The Role of Catastrophe Modeling in Alternative Risk Transfer

By Beverly Porter and S. Ming Lee*

Overview

Shortly after the terrorist attacks of last September, as the insurance industry was still in the process of tallying the losses, several analysts predicted a rise in the issuance of insurance-linked securities, or cat bonds, as an alternative to more traditional routes for transferring risk. While the surge in demand has not yet materialized as forecast (perhaps because the infusion of capital by some new Bermuda-based reinsurers has helped to alleviate potential capacity shortages), the issuance of cat bonds proceeds at steady pace and an increase in activity may yet materialize. The federal government has made clear its disinclination to provide publicly funded terrorism insurance. Should another attack of similar scale occur, or if the industry is hit by an extreme event or events of natural origin, capacity constraints will likely resurface as an important issue. The over $20 trillion available in the U.S. capital markets then become an obvious source of risk capital.

The issuance of a cat bond is a complex process involving many players. Among these are the ceding insurer or (retroceding) reinsurer, a special purpose vehicle (SPV) set up for the purpose of issuing the securities, the rating agencies that scrutinize the transaction and rate the notes, and the financial institution that structures and underwrites the transaction and markets the notes. Also critical to the process is the catastrophe modeler charged with quantifying the risk. This article focuses on the role catastrophe modeling plays in the securitization of catastrophe risk and how the modeling process varies according to the structure of the transaction.

Quantification of Natural Hazard Risk

Fundamental to structuring and pricing an insurance-linked security is a reliable estimate of expected loss to the notes. In the case of fire or automobile policies, insurance companies are well equipped to estimate potential future losses. They do so on the basis of the wealth of historical claims data that result from such policies. The relative infrequency of catastrophe events, however, and the resulting scarcity of historical loss data make it virtually impossible to reliably estimate potential future catastrophe losses using standard actuarial techniques. Furthermore, the usefulness of the loss data that do exist is limited as a result of changing property values, construction methods, demographics, and so on.

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Enter the catastrophe model. Using stochastic simulation techniques, these models generate the primary characteristics of catastrophe events (whether meteorological or seismological), and apply mathematical functions that relate the intensity of the event to structural damage. Catastrophe models provide credible, scientifically based loss estimates based on the simulation of thousands of potential scenarios, resulting in the complete probability distribution of losses.

In the context of a cat bond, the modeling will reveal the probability that investors will recover their principal in full, in part, or that they will forfeit their principal altogether. The yield on the notes will depend on these probabilities, as will their rating. Any default on the notes is triggered by the occurrence of an actual event or events during the period of coverage. The principal, which has been held in trust, is then used to pay the losses of the cedant.

The nature of the modeling undertaken to determine these probabilities will depend on the type of transaction, of which there are four principal types:

- *Indemnity*. The model estimates losses on actual company exposures. The trigger is based on losses on the issuer's book of business from an event.
- *Index*. The model estimates losses on estimated industry exposures. The trigger is based on actual industry losses resulting from an event.
- *Parametric*. The model is used to estimate the likelihood that an event of or above a given intensity will occur in a given location during the covered period. Any default on the notes is triggered not by a loss amount, but rather by the physical parameters of the actual event, should one occur.
- *Notional Portfolio*. The model estimates losses on a "reference portfolio" of company exposures, which typically stays fixed during the period of coverage. The trigger is based on *modeled* losses on the notional portfolio using the parameters of an actual event, should one occur.

Example of an indemnity-based transaction

The first truly successful cat bond issues came in 1997. The largest of these was a transaction by which USAA ceded $400 million of hurricane risk to Residential Re, an SPV set up for the sole purpose of this transaction. Funds raised from investors by Residential Re were held in trust for the purpose of paying USAA for claims against it resulting from hurricane losses along the Gulf and East Coasts of the United States. Residential Re has renewed, at different levels, its issue every year and is expanding coverage to include Hawaii hurricanes in 2002.

The catastrophe modeler selected to support the transaction was Applied Insurance Research (AIR). Their job was to estimate expected losses on USAA's book of business using the AIR hurricane model. Figure 1 below illustrates the component parts of the model (in gray).

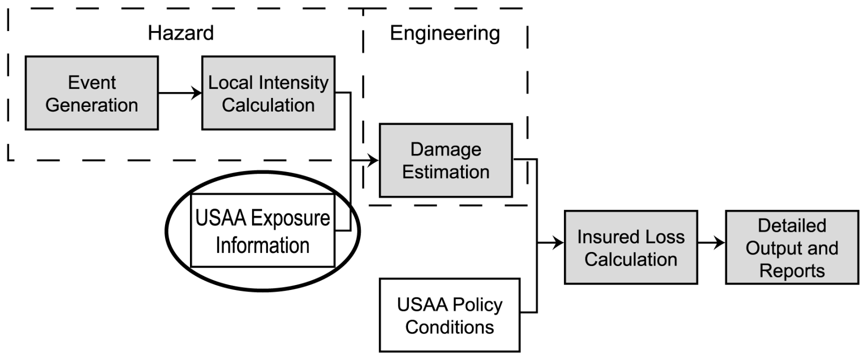

Figure 1. Catastrophe modeling components for an indemnity-based transaction

Event Generation

The first two model components address the hazard itself. Event generation deals with so-called source parameters, and answers questions about where events are likely to occur, how large or severe they are likely to be, and how frequently they are likely to occur. Most catastrophe modelers employ their own internal staffs of scientists, including meteorologists, seismologists, and geophysicists, who combine their knowledge of the underlying physics of natural hazards with the historical data on past events.

Using a deterministic approach to estimating potential catastrophe losses, one might ask: What would losses be today from a repeat of the 1923 Great Kanto earthquake in Japan? Or of Hurricane Andrew, which until last September held the record for having produced the largest U.S. insured loss in history? While it is interesting to speculate on these questions (and catastrophe models are, in fact, well equipped to provide answers), we know that an exact repeat of historical events has near zero probability of occurrence. The task of the event generation module, therefore, is to simulate all types of possible, yet realistic, future scenarios.

Local Intensity

Once the model *probabilistically* generates a potential future event, it propagates the event across the affected area. For each affected site, local intensity (in terms of surface wind speed, ground motion, etc.) is estimated. In this component as well as in the event generation component, detailed scientific and geophysical data and algorithms are employed to model the local effects of each simulated event. Windstorm models, for example, use high-resolution digital land use/land cover data to calculate surface frictional effects. Estimates of surface roughness dictate, in part, the behavior of ground level wind speeds. In the case of earthquake models, local soils affect the amplification of seismic waves.

Damage Estimation

The local intensities of each simulated event are superimposed onto a database of exposed properties – in this case, USAA's own book of business. The damage estimation component then calculates the resulting monetary damage by applying mathematical relationships, called damage functions. These capture the relationship between the intensity of the event, which varies by location, and the exposed buildings and contents.

The damage functions are region-specific and reflect a thorough understanding of local building codes and construction practices. They provide not only estimates of the mean, or expected, damage ratio corresponding to each level of intensity but, in addition, provide a complete probability distribution around the mean. Because different structures experience different degrees of damage for a given level of intensity, the damage functions need to capture this variability, or so-called secondary uncertainty.

Clearly, the quality of the exposure data is critical to the process. In the case of indemnity-based transactions, data includes, at the very least, location, construction type and occupancy; it may also include age, building height, and other information. If more detailed data is available on individual risk characteristics, such as the presence of storm shutters, such data can be used in the analysis. Considerably energy is spent by both cedant and modeler to evaluate the data and determine whether they meet logical and reasonability tests.

Insured Loss Calculation

Finally, insured losses are calculated by applying the cedant's specific policy conditions to the total damage estimates. Policy conditions may include deductibles by coverage, site-specific or blanket deductibles, coverage limits and sublimits, coinsurance, attachment points and limits for single or multiple location policies, and risk or policy specific reinsurance terms. Explicit modeling of uncertainty in both intensity and damage calculations enables a detailed probabilistic calculation of the effects of policy conditions.

Model Output

Because catastrophe models use high speed computers, many thousands of potential events can be simulated in accordance with their relative probability of occurrence. Probability distributions of losses and their complement, the exceedance probability curve, are estimated for potential levels of annual aggregate and occurrence losses that the cedant may experience given their book of business. The curves also provide the probabilities of attachment for various reinsurance layers and therefore the probabilities that investors will suffer a loss of interest on, or all or part of the principal amount of, the notes.

In the 1997 Residential Re transaction, which was of a one year term, actual losses to the holders of the notes could be triggered by the occurrence of any single Gulf or East Coast hurricane of Saffir Simpson Category 3 or greater that resulted in losses to USAA in excess of $1 billion. Concern about moral hazard was ameliorated, at least in part, by a 20% participation rate by USAA in the securitized reinsurance layer. The structure of that initial issue is shown below. This structure has remained largely the same in subsequent years, though the size of the issue has varied.

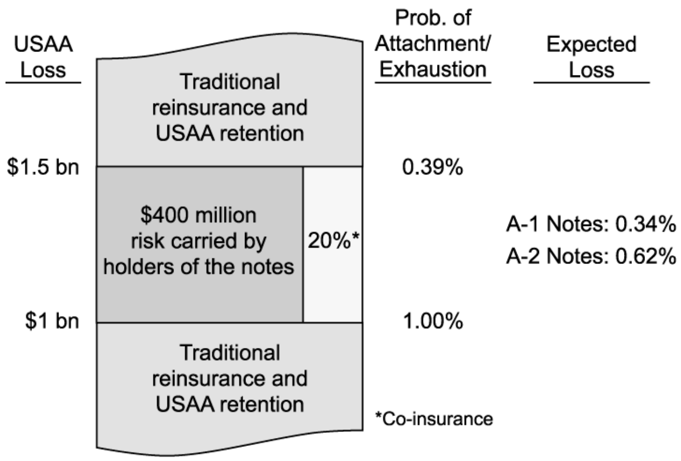

Figure 2. 1997 Residential Re (USAA) Summary Features

The results of the risk analysis indicated that the probability that USAA's hurricane losses would exceed $1 billion and that the holders of the notes would suffer a loss was 1%, and that the probability that they would suffer a complete default was 0.39%. The transaction was the first to be rated by all four rating agencies at the time.

Example of an industry loss index-based transaction

As indicated in the previous section, mechanisms to reduce moral hazard (the extent to which the cedant can control losses) can be built in to indemnity-based transactions. Because moral hazard is of legitimate concern to the investor, to alleviate that concern and to attract investors, the return on the notes may have to be raised to such an extent that the securitization is no longer attractive from the cedant's point of view. In the Residential Re case, moral hazard is reduced through USAA's co-participation rate and by the fact that the triggering event is restricted to a Category 3 hurricane or greater, something over which the cedant has no control.

Another way to reduce moral hazard, at least in greater degree, is to structure the transaction such that any default on the notes is triggered by industry losses, over which an individual cedant has less control. To estimate expected losses on the notes, then, the catastrophe modeler estimates expected *industry* losses. Modelers have developed, in house, detailed databases of property values. These annually-updated databases include estimates of total property exposures, typically at zip code resolution. Data include the number of risks and their values broken down by line of business, by coverage, by occupancy and construction type. The modeling process is illustrated in Figure 3 below.

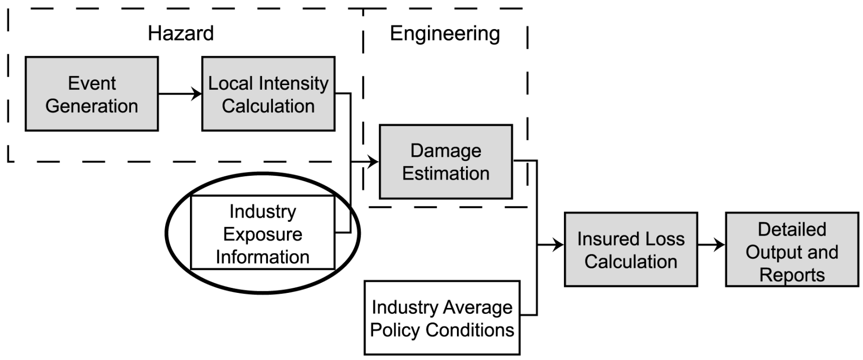

Figure 3. Catastrophe modeling components for an industry index-based transaction

The hazard components of the model operate in the same manner as for the indemnity-based transaction. Local intensity is superimposed on industry exposures and damages are estimated, as before. Insured losses are calculated by applying industry average policy conditions.

In February 2001, the California Earthquake Authority (CEA) ceded $100 million of earthquake risk to Western Capital, an SPV, which, in turn, issued $97 million in notes and $3 million in preference shares. Funds raised are held in trust for 23 months to pay claims against the CEA resulting from earthquake losses. Any loss to the holders of the notes is triggered by the occurrence of an earthquake or earthquakes that result in aggregate industry losses in California in excess of $22.5 billion during the covered period. The reporting agent of industry losses is Property Claim Services (PCS). PCS develops its estimate of industry loss by conducting surveys of insurers after the occurrence of a catastrophe event. The structure of the Western Capital transaction, for which EQECAT provided modeling support, is illustrated below.

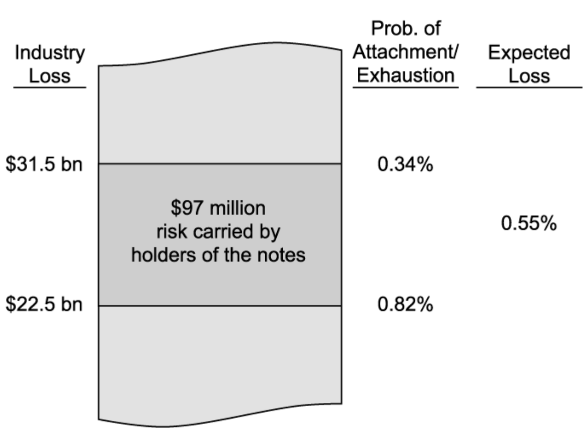

Figure 4. 2001 Western Capital (CEA) Summary Features

One incidental point worth mentioning in the context of this deal is that the covered period is more than one year; traditional reinsurance treaties are usually of one year duration. Through a two-year securitization, the cedant can avoid fluctuations in the price of reinsurance and, at the same time, lower the marginal transactions costs associated with the securitization itself. On the other hand, payout of principal is made somewhat more complex. Typically, multi-year indemnity- or index-based transactions involve an annual reset calculation. Each year, the catastrophe modeler must determine new attachment and exhaustion points that maintain the same probability of attachment and the same expected loss on the notes, given changes in the company or industry exposure database.

Another advantage of the index-based transaction from the point of view of the cedant is that there is no need to disclose details of its book of business, since losses to the notes are triggered by industry losses and not the cedant's. From the investor's point of view, this also alleviates the problem of asymmetry of information; because the investor does not need to understand the details of the issuer's business or its predilection for risk, the risk inherent in the notes is easier to evaluate. So, just as moral hazard is reduced, concerns about adverse selection are, as well.

The primary disadvantage associated with an index-based transaction is that the cedant is exposed to basis risk to the extent that its own exposures – and therefore losses – differ in kind and geographical distribution from that of the industry's, or from that of the index used to determine the payoff of the contract. It should be noted, however, that the modeler can help the cedant assess the basis risk by quantifying the correlation between the cedant's book of business and industrywide exposures.

Another disadvantage is that the index of industry losses may require a long time to develop. Preliminary surveys are conducted in the immediate aftermath of an event, but results are revised as actual claims data come in. This may take a while, particularly in the case of earthquakes. If a triggering event or events occur during the covered period, the maturity date on the notes is extended so that the value of the index can be determined. Investors must be compensated for the potential wait in terms of a higher return.

Example of a parametric transaction

In the case of a parametric trigger, losses on the notes are triggered by one or more objectively determined physical parameters of the peril, such as earthquake magnitude and location or hurricane minimum central pressure and location. From the point of view of the investor, losses on the notes are no longer connected to the cedant's losses, thus obviating any need for the investor to understand details of the cedant's business – or of the industry's, for that matter. From the investor's point of view, the catastrophe modeling process undertaken in support of the transaction is illustrated in Figure 5 below.

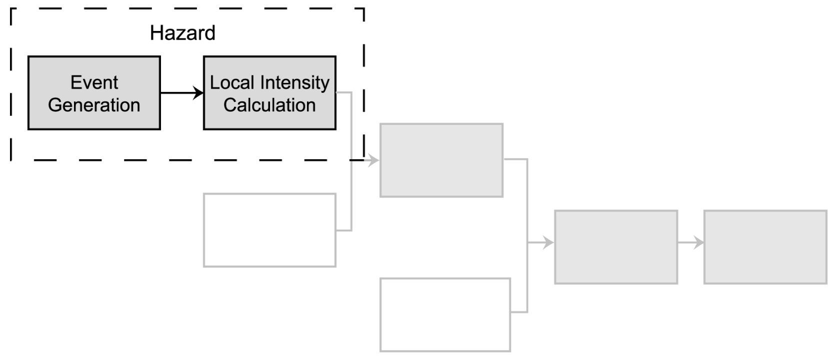

Figure 5. Catastrophe model for a parametric trigger

This is misleading, however. It is true that once the transaction has been structured and priced, the potential investor need only be concerned with gauging the modeler's expertise in estimating event frequencies and intensities, rather than in their ability to determine the vulnerability of structures and estimate probable losses on some book of business. Prior to that stage, however, the modeler must work with the cedant in determining the most *appropriate* trigger – one that mitigates, as much as possible, basis risk. That determination will very likely involve a catastrophe loss analysis of the cedant's exposures. In the end, however, some degree of basis risk will remain, which can be quantified by the modeler.

Again, from the investor's viewpoint, both adverse selection and moral hazard are no longer issues, and risk on the notes is independent of the quality of exposure data. The parametric trigger is objectively determined by a third-party, independent entity, such as the National Weather Service or the United States Geological Survey (USGS). While there may be some delay in obtaining an official and final determination of intensity from organizations such as these.

In January 2000, PRIME Capital issued $306 million of risk-linked securities in two separate offerings. Funds raised are held for three years to cover claims against Munich Re resulting from earthquakes in California, hurricanes in the Miami and New York City areas of the eastern seaboard, and European windstorm. The three-year deal protects Munich Re from fluctuations in the price of reinsurance and the parametric nature of the transaction provides transparency to the investor.

The epicenter of a triggering earthquake, for example, must be located within one of eight boxes, or seismic source zones, four around the San Francisco area (as shown in Figure 6 below), four around Los Angeles. The reporting agent of epicentral location is the USGS. Further, the moment magnitude (M_w) of a covered earthquake must be equal to or greater than certain defined magnitudes for each source zone. Again, the USGS is the reporting agency for magnitude. Losses to the notes stemming from the occurrence of hurricanes are triggered by central pressure within certain defined landfall zones. The reporting agency here is the National Hurricane Center. For European windstorms, losses to the notes are triggered by a weighted index calculated from wind speeds measured at stations across Western Europe, as reported by various governmental meteorological organizations. These transactions can be quite complex in structure. The model output illustrated in Figure 6, and provided by RMS, is for one of two regions in California and for only one of three covered perils.

Trigger Magnitude	Earthquake Principal Loss 20%	Annual Prob	80%	Annual Prob	100%	Annual Prob	Expected Loss
NC1	7.2	0.21%	7.3	0.13%	7.4	0.08%	0.14%
NC2	7.3	0.13%	7.4	0.10%	7.5	0.08%	0.10%
NC3	7.3	0.13%	7.4	0.09%	7.5	0.06%	0.09%
NC4	7.4	0.07%	7.5	0.07%	7.6	0.06%	0.07%

Figure 6. 2000 PRIME Capital (Munich Re) Summary Features

In the case of parametric transactions, scrutiny by rating agencies and investors is focused on the hazard components of the catastrophe model. Here the scientific, rather than engineering, expertise of the modeler's professional staff of seismologists, meteorologists and climate scientists is of paramount importance.

Example of a notional portfolio-based transaction

Insurance-linked securities based on losses to a notional portfolio are among the more interesting transactions. They also put the highest demand on the catastrophe modeler for, in this case, not only does the modeler quantify the risk inherent in the notes, but is also the reporting agent in determining losses to the notes after the occurrence of a covered event. That is, the trigger is based not on *actual* realized losses, but rather on *modeled* losses.

The risks that comprise the notional portfolio are typically on the books of the cedant, though, theoretically, a notional portfolio could be an entirely synthetic construct. To minimize basis risk, it is structured to be representative of the cedant's exposures at risk from the covered peril(s). The model estimates expected losses by superimposing local intensity on the notional portfolio' exposures, damage functions are applied and estimates of insured loss are calculated by applying the policy conditions of the notional portfolio.

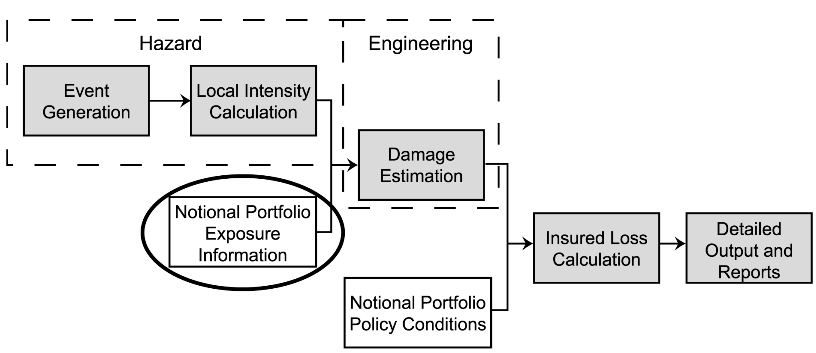

Figure 7. Catastrophe model for a notional portfolio

The model and the notional portfolio then go into escrow, for the duration of the covered period. If a qualifying event occurs, the model is pulled out of escrow and losses on the notional portfolio are estimated by inputting the actual physical parameters of the event into the model. Results will indicate whether the attachment point has been reached and what losses, if any, noteholders will experience.

From the point of view of the investor, the risk of moral hazard and the risk of portfolio growth are eliminated, since the notional portfolio stays fixed during the period of coverage. Uncertainty regarding data quality, vulnerability of the exposures and other variables is also eliminated in both the prospective risk assessment and the post-event loss determination. The cedant need not disclose as much information about its business as in the case of an indemnity-based transaction, but does face somewhat more basis risk.

Another issue with this type of transaction is the potentially complex nature of the loss calculation that takes place in the aftermath of an event. In order that it be as transparent as possible to all concerned parties (to the investor, in particular), the catastrophe modeler must develop, in writing, a step-by-step post-event calculation procedure, also held in escrow. The parameters used as input into the model are named, as are the reporting agencies, and alternatives to those parameters are listed in order of priority if the preferred parameter is not readily available. (Radius of maximum hurricane winds, for example, is not always reported by the National Weather Service, so alternatives must be selected and listed in order of preference.) The exact lines of computer code used to run the model are specified. The cedant, placement agency and modeler work closely together to develop the procedure so that the post-event calculation will go as quickly and as seamlessly as possible.

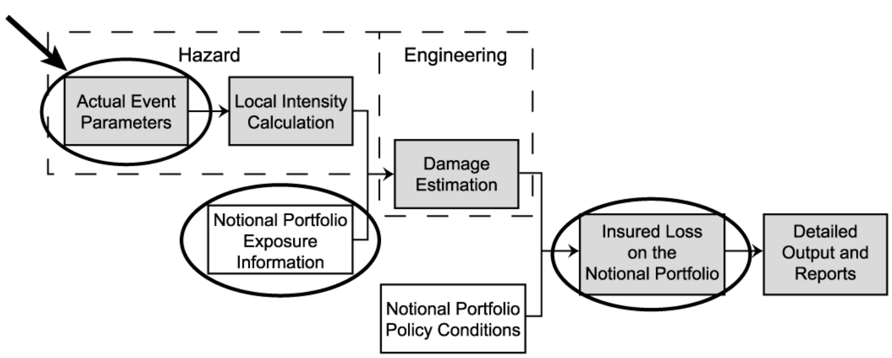

Figure 8. Catastrophe model for a notional portfolio after the occurrence of a trigger event

In July 2001, Trinom Ltd. issued $200 million in notes and preference shares with a three-year maturity to provide protection for Zurich Re against hurricane, earthquake and windstorm losses. A risk analysis was performed by AIR on three separate notional portfolios structured by Zurich Re to match specific books of its European windstorm, California earthquake and U.S. East Coast hurricane exposures. Figure 9 below illustrates one small part of this multi-faceted transaction: Class A-1 Notes covering European windstorm.

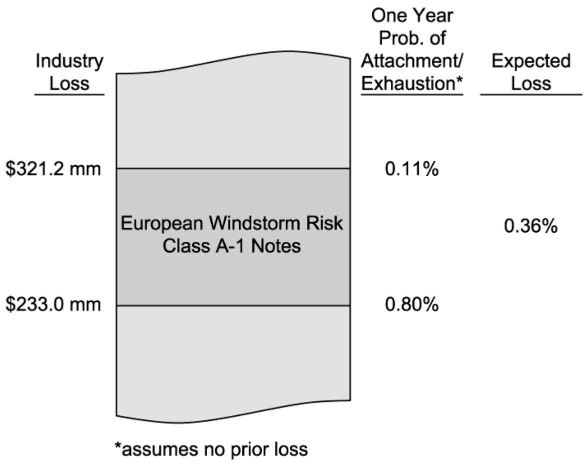

Figure 8. 2001 Trinom Ltd. (Zurich Re) Summary Features

Summary

The catastrophe modeler plays a critical role in the issuance of insurance-linked securities. The risk analysis performed is fundamental to the very structure of the transaction and to its pricing strategy. The modeler must perform a detailed analysis of loss probabilities by peril, line of business, and geography up front and, in the case of notional portfolio transactions, a post-event calculation after a triggering event has occurred. In multi-year deals involving loss triggers, the modeler must perform an annual reset of attachment and exhaustion amounts to maintain a constant probability of expected loss. They can also assist the cedant in understanding and even reducing (through development of appropriate triggers in a parametric transaction, for example) their basis risk.

Investors rely on the research and due diligence performed by the securities rating agencies, who subject the models to intense scrutiny. The modelers present the results of detailed sensitivity analyses of all major components of the model. Modelers and experts hired by the rating agencies perform stress tests for model robustness. Since cat bonds made their debut, rating agencies and investors alike have become quite sophisticated with respect to catastrophe modeling technology and hold the modeler to high standards.

The modeler is also involved in writing the offering memorandum, in which both the modeling methodology and model results are described in detail. Similarly, the modeler participates in “road shows” and other investor meetings, where the structure of the transaction and quantification of the risk is presented to potential investors. Modelers can also help investors understand the correlation between various catastrophe bonds on the market and thus help them diversify their cat bond holdings.

The financial markets, rating agencies and investor communities have by now become familiar with insurance-linked securities and the continuing convergence of the insurance and capital markets. Cat bonds provide cedants with protection against high-severity, low-frequency events, free of credit risk. They provide investors with unique opportunities to diversify their risk with products uncorrelated to fluctuations in the capital markets.

Originally used for gauging an insurance company's probably maximum loss from natural hazards, catastrophe modeling is now a critical tool for the development of finely crafted pricing, underwriting, and risk-transfer strategies, leading to overall portfolio optimization and integrated risk management.