Catastrophe Finance: An Emerging Discipline

While the recent disasters in the world’s financial markets demonstrate that finance theory remains far from perfected, science also has contributed to methods that can be used to predict and manage the effects of natural disasters. Worldwide, as many as half a million people have died in disasters such as earthquakes, hurricanes, and floods caused by tropical cyclones since the turn of the 21st century [Wirtz, 2008]. Further, natural disasters can lead to extreme financial losses, and independent financial collapses can be exacerbated by natural disasters. In financial cost, 2008 was the second most expensive year on record for such catastrophes and for financial market declines. These extreme events in the natural and financial realms push the issue of risk management to the fore; expose the deficiencies of existing knowledge and practice, and suggest that progress requires further research and training at the graduate level.

Seeking capital to recover from catastrophes, insurance and financial markets have begun to merge. As a result, weather derivatives and catastrophe (cat) bonds, whose payout is determined by the physics of the catastrophe (e.g., hurricane wind speed), and by performance metrics of the markets themselves (e.g., the Dow Jones Industrial Average (DJI), are now routinely offered to investors who seek assets they hope will be impervious to market volatility. The evaluation of these new investments requires a scientific judgment of hazard and risk.

In academia, the environmental science and financial communities have little opportunity to interact. However, the rapid growth of markets for weather derivatives, cat bonds, and carbon emissions trading presents evidence of a need for an integrated program. The markets constitute a valuable real-world laboratory to support research and education and support new career opportunities for graduates.

Catastrophe Finance in the Market

Catastrophe finance is an emerging academic field at the intersection of geohazards and market finance. It analyzes, models, and predicts catastrophes for the efficient transfer of risk through derivatives markets and cat bonds, which allow individuals or corporations to buy and sell risk (see “Transferring Risk” below). Climate and weather derivatives are currently traded on the Chicago and New York mercantile exchanges. Cat bonds also are now integral to modern risk management, and the ability to hedge against natural events is one of the most recent developments in the financial markets.

US$7 billion in publicly disclosed transac-
tions, up 40% from the previous year’s record of $4.7 billion and a 23.5% increase over the $5 billion issued during 2005 [Guy Carpenter & Co., LLC 2008]. This is expected to increase at a compound annual rate of 25–40% (Laney and Bevill, 2007), as there is a fundamental shift between the amount of property value at risk and the amount of available insurance and reinsur-
ance capital globally.

According to Barney Schaufel, a partner at Nephila Capital, a Bermuda-based hedge fund specializing in insurance risk, cat bond prices are relatively immune to general market sentiment (bull and bear markets). In fact, the correlation between cat bond prices and the DJIA is extremely weak, as market slumps will not lead to more or stron-
ger hurricanes (or earthquakes). But more frequent or intense natural disasters are only a part of the picture—even a weak hurricane can cause dam-
gage to a community has poor infrastructure. Thus, insuring against hurricane damage in seismic regions with poor infrastructure would likely come with a high premium.

The Need for Specialists in Catastrophe Finance

While the growth of cat bonds has been relatively rapid, it remains constrained by the investment community’s general lack of familiarity with quantifying the risks of a hurricane or earthquake catastrophe. Greater education in understanding the physical mechanisms behind the risk and in estimating the probability of loss is needed by investors to create a fully functioning and liquid market for these trading instruments.

The requisite education involves a combi-
nation of geosciences and environmental sciences and modern finance, particularly derivatives. These disciplines are similar in their reliance on applied probability, which should make it straightforward to combine them in catastrophe modeling. The advent of a vibrant market for trading catastrophe risk will allow an education program to achieve a sharp focus while it uncovers new opportuni-
ties for research in each discipline.

According to John Rollins, vice president of AIR Worldwide, a leading risk-modeling company, it is particularly difficult to assess risk in catastrophic events, especially those that are rare. Rollins notes that companies are searching for ways to increase their resistance against such events and that they are already seeking ways to hedge their exposure.

The requisite education involves a combination of geosciences and environmental sciences and modern finance, particularly derivatives. These disciplines are similar in their reliance on applied probability, which should make it straightforward to combine them in catastrophe modeling, as they are both dependent on continued warming, and could make pricing suggestions that are accept-
able to the sponsor and insurance and risk-management uses. Moreover, in addition to being concerned about the next hurricane this year, the insurer faces concern about the next hurricane season. A severe storm season occurs every few decades; if the severe storm hits this year, she’ll have to pay out most of her money in claims. To help remain sol-
vent, she could buy reinsurance. Alterna-
tively, she could sponsor a catastrophe (cat) bond, which would pass the risk on to an insurer. An investor would buy the bond valued at, say, $100,000; over time, the bond will increase in value until a certain threshold is reached, say, 5%, which is a catastrophic event in the Earth’s history. The insurer also turns a profit by reinsurance. If the hurricane occurs, the bond is used to buy hurricane insurance for the insurer. Finally, the bond pays out $100,000, which is used by the insurer to pay claims.

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Transferring Risk

Imagine a scenario of a farmer assuming the rainy season, which typically arrives at the beginning of June. For every month of rain, say she earns $100. However, if it does not rain in June, she earns nothing. To mitigate her risk of earning nothing, she pays into a fund to buy a financial instrument. The insurer then sells the financial instrument to the farmer. The insurer then invests the money in claims. To help remain sol-
vent, she could buy reinsurance. Alterna-
tively, she could sponsor a catastrophe (cat) bond, which would pass the risk on to an insurer. An investor would buy the bond valued at, say, $100,000; over time, the bond will increase in value until a certain threshold is reached, say, 5%, which is a catastrophic event in the Earth’s history. The insurer also turns a profit by reinsurance. If the hurricane occurs, the bond is used to buy hurricane insurance for the insurer. Finally, the bond pays out $100,000, which is used by the insurer to pay claims.

The insurer and the hotelier will need a broker, who will charge a transaction fee to insure the policy. The broker will take the investment, and define what “fails” allows the insurer to forgo her debt. Again, the insurer above is contem-
plated will be the bond value. But pricing depends on the probability of hurricanes. This is how scientists, armed with models and knowledge of climate change, can help set market values.

By J.B. Elsner, R.K. Burgert, and H.H. Jagger

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Catastrophe Finance

A New Cross-Disciplinary Opportunity

Catastrophe risk management is a process that involves using the correct catastrophe model specification (meteorological, climatological, geological), obtaining the exposure information and ensuring its continuing availability and quality (actuarial), choosing analyses options (financial), running and managing analyses, structuring securities for risk transfer (risk managerial), and synthesising the output into decision support (financial).

Interdisciplinary graduate training in a program focused on catastrophe finance will be transformational: from asking questions about return periods of wind events, to asking about questions about writing new contracts containing new clauses while considering deductibles within probable maximum loss requirements, to assessing increased professional and skills in corporations bearing and insuring hazard risks.

There is still much to be discovered about the science of catastrophes and the financial methods underpinning catastrophe-linked instruments. MBD (2008) has drawn attention to existing deficiencies found in the current state of insurance regulation, catastrophe modeling, and climate change. With new cat bonds, some of which may cover multiple perils including hurricanes and earthquakes, pricing is an issue, in part because of the opaque, proprietary nature of those who create and distribute catastrophe models.

Pacific Investment Management Company, the world’s largest bond investor, advises that to evaluate cat bond prices, investors need access to expertise in probability modeling, weather forecasting, seismology, and other technical factors. This situation has led some to advocate creation of an open-source hurricane catastrophe model (R. Munnane, New Directions in catastrophe risk models, World Bank, 26th Annual World Bank Conference, 11 October 2007), similar to the Organization for Economic Co-operation and Development’s Global Earthquake Model (Vorisek, 2008).

Toward a Sustainable Future

“The culture of our scientific enterprise is on the brink of a sea change.” So advised Fontes and Hempel (2002, p. 308) in December 2002: a book about science, trends, and the challenge of sustainability. They were referring to the issue of how sustainable use of the oceans will require new human and technological capacity as well as greater interdisciplinarity and collaboration in the scientific community. The themes that geosciences need to broaden the scope of its education programs through cross-disciplinary training (e.g., Walter, 2007) and to seek new, possibly market-based, funding sources have been expressed by other authors (Spilhaus, 2007; Forgass, 2008) and were, in fact, the subjects of significant focus at the AGU American Society of Limnology and Oceanography (ASLO) conferences in Honolulu, Hawaii (2006), and Orlando, Fla. (2008).

Markets are beginning to produce innovative opportunities to augment the wisdom of Fortress and Hempel’s counsel. Society’s need to respond to the waves of spectacular disasters from around the globe is causing firestorm investments in new financial instruments.

Aftershocks and Stress Changes

The earthquake has produced a rich data set for understanding the fault movement associated with the rupture. Changes in the style of the ground motion, the occurrence of aftershocks, and the change in the stress on the fault can all be studied in the time immediately after the earthquake. These changes are important for understanding the fault behavior and for improving the models of earthquake behavior.

Recent aftershocks have been occurring at a rate of about 1 per day, and the frequency of the aftershocks has been decreasing. This is consistent with the idea that the stress on the fault is increasing, and that the fault is moving back to its equilibrium state.

The stress changes on the fault are important for understanding the earthquake process. The stress changes are related to the seismic moment of the earthquake, and the seismic moment is a measure of the energy released during the earthquake. The seismic moment is related to the size of the earthquake, and the size of the earthquake is related to the slip on the fault.

Main Shock Rupture

Centroid moment tensor solutions for the main shock indicate that the rupture propagated along a plane that has the same strike and dip as the shallower part of the plate interface. This interface is well-defined, and it is consistent with the distribution of pre-existing stress on the plate boundaries.

The earthquake had a magnitude of 7.2, and it was the largest earthquake to occur in New Zealand since 1987.

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