,031 | 20,070 | 1,344,692 | 0.531 | 1,186,339 | 1,531,031 | 264,539 |
| 0.000279 | 2,283,397 | 88 | 68 | 1,783,397 | 20,070 | 1,364,762 | 0.765 | 418,635 | 783,397 | 0 |
| 0.000264 | 2,253,717 | 89 | 69 | 1,753,717 | 20,070 | 1,384,832 | 0.790 | 368,885 | 753,717 | 0 |
| 0.000251 | 2,002,600 | 90 | 70 | 1,502,600 | 20,070 | 1,404,902 | 0.935 | 97,698 | 502,600 | 0 |
| 0.000238 | 1,918,076 | 91 | 71 | 1,418,076 | 20,070 | 1,424,972 | 1.005 | (6,897) | 418,076 | 0 |
| 0.000226 | 1,636,795 | 92 | 72 | 1,136,795 | 20,070 | 1,445,042 | 1.271 | (308,247) | 136,795 | 0 |
| 0.000215 | 2,827,094 | 93 | 73 | 2,327,094 | 20,070 | 1,465,112 | 0.630 | 861,982 | 1,327,094 | 0 |
| 0.000204 | 2,292,350 | 94 | 74 | 1,792,350 | 20,070 | 1,485,182 | 0.829 | 307,168 | 792,350 | 0 |
| 0.000194 | 3,785,847 | 95 | 75 | 3,285,847 | 20,070 | 1,505,252 | 0.458 | 1,780,594 | 2,285,847 | 858,794 |
| 0.000184 | 1,930,004 | 96 | 76 | 1,430,004 | 20,070 | 1,525,322 | 1.067 | (95,318) | 430,004 | 0 |
| 0.000174 | 1,637,180 | 97 | 77 | 1,137,180 | 20,070 | 1,545,392 | 1.359 | (408,213) | 137,180 | 0 |
| 0.000166 | 2,220,304 | 98 | 78 | 1,720,304 | 20,070 | 1,565,462 | 0.910 | 154,841 | 720,304 | 0 |
| 0.000157 | 1,641,512 | 99 | 79 | 1,141,512 | 20,070 | 1,585,532 | 1.389 | (444,020) | 141,512 | 0 |
| 0.002974 | 2,078,324 | 100 | 80 | 1,578,324 | 20,070 | 1,605,602 | 1.017 | (27,279) | 578,324 | 0 |
| Wt. Average | 305,986 | 13.94 | 3.90 | 73,755 | | 78,200 | 1.037 | (4,445) | 6,205 | 260 |

## *Exhibit II – XYZ Insurance Company Scenarios*

| Pr{Scenario} | Ground Up Loss (L) | Index Values (I) | Purchased Index | Pre-Hedge Loss Loss (HL) | Number of Options (N) | Index Recovery(R) | Coverage Ratio (RR) | Post-Hedge Net Loss (NL) | Direct PD | Net PD |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.075000 | 0 | 0 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.068750 | 42,643 | 1 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.063063 | 39,749 | 2 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.057884 | 83,055 | 3 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.053168 | 202,689 | 4 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.048869 | 139,508 | 5 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.044949 | 143,933 | 6 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.041373 | 254,471 | 7 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.038109 | 248,129 | 8 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.035127 | 1,405,806 | 9 | 0 | 905,806 | 0 | 0 | 0.000 | 905,806 | 0 | 35,136 |
| 0.032402 | 51,813 | 10 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.029911 | 107,265 | 11 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.027630 | 876,571 | 12 | 0 | 376,571 | 0 | 0 | 0.000 | 376,571 | 0 | 0 |
| 0.025543 | 1,456,437 | 13 | 0 | 956,437 | 0 | 0 | 0.000 | 956,437 | 0 | 85,767 |
| 0.023630 | 207,307 | 14 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.021877 | 803,669 | 15 | 0 | 303,669 | 0 | 0 | 0.000 | 303,669 | 0 | 0 |
| 0.020268 | 264,872 | 16 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.018792 | 886,432 | 17 | 0 | 386,432 | 0 | 0 | 0.000 | 386,432 | 0 | 0 |
| 0.017435 | 1,276,592 | 18 | 0 | 776,592 | 0 | 0 | 0.000 | 776,592 | 0 | 0 |
| 0.016188 | 469,339 | 19 | 0 | 0 | 0 | 0 | 1.000 | 0 | 0 | 0 |
| 0.015041 | 1,534,278 | 20 | 0 | 1,034,278 | 0 | 0 | 0.000 | 1,034,278 | 34,278 | 163,608 |
| 0.013985 | 884,493 | 21 | 1 | 384,493 | 23,235 | 23,235 | 0.060 | 361,258 | 0 | 0 |
| 0.013012 | 323,247 | 22 | 2 | 0 | 23,235 | 46,470 | 0.000 | (46,470) | 0 | 0 |
| 0.012115 | 907,746 | 23 | 3 | 407,746 | 23,235 | 69,705 | 0.171 | 338,042 | 0 | 0 |
| 0.011288 | 685,955 | 24 | 4 | 185,955 | 23,235 | 92,940 | 0.500 | 93,015 | 0 | 0 |
| 0.010524 | 3,952,325 | 25 | 5 | 3,452,325 | 23,235 | 116,174 | 0.034 | 3,336,150 | 2,452,325 | 2,465,481 |

## Exhibit II (Continued) – XYZ Insurance Company Scenarios

| Pr{Scenario} | Ground Up Loss (L) | Index Values (I) | Purchased Index | Pre-Hedge Loss Loss (HL) | Number of Options (N) | Index Recovery(R) | Coverage Ratio (RR) | Post-Hedge Net Loss (NL) | Direct PD | Net PD |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.009819 | 2,348,231 | 26 | 6 | 1,848,231 | 23,235 | 139,409 | 0.075 | 1,708,822 | 848,231 | 838,152 |
| 0.009166 | 315,437 | 27 | 7 | 0 | 23,235 | 162,644 | 0.000 | (162,644) | 0 | 0 |
| 0.008562 | 205,797 | 28 | 8 | 0 | 23,235 | 185,879 | 0.000 | (185,879) | 0 | 0 |
| 0.008003 | 1,596,349 | 29 | 9 | 1,096,349 | 23,235 | 209,114 | 0.191 | 887,235 | 96,349 | 16,565 |
| 0.007486 | 2,329,318 | 30 | 10 | 1,829,318 | 23,235 | 232,349 | 0.127 | 1,596,970 | 829,318 | 726,300 |
| 0.007005 | 351,319 | 31 | 11 | 0 | 23,235 | 255,584 | 0.000 | (255,584) | 0 | 0 |
| 0.006560 | 960,589 | 32 | 12 | 460,589 | 23,235 | 278,819 | 0.605 | 181,770 | 0 | 0 |
| 0.006146 | 723,125 | 33 | 13 | 223,125 | 23,235 | 302,053 | 1.354 | (78,929) | 0 | 0 |
| 0.005761 | 664,338 | 34 | 14 | 164,338 | 23,235 | 325,288 | 1.979 | (160,951) | 0 | 0 |
| 0.005404 | 591,126 | 35 | 15 | 91,126 | 23,235 | 348,523 | 3.825 | (257,397) | 0 | 0 |
| 0.005071 | 517,534 | 36 | 16 | 17,534 | 23,235 | 371,758 | 21.202 | (354,224) | 0 | 0 |
| 0.004761 | 502,877 | 37 | 17 | 2,877 | 23,235 | 394,993 | 137.311 | (392,116) | 0 | 0 |
| 0.004472 | 109,549 | 38 | 18 | 0 | 23,235 | 418,228 | 0.000 | (418,228) | 0 | 0 |
| 0.004203 | 823,848 | 39 | 19 | 323,848 | 23,235 | 441,463 | 1.363 | (117,615) | 0 | 0 |
| 0.003952 | 3,230,999 | 40 | 20 | 2,730,999 | 23,235 | 464,698 | 0.170 | 2,266,301 | 1,730,999 | 1,395,631 |
| 0.003717 | 1,051,923 | 41 | 21 | 551,923 | 23,235 | 487,932 | 0.884 | 63,991 | 0 | 0 |
| 0.003498 | 298,954 | 42 | 22 | 0 | 23,235 | 511,167 | 0.000 | (511,167) | 0 | 0 |
| 0.003293 | 460,787 | 43 | 23 | 0 | 23,235 | 534,402 | 0.000 | (534,402) | 0 | 0 |
| 0.003102 | 264,946 | 44 | 24 | 0 | 23,235 | 557,637 | 0.000 | (557,637) | 0 | 0 |
| 0.002922 | 281,554 | 45 | 25 | 0 | 23,235 | 580,872 | 0.000 | (580,872) | 0 | 0 |
| 0.002754 | 969,825 | 46 | 26 | 469,825 | 23,235 | 604,107 | 1.286 | (134,282) | 0 | 0 |
| 0.002597 | 563,198 | 47 | 27 | 63,198 | 23,235 | 627,342 | 9.927 | (564,144) | 0 | 0 |
| 0.002450 | 212,832 | 48 | 28 | 0 | 23,235 | 650,577 | 0.000 | (650,577) | 0 | 0 |
| 0.002311 | 461,058 | 49 | 29 | 0 | 23,235 | 673,811 | 0.000 | (673,811) | 0 | 0 |
| 0.002181 | 8,460,887 | 50 | 30 | 7,960,887 | 23,235 | 697,046 | 0.088 | 7,263,841 | 6,960,887 | 6,393,171 |

## Exhibit II (Continued) – XYZ Insurance Company Scenarios

| Pr{Scenario} | Ground Up Loss (L) | Index Values (I) | Purchased Index | Pre-Hedge Loss Loss (HL) | Number of Options (N) | Index Recovery(R) | Coverage Ratio (RR) | Post-Hedge Net Loss (NL) | Direct PD | Net PD |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.002059 | 1,631,235 | 51 | 31 | 1,131,235 | 23,235 | 720,281 | 0.637 | 410,954 | 131,235 | 0 |
| 0.001945 | 150,816 | 52 | 32 | 0 | 23,235 | 743,516 | 0.000 | (743,516) | 0 | 0 |
| 0.001837 | 1,143,664 | 53 | 33 | 643,664 | 23,235 | 766,751 | 1.191 | (123,087) | 0 | 0 |
| 0.001736 | 558,547 | 54 | 34 | 58,547 | 23,235 | 789,986 | 13.493 | (731,439) | 0 | 0 |
| 0.001641 | 1,321,459 | 55 | 35 | 821,459 | 23,235 | 813,221 | 0.990 | 8,238 | 0 | 0 |
| 0.001551 | 2,999,368 | 56 | 36 | 2,499,368 | 23,235 | 836,456 | 0.335 | 1,662,912 | 1,499,368 | 792,242 |
| 0.001467 | 1,279,019 | 57 | 37 | 779,019 | 23,235 | 859,690 | 1.104 | (80,672) | 0 | 0 |
| 0.001387 | 983,947 | 58 | 38 | 483,947 | 23,235 | 882,925 | 1.824 | (398,979) | 0 | 0 |
| 0.001312 | 488,693 | 59 | 39 | 0 | 23,235 | 906,160 | 0.000 | (906,160) | 0 | 0 |
| 0.001242 | 380,108 | 60 | 40 | 0 | 23,235 | 929,395 | 0.000 | (929,395) | 0 | 0 |
| 0.001175 | 2,653,583 | 61 | 41 | 2,153,583 | 23,235 | 952,630 | 0.442 | 1,200,953 | 1,153,583 | 330,284 |
| 0.001112 | 3,530,208 | 62 | 42 | 3,030,208 | 23,235 | 975,865 | 0.322 | 2,054,343 | 2,030,208 | 1,183,674 |
| 0.001053 | 1,799,850 | 63 | 43 | 1,299,850 | 23,235 | 999,100 | 0.769 | 300,750 | 299,850 | 0 |
| 0.000997 | 914,127 | 64 | 44 | 414,127 | 23,235 | 1,022,335 | 2.469 | (608,207) | 0 | 0 |
| 0.000944 | 626,691 | 65 | 45 | 126,691 | 23,235 | 1,045,569 | 8.253 | (918,878) | 0 | 0 |
| 0.000894 | 514,203 | 66 | 46 | 14,203 | 23,235 | 1,068,804 | 75.253 | (1,054,602) | 0 | 0 |
| 0.000847 | 4,111,945 | 67 | 47 | 3,611,945 | 23,235 | 1,092,039 | 0.302 | 2,519,906 | 2,611,945 | 1,649,236 |
| 0.000803 | 320,940 | 68 | 48 | 0 | 23,235 | 1,115,274 | 0.000 | (1,115,274) | 0 | 0 |
| 0.000761 | 1,065,409 | 69 | 49 | 565,409 | 23,235 | 1,138,509 | 2.014 | (573,100) | 0 | 0 |
| 0.000721 | 2,082,569 | 70 | 50 | 1,582,569 | 23,235 | 1,161,744 | 0.734 | 420,825 | 582,569 | 0 |
| 0.000683 | 234,157 | 71 | 51 | 0 | 23,235 | 1,184,979 | 0.000 | (1,184,979) | 0 | 0 |
| 0.000648 | 6,755,845 | 72 | 52 | 6,255,845 | 23,235 | 1,208,214 | 0.193 | 5,047,632 | 5,255,845 | 4,176,962 |
| 0.000614 | 330,202 | 73 | 53 | 0 | 23,235 | 1,231,448 | 0.000 | (1,231,448) | 0 | 0 |
| 0.000582 | 629,192 | 74 | 54 | 129,192 | 23,235 | 1,254,683 | 9.712 | (1,125,491) | 0 | 0 |
| 0.000552 | 1,598,952 | 75 | 55 | 1,098,952 | 23,235 | 1,277,918 | 1.163 | (178,966) | 98,952 | 0 |

## Exhibit II (Continued) – XYZ Insurance Company Scenarios

| Pr{Scenario} | Ground Up Loss (L) | Index Values (I) | Purchased Index | Pre-Hedge Loss Loss (HL) | Number of Options (N) | Index Recovery(R) | Coverage Ratio (RR) | Post-Hedge Net Loss (NL) | Direct PD | Net PD |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.000524 | 5,788,292 | 76 | 56 | 5,288,292 | 23,235 | 1,301,153 | 0.246 | 3,987,139 | 4,288,292 | 3,116,469 |
| 0.000497 | 2,767,443 | 77 | 57 | 2,267,443 | 23,235 | 1,324,388 | 0.584 | 943,055 | 1,267,443 | 72,385 |
| 0.000471 | 504,250 | 78 | 58 | 4,250 | 23,235 | 1,347,623 | 317.060 | (1,343,372) | 0 | 0 |
| 0.000447 | 3,101,102 | 79 | 59 | 2,601,102 | 23,235 | 1,370,858 | 0.527 | 1,230,244 | 1,601,102 | 359,574 |
| 0.000424 | 3,033,194 | 80 | 60 | 2,533,194 | 23,235 | 1,394,093 | 0.550 | 1,139,102 | 1,533,194 | 268,432 |
| 0.000402 | 1,569,098 | 81 | 61 | 1,069,098 | 23,235 | 1,417,327 | 1.326 | (348,230) | 69,098 | 0 |
| 0.000381 | 5,617,198 | 82 | 62 | 5,117,198 | 23,235 | 1,440,562 | 0.282 | 3,676,635 | 4,117,198 | 2,805,965 |
| 0.000362 | 1,863,143 | 83 | 63 | 1,363,143 | 23,235 | 1,463,797 | 1.074 | (100,655) | 363,143 | 0 |
| 0.000343 | 6,409,816 | 84 | 64 | 5,909,816 | 23,235 | 1,487,032 | 0.252 | 4,422,784 | 4,909,816 | 3,552,114 |
| 0.000326 | 665,437 | 85 | 65 | 165,437 | 23,235 | 1,510,267 | 9.129 | (1,344,830) | 0 | 0 |
| 0.000309 | 6,841,872 | 86 | 66 | 6,341,872 | 23,235 | 1,533,502 | 0.242 | 4,808,371 | 5,341,872 | 3,937,701 |
| 0.000294 | 3,315,902 | 87 | 67 | 2,815,902 | 23,235 | 1,556,737 | 0.553 | 1,259,165 | 1,815,902 | 388,495 |
| 0.000279 | 571,843 | 88 | 68 | 71,843 | 23,235 | 1,579,972 | 21.992 | (1,508,129) | 0 | 0 |
| 0.000264 | 1,129,959 | 89 | 69 | 629,959 | 23,235 | 1,603,206 | 2.545 | (973,248) | 0 | 0 |
| 0.000251 | 2,040,655 | 90 | 70 | 1,540,655 | 23,235 | 1,626,441 | 1.056 | (85,786) | 540,655 | 0 |
| 0.000238 | 883,495 | 91 | 71 | 383,495 | 23,235 | 1,649,676 | 4.302 | (1,266,181) | 0 | 0 |
| 0.000226 | 2,540,570 | 92 | 72 | 2,040,570 | 23,235 | 1,672,911 | 0.820 | 367,659 | 1,040,570 | 0 |
| 0.000215 | 646,100 | 93 | 73 | 146,100 | 23,235 | 1,696,146 | 11.609 | (1,550,046) | 0 | 0 |
| 0.000204 | 3,412,615 | 94 | 74 | 2,912,615 | 23,235 | 1,719,381 | 0.590 | 1,193,234 | 1,912,615 | 322,564 |
| 0.000194 | 207,274 | 95 | 75 | 0 | 23,235 | 1,742,616 | 0.000 | (1,742,616) | 0 | 0 |
| 0.000184 | 972,386 | 96 | 76 | 472,386 | 23,235 | 1,765,851 | 3.738 | (1,293,465) | 0 | 0 |
| 0.000174 | 1,422,507 | 97 | 77 | 922,507 | 23,235 | 1,789,085 | 1.939 | (866,578) | 0 | 0 |
| 0.000166 | 5,587,967 | 98 | 78 | 5,087,967 | 23,235 | 1,812,320 | 0.356 | 3,275,647 | 4,087,967 | 2,404,977 |
| 0.000157 | 795,072 | 99 | 79 | 295,072 | 23,235 | 1,835,555 | 6.221 | (1,540,483) | 0 | 0 |
| 0.002974 | 1,071,199 | 100 | 80 | 571,199 | 23,235 | 1,858,790 | 3.254 | (1,287,592) | 0 | 0 |
| Wt. Average | 540,924 | 13.94 | 3.90 | 284,281 | | 90,531 | 1.769 | 193,749 | 87,553 | 78,158 |

# Glossary

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| Adverse selection | A situation in which a pricing policy encourages exposures with relatively greater costs to do business. For example, a rise in insurance prices over a broad classification of exposures that leads only the relatively poorer risks to buy insurance. |
| Basis risk | Risk that there may be a difference between the performance of the hedge and the losses sustained from the hedged exposure. It is the risk that the value of the underlying or index used and/or structure of the settlement of the derivative may not provide the desired offset to the insurer's loss. |
| Call option | An option that grants the holder the right but not the obligation to buy the underlying asset at a predetermined price (strike price). The buyer of a call option has purchased insurance against increases in the price of the underlying asset over the option's life. |
| Catastrophe | An event that causes more than a specified amount of insured property damage, say $25 million, and affects a number of policyholders. |
| Counterparty | In seeking to transfer catastrophe risk through insurance options, an insurer would seek to purchase a catastrophe option through one of the exchanges or over-the-counter directly from a principal otherwise known as a counterparty. |
| Coverage ratio | Ratio of recovery (from the hedging transaction) to hedged loss. |
| Credit risk | The risk of loss due to a counterparty being unable to fulfill its contractual obligations. Credit risk has two components: (1) Current exposure—which is determined by marking-to- |

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| | market a portfolio of derivatives and summing positions with a positive market value (or in a gain position), and (2) Potential exposure—which estimates the likelihood that future movements in financial prices will negatively affect the value of the derivative portfolio. |
| Derivative instrument | A financial instrument whose value is determined or derived from the values of an underlying instrument. Derivatives include a wide assortment of products and can be traded on organized exchanges or privately negotiated (over-the-counter or OTC). See Exchange-traded and Over-the-counter. |
| Exchanges | Chicago Board of Trade (CBOT) or Chicago Mercantile Exchange (CME). |
| Exchange-traded options/contract | Derivatives traded on established exchanges such as the Chicago Board of Trade (CBOT) or Chicago Mercantile Exchange (CME). Exchange-traded instruments have standardized contract terms and require positions to be marked-to-market daily. |
| Exposure basis | Underlying characteristics of the book of business that is being hedged. Changes to exposure basis may occur as the company writes new business and some risks are cancelled or non-renewed which may cause the composition of the book to change from the exposure base underlying the hedge. |
| GCCI | Guy Carpenter Catastrophe Index (GCCI) compares homeowner properties to insured damage caused by atmospheric perils such as hurricanes, tornadoes, thunderstorms, windstorms, hail, and winter storms. The GCCI number expresses the industry's loss in the form of a loss-to-value ratio or damage rate. The higher the number, the worse the financial impact for property/casualty companies. |
| Hedge | To offset the risks associated with one position by establishing an opposing |

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| | position. |
| Indemnity-based transaction | Transaction whose settlement is directly related to the loss experience of the company issuing the securities. |
| Index-based transaction | Transaction whose settlement is triggered or derived from the value of an independent index. Includes exchange-traded index options, over-the-counter options or other derivatives that rely on an index for triggering or establishing the value of the instrument |
| Index-based insurance derivatives | Include exchange-traded index options, over-the-counter options or other derivatives that rely on an index for triggering or establishing the value of the instrument. |
| Insurance-based securities | Securities that bridge the insurance and capital markets. These might provide an alternative to traditional reinsurance, although the cost advantage will vary throughout the insurance underwriting cycle. |
| Integrated risk products | Structured to focus on hedging the downside risk of the cedant's operating results. These products differ from alternative reinsurance products in that their coverage might include, in addition to purely insurance risk, losses on financial risks such as interest rate changes, stock index movements or fluctuations in foreign exchange rates. |
| Loss-based or indemnity-based derivatives | Include catastrophe bonds and contingent capital facilities (e.g., surplus notes, CatEputs™). |
| Model risk | Risk that the model used to evaluate the expected effectiveness of the hedge does not accurately predict the actual industry and/or company results. |
| Moral hazard | Possibility of a company's increasing its reported losses (beyond its actual losses) in order to enhance the payoff of the contract. |
| Mortgage-backed securities | A security, such as a bond, pass-through, CMO, or REMIC that derives its cash flows and market value from |

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| | underlying Mortgage Backed Securities and/or Mortgage Bonds, Loans, and/or Notes. |
| Notional amount/principal | The underlying face amount used to determine the cash flows to be exchanged in a derivative contract. Notional principal determines the amount of cash flows, but does not represent the value of a derivative or the amount at risk. For example, a property catastrophe option may be written to provide a fixed payout in the event of an occurrence of an earthquake exceeding a specific value on the Richter scale during the agreed exposure period. In this case the notional amount/payment provision would be the fixed payout of the contract. |
| Option | A contract giving the holder the right, but not the obligation to buy (call) or sell (put) a specified underlying asset at a pre-agreed price at either a fixed point in the future (European style) or at any time up to maturity (American style). Options are sold both over-the-counter (OTC) and on organized exchanges. |
| Over-the-counter options | Trading in financial instruments transacted off organized exchanges. Generally the parties must negotiate all details of the transactions, or agree to certain simplifying market conventions. OTC trading includes transactions among market-makers and between market-makers and their customers. Firms mutually determine their trading partners on a bilateral basis. |
| Payout | Dollar amount an option or swap buyer/seller may receive or pay. |
| PCS index | Property Claims Services' (PCS) indices track the aggregate amount of insured losses resulting from catastrophic events which occur in given regions and risk periods. Previously, the CBOT listed a catastrophe contract on an index |

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| | provided by Insurance Services Office (ISO). The reliability of the ISO index became a concern when the industry's losses from the Northridge earthquake were not adequately reflected in the index. The PCS indices are a much broader reflection of how an event affects the insurance industry. |
| Pre-event effectiveness | Refers to the hedger’s ability to quantify the expected effectiveness of the transaction. |
| Protected Cell Company Model Act | Model legislation (and supporting accounting treatment) for fully funded transactions being finalized by the NAIC. |
| RMS index | The RMS CAT Index uses RMS' IRAS™ (Insurance and Investment Risk Assessment System) technology, which simulates natural disaster events using state-of-the-art computer models and sophisticated engineering databases. When a qualifying event occurs, a database of exposed properties is input into IRAS along with technical parameters describing the event. IRAS simulates the actual event and calculates losses. Individual event losses are then reported by RMS; cumulative event losses comprise the Index. |
| Special purpose reinsurer | Reinsurers whose sole purpose are to transform a traditional reinsurance transaction into an insurance-linked security for investors. Use of the special purpose reinsurer allows the ceding company to account for the transaction as reinsurance. |
| Timing risk | Risk associated with estimation errors in interim financial reporting between the time the event occurs and the settlement of the derivative. |
| Underlying | The designated financial instrument which must be delivered in completion of an option contract or a futures contract. For example, a property catastrophe option may be written to provide a fixed |

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| | payout in the event of occurrence of an earthquake exceeding a specific value on the Richter scale during the agreed exposure period. In this case the underlying would be the Richter scale. Other examples of underlyings include the PCS index, GCCI, SIGMA index, RMS index, wind speed, temperature, statewide loss ratio for a line of business or inches of rain. |