# 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 faces steep challenges in the quest to predict and manage the effects of natural disasters. Worldwide, as many as half a million people have died in disasters such as earthquakes, tsunamis, and 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 more by the physics of the catastrophe (e.g., hurricane wind speed) than by performance metrics of the markets themselves (e.g., the Dow Jones Industrial Average (DJIA)), 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 risk.

In academia, the environmental science and finance 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 suggest 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" sidebar).

Climate and weather derivates are currently traded on the Chicago and New York mercantile exchanges. Cat bonds also are now integral to modern risk management practices. In 2007 the cat bond market broke all previous issuance records with US$7 billion in publicly disclosed transactions, up 49% from the previous year's record of $4.7 billion and a 250% increase over the $2 billion placed during 2005 [*Guy Carpenter,* 2008]. This is expected to increase at a compound annual rate of 25–40% [*Lane and Beckwith,* 2007], as there is a fundamental shortfall between the amount of property value at risk and the amount of available insurance and reinsurance capital globally.

According to Barney Schauble, 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 stronger hurricanes (or earthquakes).

But more frequent or intense natural disasters are only a piece of the picture—even a weak earthquake can cause damage if a community has poor infrastructure. Thus, insuring against earthquake 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 evaluating 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 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 into a coherent program. The advent of a vibrant market for trading catastrophe risk will allow an education program to achieve a sharp focus while it uncovers new opportunities for research in each discipline.

According to John Rollins, vice president of AIR Worldwide, a leading risk-modeling company, companies exposed to hazard risks are now aggressively seeking well-trained, well-rounded risk managers with strong backgrounds in geoscience, financial concepts, and insurance [*Rollins,* 2008]. He notes that companies are searching universities for recent graduates with the requisite intelligence and analytical background but are resigned at least for now to train in-house. The increasing awareness of catastrophe risk, greater transparency demands by regulators and rating agencies, interest by insurance executives to have catastrophe modeling experts, and increasing capital in the markets are driving this demand. The demand will likely increase and could possibly lead to a new profession of catastrophe risk management.

Environmental science and geoscience students have the math and statistics abilities needed to understand and predict relationships associated with hazards, and a program that includes exposure to the financial world would greatly expand career opportunities. Moreover, in addition to being numerically adept and aware of finance and markets, these students will have specific familiarity with the physical processes that govern the Earth and atmosphere that math graduates have not yet gained. They will fit firms looking to invest in assets that are uncorrelated with other financial instruments, thus providing good diversification and hedging opportunities for the firms. According to a recent article in the *Financial Times*, the business schools at Massachusetts Institute of Technology, Harvard, Oxford, Columbia, London School of Economics, and elsewhere have brought the courses and expertise of public health, arts, and sciences faculty into their schools.

A graduate program in catastrophe finance would bring courses and expertise of environmental sciences and geosciences into risk management and insurance. Learning outcomes for a graduate program in catastrophe finance would include the ability to analyze and model correlated "random walks," to forecast the probability of catastrophes in geosciences and finance, and to apply knowledge in the insurance, risk management, and investment banking industry. Successful catastrophe finance programs will have faculty and graduates that feel comfortable at the interface of science, finance, and insurance. It would likely provide the career skills and contacts needed to succeed in a variety of career paths outside traditional geoscience disciplines, providing trainees with essential professional skills other than research capabilities.

*Example: Hurricane Risk*

The logic behind a graduate program in the area of catastrophe finance can be seen through the potential evolution of the science and technology of catastrophe modeling into the practice of catastrophe risk management. For example, a climatologist with no background in financial markets could be tasked to examine what regions of an exposed coast are most vulnerable to high wind speeds from hurricanes conditional on a warmer planet. But a climatologist with business knowledge could work with a hurricane risk modeler to determine what regions contain a company's highest losses per exposure unit. Further, a climatologist with a background in financial markets could be tasked to evaluate the adequacy of pricing models by location and perhaps conditional on continued warming as well as to make pricing suggestions that are acceptable to the sponsor and investor.

Hurricane cat models incorporate the frequency and severity characteristics of the modeled peril in today's climate regime. Therefore, there are basic questions for the cat modeler to answer: (1) Does the historical record of the peril—the most dependable portion of which is generally 50–150 years long—have a signature that is clearly distinguishable from what we are experiencing today? (2) How is the signature going to change in the future if the Earth continues to warm? Insurers and risk managers use cat modeling to assess the risk in a portfolio of exposures. This might help guide an insurer's underwriting strategy or help him decide how much reinsurance to purchase.

Some state insurance departments (like Florida's) allow insurers to use cat modeling to set premiums. Insurance-rating agencies

***Catastrophe Finance*** cont. on page 282

By J. B. Elsner, R. K. Burch, and T. H. Jagger

## Transferring Risk

Imagine a scenario of a farmer awaiting 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 makes a bet with a financial agent that if it does rain in June, she'll pay $25. The financier takes the bet, knowing that he will probably win. Thus, when it does rain, the financier earns $25 and the farmer nets $75. If, by chance, it does not rain, the farmer gets $25 from the financier.

At the same time, a hotelier knows that when the rainy season starts, his business, which usually earns $100 a month, will slow to a stop. He makes a bet with the same financier that if it does not rain in June, he will pay the financier, say, $20. Because the odds are not in the hotelier's favor, the financier will only take the bet if the amount he pays the hotelier if it rains is less than the amount he earns from the farmer when it rains. Thus, when it does rain, the hotelier gets $20 from the financier. Because the financier earned $25 from the farmer, the financier's net earnings if it rains in June is $5. However, if it does not rain, the financier gets $20 from the hotelier but has to pay $25 to the farmer—he is out $5. This is a risk the financier is willing to take because the probability of him earning outweighs that of losing, given that it usually rains in June.

The farmer and the hotelier have essentially purchased insurance. The financier can even hedge his own risks of loss by charging a flat transaction fee. The numbers above are contrived; the market will set the value of payouts and premiums.

But what happens when people want to purchase insurance against a catastrophe? Imagine an insurer of coastal properties concerned about the next hurricane season. A severe storm happens once 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 solvent, she could buy reinsurance. Alternatively, she could sponsor a catastrophe (cat) bond, which would pass the risk on to an investor. An investor would buy the bond valued at, say, $100,000; over time, the insurer will repay the bond with, say, 15% interest. If no hurricane hits during the year, the investor makes 15% on his investment. The insurer also turns a profit because she continues to collect premiums. But if this low-probability severe hurricane does hit, then the investor loses his $100,000, which is used by the insurer to pay claims.

The insurer and the investor will need a broker who will charge a transaction fee to issue the bond, ensure payments of the interest, and define what "hit" allows the insurer to forgo her debt. Again, the numbers above are contrived; the market will set the bond value. But pricing depends on the probability of hurricanes. This is how scientists, armed with models and with knowledge of expected climate changes, can help set market values.

cont. from page 281

use cat modeling to assess the financial strength of insurers that take on catastrophe risk. Reinsurance companies and brokers use cat modeling in the pricing and structuring of reinsurance treaties. Likewise, cat bond investors, investment banks, and bond-rating agencies use cat modeling in the pricing and structuring of insurance, catastrophe bonds, and hedging strategies.

### *A New Cross-Disciplinary Opportunity*

Catastrophe risk management is a process that involves using the correct cat model specification (meteorological, climatological, geological), obtaining the exposure information and ensuring its continuing availability and quality (actuarial), choosing analysis options (financial), running and managing analysis jobs, structuring securities for risk transference (risk managerial), and synthesizing 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 conditional on climate change to asking questions about writing new contracts conditional on climate change while considering deductibles within probable maximum loss regulatory guidelines, which will lead to increased professionalism 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 underlying catastrophe-linked instruments. *Mills* [2008] has drawn attention to existing deficiencies found in the current state of insurance regulation, catastrophe modeling, and climate change. With 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 cat model (R. J. Murnane, New directions in catastrophe risk models, World Bank brown-bag lunch presentation, 9 October 2007), similar to the Organization for Economic Co-operation and Development's Global Earthquake Model [*Nature Geoscience,* 2008].

### *Toward a Sustainable Future*

"The culture of our scientific enterprise is on the brink of a sea change." So advised *Fortes and Hempel* [2002, p. 306] in *Oceans 2020*, 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 financial commitment and, ultimately, new forms of partnerships and collaboration in the scientific community. The themes that geoscience needs to broaden the scope of its educational programs through cross-disciplinary training [e.g., *Weiler,* 2007] and to seek new, possibly market-based, funding sources have been expressed by other authors [*Spinrad,* 2007; *Farrington,* 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), respectively.

Markets are beginning to provide innovative opportunities to implement the wisdom of Fortes and Hempel's counsel. Society's need to respond to the series of spectacular disasters from around the globe in recent years and the threat from global warming is now compounded by great turmoil in world financial markets. From this will come greater recognition that financial innovations like cat bonds, which depend on knowledge of the geosciences, are an important and complementary means of addressing the problems caused by catastrophes. As it turns out, providing the public with insurance against catastrophes can also provide investors with an important risk management tool, which increases the need for trained professionals. To the degree that these innovations achieve their purpose and market success, it brings the science community a powerful new ally in its effort to spread knowledge and interest (capacity) outside the scientific community. It is time for faculties from geosciences and finance to collaborate and to train a new generation of students to better manage a sustainable future.

### *Acknowledgments*

Work on this paper was supported through grants from Florida State University, the U.S. National Science Foundation (ATM-0738172), the Risk Prediction Initiative (RPI08-02-002), and the Florida Catastrophic Storm Risk Management Center. The views expressed are those of the authors and do not reflect those of the funding agencies.

### *References*

Carpenter, G. (2008), 2008 reinsurance market review: Near misses call for caution, 60 pp., Guy Carpenter and Co., LLC, New York.

Farrington, J. W. (2008), Inspired by curiosity, inspired by use: A paradigm for ocean science and engineering research, paper presented at the 2008 Ocean Sciences Meeting, Am. Soc. of Limnol. and Oceanogr., Orlando, Fla., 2–7 March. (Available at http://www.aslo.org/orlando2008/)

Fortes, M. D., and G. Hempel (2002), Capacity building, in *Oceans 2020: Science, Trends, and the Challenge of Sustainability*, edited by J. G. Field, G. Hempel, and C. P. Summerhayes, pp. 283–307, Island Press, Washington, D. C.

Lane, M. N., and R. G. Beckwith (2007), That was the year that was! The review of the insurance securitization market, Lane Finan., LLC, Wilmette, Ill., 20 April.

Mills, E. (2008), The role of U.S. insurance regulators in responding to climate change, *UCLA J. Environ. Law Policy, 26,* 129–168.

*Nature Geoscience* (2008), Editorial: Globalizing quake information, *1*(12), Dec.

Rollins, J. (2008), The growing need for talent in catastrophe modeling and risk management, *AIR Currents*, AIR Worldwide Corp., Boston, Mass.

Spinrad, R. (2007), From the president: Economic lessons are OK too, *Oceanography, 20,* 7.

Weiler, C. S. (2007), Meeting Ph.D. graduates' needs in a changing global environment, *Eos Trans. AGU, 88*(13), 149, 151.

Wirtz, A. (2008), Hitting the poor: Impact of natural catastrophes in economies at various stages of development, paper presented at International Disaster and Risk Conference (IDRC) 2008 Davos, Davos, Switzerland, 25–29 Aug.

—James B. Elsner, Department of Geography, Florida State University, Tallahassee; E-mail: jelsner@fsu.edu; R. King Burch, Honolulu, Hawaii; and Thomas H. Jagger, Florida State University