Catastrophe Risk Financing in Developing Countries

PRINCIPLES FOR PUBLIC INTERVENTION

THE WORLD BANK

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Foreword

At a time when both the frequency and intensity of natural disasters are on the rise, the ability of developing countries to reduce their vulnerability and limit their fiscal exposure is becoming a priority. When disasters strike, countries with limited economic resilience often seek assistance from the international donor community or divert funds from development projects to cover emergency and recovery needs. Even though the importance of catastrophe risk financing is recognized, catastrophe risk markets remain hampered by market imperfections that limit their expansion, particularly in developing countries.

The 1992 U.N. Framework Convention on Climate Change and the subsequent Kyoto Protocol refer to the potential role of insurance in disaster mitigation. The Hyogo Framework for Action 2005–2015, signed in January 2005, identifies the need to promote the development of financial risk-sharing mechanisms, particularly insurance and reinsurance against disasters, as a priority action for building the resilience of nations and communities to recover after disasters. While this is only one recommendation among many, the need for innovative risk financing mechanisms is particularly relevant to the middle- and low-income countries.

The risks from natural disasters caused by a changing climate present a growing threat to developing countries that lack the financial and material resources to mitigate their risks. Furthermore, long return periods for the most severe disasters often tend to dampen public and private motivation to develop appropriate catastrophe risk financing programs, including

insurance programs. Funding for relief and reconstruction in developing countries generally comes from very different sources than is the case in industrial countries. In more advanced economies, losses from natural disasters are typically funded through a combination of private risk financing arrangements and an efficient public revenue system relying on wide and deep taxation catchments. In middle- and low-income countries, which have relatively low tax ratios and ongoing fiscal pressures and where catastrophe risk markets are often underdeveloped, funding sources for post-disaster reconstruction tend to be more varied, with strong reliance on ex-post borrowing and assistance from international donors. In addition, the lack of immediate liquidity in the aftermath of a disaster often retards recovery and forces the government to conduct an emergency budget reallocation, which can be detrimental to the long-term fiscal stabilization programs and investment programs. Assistance from multilateral financial agencies plays a particularly important role in middle-income countries, while support from bilateral donors is generally dominant in low-income countries. The World Bank alone has disbursed more than US$40 billion in emergency loans related to natural disasters over the last three decades.

This book, *Catastrophe Risk Financing in Developing Countries: Principles for Public Intervention,* is the result of a joint effort by two World Bank vice presidencies—the Financial and Private Sector Development Network and the Sustainable Development Network—in collaboration with the Global Facility for Disaster Reduction and Recovery (GFDRR). It aims to promote catastrophe risk financing as an integral part of a country's economic policy and an important component of a proactive and strategic framework for disaster risk management. The World Bank has led the agenda on country-level disaster risk management by developing a multipillar disaster risk management approach, in which catastrophe risk financing is an important component. The World Bank Financial and Private Sector Development Vice Presidency, working with regional colleagues, has assisted partner countries in the development of catastrophe risk financing solutions since the late 1990s. Examples include the Turkish Catastrophe Risk Insurance Pool, the Mongolia Livestock Insurance Pool, and the Caribbean Catastrophe Risk Insurance Facility. As part of the Sustainable Development Network, GFDRR is the World Bank's global initiative to enhance national capacities to reduce vulnerability by integrating risk reduction in country development strategies. It is supporting a number of

catastrophe risk financing projects, including the Pacific Catastrophe Risk Pool Initiative.

The book makes a compelling case for public intervention to enhance catastrophe insurance markets and help countries better shoulder the economic and fiscal impacts when disasters strike. The need for ex-ante catastrophe risk financing that efficiently meets disaster needs and fosters longer-term risk management is critical, but such support will not become available without strong and proactive leadership from the donor community and international financial institutions, such as the World Bank.

The authors, J. David Cummins and Olivier Mahul, analyze the current market imperfections that hamper the development of catastrophe risk financing solutions in developing countries, discuss the rationale for public intervention in catastrophe risk financing markets, and propose a comprehensive risk financing approach that links the donor community's disaster assistance to low- and middle-income countries with the broader disaster risk management agenda. They offer a set of key principles for public intervention in catastrophe risk markets and recommendations aimed at stimulating efficient catastrophe risk financing solutions—for example, leveraging more public-private partnerships, promoting competitive risk markets, contributing to the development of risk market infrastructure, and providing technical assistance. Effective legal and regulatory frameworks and public subsidy incentives to minimize the distortion of price signals can also catalyze efficient and competitive insurance and reinsurance markets. The authors conclude that the role of the international development community is paramount in providing access to catastrophe risk markets and expanding the range of risks covered. This is welcome news for highly exposed countries that currently have only limited options and must struggle to recover from a disaster's devastating effects.

We hope that this book will contribute to the dialogue on disaster risk management with the disaster-prone countries and will assist them to engage in risk financing efforts.

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Acknowledgments

Abbreviations

ADB	Asian Development Bank
AEL	annual expected loss
AICI	Agricultural Insurance Company of India
AMO	Atlantic Multidecadal Oscillation
ART	alternative risk transfer
BAAC	Bank for Agriculture and Agricultural Cooperatives (Thailand)
BCE	Bermuda Commodities Exchange
CABEI	Central American Bank for Economic Integrations
CAPM	capital asset pricing model
CARICOM	Caribbean Community (an organization)
CAT	catastrophe
CATEX	Catastrophe Risk Exchange
CatNat	Catastrophes Naturelles (French program for catastrophe risk management)
CBOT	Chicago Board of Trade
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CEA	California Earthquake Authority
CME	Chicago Mercantile Exchange
CRED	Centre for Research on the Epidemiology of Disasters
CSN	contingent surplus note
DDO	draw-down option
DFID	U.K. Department for International Development

DRM	Disaster Risk Management
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
EM-DAT	Emergency Disasters Database
EQC	New Zealand Earthquake Commission
EQECAT	a catastrophe modeling firm
FHCF	Florida Hurricane Catastrophe Fund
FIDES	Latin American Federation of Insurance Companies
FONDEN	National Calamity Fund (Mexico)
FSDT	Financial Sector Deepening Trust
GAO	Government Accounting Office (United States)
GDP	gross domestic product
GFDRR	Global Facility for Disaster Reduction and Recovery
GNI	gross national income
HFA	Hyogo Framework for Action
IADB	Inter-American Development Bank
IBRD	International Bank for Reconstruction and Development (of the World Bank Group)
IDA	International Development Association (of the World Bank Group)
IFI	international financial institution
IFRS 4	an international insurance reporting standard
ILW	industry loss warranty
IPCC	Intergovernmental Panel on Climate Change
IMF	International Monetary Fund
INS	Instituto Nacional de Seguro (public insurance company of Costa Rica)
JER	Japanese Earthquake Reinsurance Company
LIBOR	London Inter-Bank Offered Rate
LIIP	Livestock Insurance Indemnity Pool
LOL	loss online
MFI	microfinance institution
MMI	Modified Mercalli Intensity
NAIS	National Agriculture Insurance Scheme (India)
NOAA	National Oceanic and Atmospheric Administration (United States)

NYMEX	New York Mercantile Exchange
OECD	Organization for Economic Co-operation and Development
OECS	Organisation of Eastern Caribbean States
PCS	Property Claims Services
PML	probable maximum loss
PSNP	Productive Safety Net Programme (Ethiopia)
RFE	rainfall estimate
ROI	return on investment
ROL	rate online
RTER	reinsurer's target economic return (or risk loading)
SME	small and medium enterprises
SPR	single purpose reinsurer
TCIP	Turkish Catastrophe Insurance Pool
TIV	total insured value
TREIP	Taiwan Residential Earthquake Insurance Pool
UN	United Nations
USAID	U.S. Agency for International Development
WFP	World Food Programme
WMO	World Meteorological Organization
WTC	World Trade Center

Glossary

Adverse Selection   Adverse selection occurs when potential insurance purchasers know more about their risks than the insurer does, leading to participation by high risk individuals and nonparticipation by low-risk individuals. Insurers react by either charging higher premiums or not insuring at all, as in the case of floods.

Annual Expected Loss   Expected loss per year when averaged over a very long period (for example, 1,000 years). Computationally, AEL is the summation of products of event losses and event occurrence probabilities for all stochastic events in a loss model.

Alternative Risk Transfer   Refers to any non-traditional form of insurance risk transfer. Catastrophe bonds are a form of ART.

Basis Risk   The risk, with index insurance, that the index measurements will not match individual losses. Some households that experience loss will not be covered, for example, and some households that experience no loss will receive indemnity payments. As the geographical area covered by the index increases, basis risk will increase as well.

Capacity   The maximum amount of insurance or reinsurance that the insurer, reinsurer, or insurance market will accept.

Captive Insurance   The arrangement whereby a subsidiary company provides insurance or reinsurance for its parent.

Catastrophe   A severe, usually sudden, disaster that results in heavy losses.

Catastrophe Bond   High-yielding, insurance-linked security providing for payment of interest and/or principal to be suspended or cancelled in the event of a specified catastrophe, such as an earthquake.

Catastrophe Model   A computerized model generating a set of simulated events to calculate losses arising from a catastrophe.

Catastrophe Swap   Contract used by investors to exchange (swap) a fixed payment for a certain portion of the difference between insurance premiums and claims.

Claim   An insurer's application for indemnity payment after a covered loss has occurred.

Combined Ratio   Represents the total of acquisition and administrative expenses and claims and insurance benefits incurred divided by premiums earned.

Direct Loss   Recovery cost of the damaged assets.

Diversification   Refers to the variety of assets within a portfolio in terms of its geographical or sectoral spread, or in terms of its credit quality. In general, risk is reduced as portfolio diversification increases.

Exceedance Probability   Likelihood that the losses will exceed a specified loss amount.

Exposure   The amount (sum insured), exposed to the insured peril(s) at any one time.

Facultative Reinsurance   The reinsurance of individual risk at the option of the reinsurer and the ceding company, whether under a treaty or by negotiation.

Hard Reinsurance Market   The supply of reinsurance coverage is restricted and prices rise.

Hazard   A physical or moral feature that increases the potential for a loss arising from an insured peril or that may influence the degree of damage.

Indemnity   The amount payable by the insurer to the insured, in the form of cash, repair, replacement, or reinstatement, in the event of an insured loss. This amount is measured by the extent of the insured's pecuniary loss. It is set at a figure equal to but not more than the actual value of the objects insured just before the loss, subject to the adequacy of the sum insured.

Indirect Losses   Economic consequences of the damaged assets (e.g., foregone revenue).

Insurance   A financial mechanism that aims to reduce the uncertainty of loss by pooling a large number of uncertainties so that the burden of loss is distributed. Generally, each policyholder pays a contribution to a fund, in the form of a premium, commensurate with the risk he introduces. The insurer uses these funds to pay the losses (indemnities) suffered by any of the insured.

Insurance Captive   An insurance company that is owned and controlled by its insureds.

Insurance Policy   A formal document (including all clauses, riders, and endorsements) that expresses the terms, exceptions, and conditions of the contract of insurance between the insurer and the insured. It is not the contract itself but evidence of the contract.

Layer   The term used to define a range of potential loss that is covered by insurance. For example, an insurance contract may pay indemnities only for losses within a specified range of magnitude.

Limit   Maximum indemnity payout specified in the insurance policy.

Loss on Line   Annual expected loss as a percentage of the policy limit.

Moral Hazard   In insurance, moral hazard refers to the problems generated when the insured's behavior can influence the extent of damage that qualifies for insurance payouts. Examples of moral hazard are carelessness, fraudulent claims, and irresponsibility.

Parametric Insurance   Parametric insurance makes indemnity payments based not on an assessment of the policyholder's individual loss, but rather on measures of a parametric index that is assumed to proxy actual losses.

Premium   The monetary sum payable by the insured to the insurers for the period (or term) of insurance granted by the policy.

Premium = premium rate × amount of insurance

Also, the cost of an option contract—paid by the buyer to the seller.

Premium Rate   The price per unit of insurance. Normally expressed as a percentage of the sum insured.

Price Multiple   Ratio of the rate on line to the loss on line.

Probable Maximum Loss (PML)   The largest loss believed to be possible for a certain type of event in a defined return period, such as 1 in 100 years, or 1 in 250 years.

Rate on Line   Insurance premium as a percentage of the policy limit.

Reinsurance   When the total exposure of a risk or group of risks presents the potential for losses beyond the limit that is prudent for an insurance company to carry, the insurance company may purchase reinsurance (that is, insurance of the insurance). Reinsurance has many advantages, including 1) leveling the results of the insurance company over a period of time; 2) limiting the exposure of individual risks and restricting losses paid out by the insurance company; 3) possibly increasing an insurance company's solvency margin (percent of capital and reserves to net premium income), hence the company's financial strength; and 4) enabling the reinsurer to participate in the profits of the insurance company, but also to contribute to the losses, the net result being a more stable loss ratio over the period of insurance.

Risk Financing   The process of managing risk and the consequences of residual risk through products such as insurance contracts, CAT bonds, reinsurance, or options.

Risk Layering   The process of separating risk into tiers that allow for more efficient financing and management of risks.

Risk Pooling   The aggregation of individual risks to manage the consequences of independent risks. Risk pooling is based on the law of large numbers. In insurance terms, the law of large numbers demonstrates that pooling large numbers of roughly homogenous, independent exposure units can yield a mean average consistent with actual outcomes. Thus, pooling risks allows an accurate prediction of future losses and helps determine premium rates.

Risk Retention   The process whereby a party retains the financial responsibility for loss in the event of a shock.

Risk Transfer   The process of shifting the burden of financial loss or responsibility for risk financing to another party, through insurance, reinsurance, legislation, or other means.

Soft Reinsurance Market   The reinsurance coverage supply is plentiful and prices decline.

Systemic Risk   Risk that impact the entire financial system, rather than individual sectors. Exposure to systemic risk cannot be avoided through diversification.

Total Economic Losses   Sum of direct and indirect losses.

Overview

T*he exposure of low- and middle-income countries to natural disasters is increasing.* Because of a variety of factors, ranging from the growing concentration of population and assets in risky areas to increases in climate variability, the economic costs of major slow-onset disasters (e.g., drought) and rapid-onset disasters (e.g., hurricanes, earthquakes) in developing countries are on the rise. Although the costliest disasters generally occur in developed countries, which have the highest concentration of assets, small island economies experience the largest capital stock losses as a proportion of gross domestic product (GDP). Middle-income countries have experienced the largest direct losses, in terms of annual average direct losses compared to GDP.

Post-disaster financing strategies generally have high opportunity costs for developing countries. When a disaster occurs, budget allocations are often diverted from priority development projects to fund emergency and recovery needs. Raising new debt in an expensive post-event capital market may significantly affect the country's debt service, and raising taxes may discourage new private investments that are central to restarting the economy. Post-disaster assistance from the international donor community may be slow and unreliable. In the face of the rising frequency and intensity of losses in low- and middle-income countries, the old model of post-disaster financing and reliance on the donor community is increasingly inefficient.

There is a critical need to develop ex-ante funding programs that are more efficient in meeting disaster needs and fostering disaster risk management (DRM) efforts. Ex-ante financial programs can be developed to meet several needs. They can provide immediate liquidity to governments for post-disaster relief and reconstruction of damaged government properties and infrastructure, and offer insurance to homeowners, businesses, and the agricultural community to mitigate the financial impact of disasters. Several recently completed and proposed projects have provided useful examples for developing efficient disaster financing strategies that dovetail with new efforts to outline a more proactive disaster risk management framework for the developing world.

Toward a Country Catastrophe Risk Financing Framework

International financial institutions and the donor community promote a proactive DRM approach. The donor community and international financial institutions (IFIs), like the World Bank, support a more proactive disaster risk management approach and encourage governments to shift their focus from post-event disaster response to a comprehensive DRM framework by developing better early warning systems, institutional capacities for emergency preparedness, risk mitigation investments to protect critical infrastructure, and innovative risk financing products. In partnership with the United Nations, the World Bank established the Global Facility for Disaster Reduction and Recovery (GFDRR) in 2006 to facilitate comprehensive disaster prevention, risk management, increased investments in prevention and preparedness, and risk financing. Several major donors have joined this partnership. In particular, GFDRR financial and technical assistance supports the development of national strategies and capacity-building interventions to enhance investment in risk reduction and risk transfer mechanisms.

The DRM framework includes a country catastrophe risk financing model. To help countries reduce their reliance on external assistance, the World Bank has developed a country catastrophe risk financing model. This model promotes market-based catastrophe risk financing solutions for homeowners, businesses, farmers, and governments through public-private

partnerships, supported by the donors and IFIs. It assists countries in developing tailor-made catastrophe risk financing strategies through an optimal combination of financial instruments. This framework relies on three pillars: i) assessing the government's contingent liability to natural disasters; ii) enabling risk transfer to competitive insurance and reinsurance markets; iii) financing sovereign risk.

A few catastrophe insurance programs in developing countries have been successfully implemented. Despite the increasing involvement of the international donor community, only a few developing countries have developed affordable, effective and sustainable catastrophe insurance programs without heavy public subsidies. Many insurance pilots, particularly in agriculture, face technical, operational and institutional challenges when they are scaled up.

Property catastrophe insurance programs for homeowners have emerged in some middle-income countries, such as Turkey. The Turkish Catastrophe Insurance Pool (TCIP) was established in the aftermath of the Marmara earthquake in 2000, with the assistance of the World Bank. The pool offers efficiently priced earthquake insurance to homeowners. The TCIP sold more than 2.7 million policies (i.e., 20 percent penetration) in 2007, compared to 600,000 covered households when the pool was set up. A similar catastrophe pool is being developed in Romania and for South-Eastern European countries.

Index-based insurance offers new opportunities for the emergence of commercial agriculture insurance in low- and middle-income countries, but its scalability still needs to be demonstrated. The emergence of index-based insurance, both at the micro (farmer) and macro (government) level, supported by the World Bank and donors, contributes to a revisiting of a potential role for agriculture insurance in economies where agricultural sectors have become more profitable and commercially oriented. Index-based insurance products, which rely on the measurement of an objective and independent proxy, offer new opportunities to transfer the systemic components of crop losses caused by droughts, low temperatures or extended floods. An index-based insurance program is also piloted for livestock in Mongolia. While this type of insurance shows promise, it is cost-effective only for specific crops, perils, and geographical areas. Implemented in more than 15 countries, such as in India and Mexico,

index-based agricultural insurance still needs to demonstrate sustainability and scalability, particularly in low-income countries.

Sovereign risk financing allows countries to secure access to financial capacity when a disaster hits. Sovereign risk financing is particularly justified for countries for which potential losses caused by natural disasters are large relative to their national economies, or where the cost of mobilizing post-disaster funding is high. A cost-effective sovereign risk financing strategy relies on an optimal layering of catastrophe risk, including establishment of a reserve fund to cover small and recurrent losses, contingent credit, and financial instruments such as reinsurance and catastrophe bonds. The Caribbean Catastrophe Risk Insurance Facility (CCRIF) offers Caribbean countries budget insurance akin to business interruption coverage that will provide immediate liquidity in the case of a major hurricane or earthquake. The Mexican government secured US$450 million in contingent disaster financing through traditional reinsurance and catastrophe bonds covering a major earthquake affecting Mexico. The World Bank is investigating new financial services to help countries transfer their catastrophe risks to the capital markets, including multi-country catastrophe bonds and weather derivatives.

Regional catastrophe insurance pools can offer developing countries access to international reinsurance on competitive terms and new business opportunities to the reinsurance industry. Governments are often hesitant to purchase insurance from private agents for bureaucratic reasons. Likewise, insurers may be reluctant to start a business relationship with a government, since it is unlikely to offer a long-term commitment because of changing annual budgets and political regimes. Regional catastrophe insurance pools, such as the CCRIF, can facilitate access to the reinsurance markets on competitive terms by pooling country-specific risks into a single, better structured portfolio. They create new business opportunities to the reinsurance industry, which may not have otherwise approached these countries on an individual basis because of the high transaction costs.

Why Should Donors Intervene in Catastrophe Risk Markets?

The historical framework of disaster recovery for low- and middle-income countries is a heavy dependence on post-disaster assistance,

particularly contributions from donors. As the impact of disasters has increased, this system is becoming increasingly unsustainable and a more proactive approach to disaster risk management is needed. Evidence shows that disaster-related external assistance is usually not incremental, but instead largely displaces funding for development, if not immediately, then over one to two years. In addition to crowding out other investment lending programs, reallocations have been a large part of the IFIs' response to disasters. Although reallocations can give countries flexibility to react to unforeseen needs, they divert funds from their original purposes and can prevent the achievement of planned development goals.

The catastrophe insurance markets are underdeveloped in low- and middle-income countries. More than 40 percent of the direct losses from natural disasters are insured in developed countries, usually through compulsory insurance. On the contrary, it is estimated that less than 10 percent of these losses are covered by insurance in middle-income countries and less than 5 percent in low-income countries. This is a direct consequence of the underdeveloped non-life insurance markets. The insurance penetration, measured as a percentage of GDP, is 1.4 percent in Latin America and Africa, compared to 3 percent in Europe and almost 5 percent in North America.

Insurance is a complex financial product requiring sophisticated financial infrastructure. Insurance markets are heavily dependent on information flows. Information on policyholder risk characteristics is transmitted from insurance intermediaries, such as brokers and agents, to primary insurance companies that issue policies to individuals and businesses. Primary insurers in turn need to provide information to global reinsurers when they purchase reinsurance. This is often done through reinsurance brokers. Breakdowns in the informational flows at any point in the process can lead to serious market problems, such as incorrect pricing, inadequate loss reserves, insufficient equity capital, and poorly designed reinsurance programs.

Market imperfections can impede the emergence of competitive catastrophe insurance markets. On the demand side, the development of efficient catastrophe insurance markets is undermined by low non-life insurance penetration, inadequate awareness of catastrophe risk exposure, and limited ability to pay insurance premiums due to low incomes. At the

government level, very few countries have developed national disaster risk management programs, which could facilitate the emergence of risk financing solutions and the availability of inexpensive post-disaster funding. For middle-income countries, some of the demand side imperfections are less severe than for the low-income countries. For instance, reasonably well-developed insurance markets exist in some middle-income countries, and the level of financial literacy among consumers tends to be higher.

Supply-driven market imperfections are mainly due to limited technical capacity, undercapitalization of local insurers, and regulatory impediments. The level of technical expertise required to interact effectively with the reinsurance and capital markets has grown rapidly. However, domestic companies in many developing countries tend to lack the necessary financial and actuarial expertise to design and price catastrophe insurance programs and to present attractive proposals to international reinsurers. The problem is most acute in low-income countries. International reinsurers are often discouraged from doing business in low- and middle-income countries because of a lack of data or the absence of catastrophe risk models. In addition, many of the domestic insurers, particularly in low-income countries, are undercapitalized, which considerably limits their ability to offer catastrophe insurance. Regulatory requirements may also impede the supply of catastrophe insurance.

Catastrophe reinsurance capacity is available for developing countries as long as their risk portfolio is properly structured and adequately priced. The capacity of the global catastrophe reinsurance (and particularly catastrophe excess of loss) increased from US$160 billion in 2006 to almost US$180 billion in 2007, including more than US$20 billion raised by new or existing reinsurance companies following the 2006 hurricane season. Capital also enters the catastrophe reinsurance market through a non-traditional financial instrument such as catastrophe (CAT) bonds. Nearly US$8 billion in new risk capital was raised in the CAT bond market in 2007. Although 75 percent of the catastrophe reinsurance capacity is allocated to North America and Western Europe, reinsurance companies are more and more interested in allocating capital to middle- and low-income countries in order to diversify their portfolios. However, the requisite portfolio preparation work, such as catastrophe risk modeling and data

collection, can be expensive relative to potential revenues, particularly in low-income countries.

Catastrophe reinsurance prices in middle-income countries tend to be lower than those in some developed countries because of the diversification benefits. Catastrophe reinsurance prices are sometimes considered "excessive," because reinsurance premiums are often much greater than the expected reinsured losses. The price of catastrophe reinsurance is mainly driven by the expected loss, the expense load, and the contingency load. In middle- and low-income countries, the expense load tends to be higher than that in developed countries because of higher startup and administrative costs. The total cost of capital tends to be lower for countries where catastrophe risks are not highly correlated with the peak risks in developed countries, because investors tend to reward risk diversification. The catastrophe bond in Mexico and the Caribbean Catastrophe Risk Insurance Facility demonstrate that well-structured portfolios can be placed on reinsurance and capital markets on good terms. Catastrophe reinsurance is currently almost non-existent in most low-income countries, except a few deals on agriculture insurance supported by the donor community. In those cases, catastrophe reinsurance prices tend to follow those of middle-income countries when the deal is well structured, but this requires significant effort and investment.

Domestic insurance markets in middle- and low-income countries are particularly exposed to catastrophe reinsurance cycles. Reinsurance markets experience periodical market fluctuations ("hard markets") when coverage supply is restricted and prices rise sharply. Such fluctuations have limited impact in middle- and low-income countries, where exposure to risk is relatively small and not highly correlated with peak exposures in developed markets, and particularly in the U.S. market. This is a direct consequence of the increasing pricing discrimination between countries, and even between regions within a country. Nevertheless, these fluctuations can significantly impact the domestic catastrophe insurance market in middle- and low-income countries, through price increases and/or reduction of supply, because many of the domestic insurance companies rely extensively on external risk capital provided by the international reinsurance markets. Undercapitalized insurers cannot retain more catastrophe

risks when the market is hard and, consequently, their insurance prices follow the volatility of the reinsurance prices.

Catastrophe insurance market imperfections can justify intervention by the public sector, supported by the development community. The development of catastrophe insurance and reinsurance markets in low- and middle-income countries is impeded by a variety of demand side and supply side market imperfections. Overcoming these problems is an essential step in putting together risk transfer programs that can be presented to international reinsurance and capital markets. Technical assistance may be needed to create domestic insurance and financial infrastructure for risk packages that can be reinsured or securitized. If this step can be accomplished, the reinsurance placements and securitizations should be relatively successful, that is, risk transfer can be accomplished at a reasonable price and without significant exposure to supply constraints. The rationale is that risk transfer placements from developing countries are generally quite small in comparison with developed-market transactions and are valuable to reinsurers and investors for diversification purposes, because they cover off-peak perils and geographical areas where reinsurers and investors currently have little exposure. The story is similar for middle-income countries, except that some technical capability is already present to assist in structuring packages of risks for transfer into global markets. However, there is significant heterogeneity across the middle-income countries in regard to the severity of the supply side imperfections.

How Should Donors Intervene in Catastrophe Risk Markets?

The donor community has an interest in facilitating the development of catastrophe risk financing markets, given market inefficiencies and the clear fiscal and developmental implications of natural disasters for middle- and low-income countries. To date, the World Bank has led this agenda among the development community, through building a DRM framework in which catastrophe risk financing is an important component and supporting the development of risk financing instruments and vehicles.

Public interventions in catastrophe insurance markets should be "market-enhancing." The market-enhancing view recognizes that market failures

can create suboptimal allocations of resources and that private sector coordination is not always effective. Public policy should facilitate the development of risk market infrastructure that enables market-based solutions, such as the creation of public goods (for example, data collection and management systems) and the provision of technical assistance. Governments should avoid creating permanent, new government institutions to substitute for private solutions, although government institutions can be invoked in very specific circumstances where risks are ill-defined and private market solutions are not available.

Public intervention clearly has a role in catastrophe insurance markets, but inappropriate intervention can be ineffective or even detrimental, leading to public failure. Public insurance programs have been shown to be inefficient, because they are unlikely to follow the key principles for efficient catastrophe insurance, which rely on risk segregation and price discrimination to control adverse selection and the use of various mechanisms to control moral hazard. Likewise, the provision of direct insurance premium subsidies tends to distort the market price signal and encourages policyholders to over-invest in risky areas.

Five key principles should guide public intervention in catastrophe insurance markets. The principles reflect the need for close partnerships between the countries, the donor community, and international financial institutions such as the World Bank for the development of competitive catastrophe insurance and reinsurance markets.

- *Promote catastrophe risk financing in the dialogue on disaster risk management with low- and middle-income countries.* Disaster risk management should become part of a wider dialogue with countries regarding macroeconomic stability and growth. The lack of disaster risk financing has a significant impact on fiscal discipline, debt sustainability and country ratings. Catastrophe risk financing solutions, including insurance, should be encouraged within the five-pillar DRM framework. Risk financing solutions should be designed to further induce policyholders to mitigate their risks.

- *Enhance competitive catastrophe risk markets.* The development community can play an important informational role to help create more efficient insurance and reinsurance markets. An effective legal and

regulatory framework is needed to support competitive markets. Public-private partnerships can stimulate the development of competitive domestic insurance industries and facilitate access to international reinsurance and capital markets to generate effective and affordable insurance solutions for private agents (for example, property insurance for homeowners) as well as governments (for example, sovereign insurance).

- *Use risk-based price signals to encourage catastrophe risk management.* One of the important roles of competitive financial markets is the provision of price signals. In competitive markets, insurance premiums should be risk-based and differentiated, thus reflecting the underlying risk exposure. These draw attention to the catastrophe risk exposure of individuals, firms or governments, and allow them to evaluate the benefits of a disaster risk management program by comparing the cost of risk reduction investments with the resulting reduction in potential losses.

- *Limit public subsidy programs to those that minimize distortions of market price signals.* Premiums should be risk-based and differentiated, thus reflecting the underlying risk exposure. These market price signals would inform policyholders about their true risk exposure and encourage them to engage in cost-effective mitigation measures. Market-enhancing insurance subsidies can be justified to finance the development of risk market infrastructure. These should be targeted at startup costs for specific insurance programs, the development of public goods and the provision of technical assistance. These public subsidies should be made available to all market players in order to enhance competitive markets. Direct insurance premium subsidies should be avoided, because: i) they distort the market price signal and thus give policyholders the wrong economic incentives; ii) they tend to benefit high-risk policyholders to the detriment of low-risk policyholders; and iii) they are almost impossible to phase out in the long term. However, they could be justified as part of a social safety-net program, where the government wants to provide financial assistance to targeted households and the delivery system developed by the insurance industry is more effective than the public delivery systems in reaching the targeted population.

- *Develop customized catastrophe insurance solutions*. Risk financing solutions typically need to be tailored to specific local conditions. The role of donors in the financing of natural disaster protection should be tailored to country-specific variables, including risk exposure, the ability to diversify risks spatially and across time (for example, debt level, tax base), the degree of development of the domestic insurance market, the access to international (re)insurance and capital markets.

What Roles for the Donor Community?

The donor community can play four key complementary roles in the development of catastrophe insurance solutions for developing countries. In appraising the role of donors and IFIs in supporting the development of catastrophe risk financing solutions, the following can be identified: convening power, promoter of public goods that permit the development of risk market infrastructure, provider of technical assistance for innovative catastrophe insurance solutions, and financier.

- *Convening Power*. Using their in-depth knowledge of the client countries, their relationship with donors, and their reputation for impartiality in dealing with countries and the international reinsurance market, the World Bank and other IFIs can play a catalytic role in the development of efficient partnerships among countries, donors, and private markets for the financing of catastrophe risks.

- *Promoter of Public Goods*. Donors can play a major role in financing public goods that contribute to the creation of a risk market infrastructure, which facilitates the development of market-based risk financing solutions. Public goods include information collection and management systems, catastrophe risk assessment programs, risk modeling development programs, awareness and education campaigns, and institutional capacity building.

- *Provider of Technical Assistance for Innovative Catastrophe Insurance Solutions*. Donors can promote the emergence of innovative risk financing solutions, including index-based insurance products, national and regional catastrophe insurance pools (for example, TCIP, CCRIF),

and risk transfer vehicles (such as reinsurance, catastrophe bonds, weather derivatives).

- *Financier.* Donors and international financial institutions such as the World Bank can also finance catastrophe risk insurance programs by providing initial capital or reserves to public-private insurance vehicles, contingent loans, temporary premium finance, or by acting as enhancers or credit guarantors of future payments.

Public intervention in catastrophe insurance markets, supported by the donor community and the World Bank, should be country specific. Low-income countries, where the domestic non-life insurance market is undeveloped, should focus in the short term on the development of sovereign catastrophe insurance solutions and the promotion of public goods related to risk market infrastructure. These countries are usually not mature enough for the promotion of catastrophe insurance pools for private homeowners. Middle-income countries, where the domestic non-life insurance market is more developed, should help the private insurance industry offer market-based catastrophe insurance solutions to homeowners and to small and medium enterprises, including the agricultural sector. This book offers a framework, with lessons drawn from recent experience, guiding principles for public intervention and potential roles for donors and IFIs. These lessons are expected to be used in developing affordable, effective and sustainable country-specific catastrophe insurance programs.

Introduction

Because of a variety of factors, ranging from the growing concentration of population and assets in risky areas to increases in climate variability, the economic costs of major disasters in developing countries are on the rise. Although, in absolute terms, the costliest disasters occur mainly in developed countries, which have the highest concentration of assets, small and less developed economies experience the largest losses as measured by the effect on GDP. This chapter reviews the recent shift from post-disaster assistance to the proactive disaster risk management framework, promoted by the donor community and international financial institutions like the World Bank, with a particular attention on catastrophe risk financing.

Cost of Natural Disasters in Developing Countries

Scientific data shows that the frequency and severity of natural disasters is on the rise. The reported number of disasters has been increasing, from about 140 in 1980 to more than 400 in 2006. Hydro-meteorological events accounted for approximately 90 percent of the total natural disasters over this period (World Bank 2006a).

Social and economic vulnerability to natural events is rising as the world becomes more populated and people continue to damage the environment, which in turn intensifies the effects of natural disasters. New economic opportunities bring people into urban and fragile coastal areas, where the destruction caused by earthquakes and extreme weather events is often greatest. The more vulnerable people are, the more disastrous a natural event will be.

In drought, problems associated with a shortage of water are exacerbated by deforestation, soil erosion, and inappropriate land use. Floods are caused by the silting up of rivers and the loss of absorptive capacity of the soil—both due to poor agricultural practices that destroy groundcover and other natural environmental defenses. Destruction of forests and overgrazing to meet the needs of growing populations leads to desertification. Earthquakes are most destructive when steeply sloped land loses grass and forest cover and becomes occupied with informal housing.

There is also growing evidence that this process is being driven by manmade carbon dioxide emissions, which may alter weather patterns by increasing not only mean temperatures or rainfall levels, but also the frequency of extreme events. Relatively modest increases in temperatures or rainfall can have a much greater impact on the frequency of extreme events, and hence the distribution of losses, as the relationship between hazard and losses is non-linear (IPCC 2007).

The economic costs of major disasters in constant dollars are now estimated to be 20 times higher than they were in the 1970s (Swiss Re 2007d). See Figure 1.1. These figures mainly capture the direct effects, but the overall macroeconomic impact of natural disasters is much larger, because in the aftermath of a natural disaster, output growth tends to decline, the external balances worsen, and the fiscal balance deteriorates.

In absolute terms, the costliest disasters mainly occur in developed countries (or at least in large economies) where the concentration of assets, and thus potential losses, is the highest. However, in such economies, the capital stock losses as a proportion of GDP is limited to a few percentage points (see Table 1.1). For instance, Hurricane Katrina, the costliest natural disaster in history, amounted to only 1.1 percent of U.S. GDP. On the contrary, smaller, less-developed economies experience losses that are lower in absolute monetary terms, but much more severe

Figure 1.1 Direct Losses from Natural Disasters, Worldwide
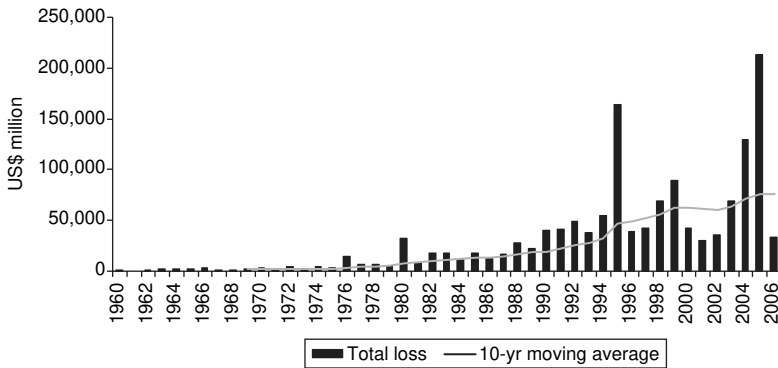
The estimated direct losses (in values of 2006) from natural disasters (CRED definition) excludes: epidemic, insect infestation, slides, and wildfires.
Source: CRED EM-DAT database.

Table 1.1 Major Disasters in the Last 40 Years

Year	Natural disaster	Country	Region	Direct loss (US$ million)	Direct loss (% of GDP)
Large Economies					
2005	Hurricane (Katrina)	USA	North America	125,000	1.1%
1995	Earthquake	Japan	East Asia	100,000	3.2%
1998	Flood	China	East Asia	30,000	0.7%
2004	Earthquake	Japan	East Asia	28,000	0.8%
1992	Hurricane (Andrew)	USA	North America	26,500	0.4%
Small Island Economies					
1988	Hurricane (Gilbert)	St. Lucia	Caribbean	1,000	365%
1991	Cyclone (Val and Wasa)	Samoa	Oceania	278	248%
2004	Hurricane (Ivan)	Grenada	Caribbean	889	203%
1990	Cyclone (Ofa)	Samoa	Oceania	200	178%
1985	Cyclone (Eric and Nigel)	Vanuatu	Oceania	173	143%

Source: CRED EM-DAT database, World Bank (2006a).

in their effect on GDP. Small island economies are particularly vulnerable to natural disasters, with direct losses representing several times their GDP. Hurricane Gilbert in 1988 caused damages exceeding 365 percent of St. Lucia's GDP; a few years later, Hurricane Ivan caused damages estimated at 203 percent of GDP in Grenada.

Middle-income countries have been the most affected by natural disasters (with regard to their direct losses in percentage of GDP) over the last two decades, as shown in Figure 1.2. The annual average cost (including both disaster and non-disaster years) faced by middle-income countries represents 1 percent of GDP over the period 2001–2006, with a peak of 1.6 percent of GDP in 1995–2000. Fourteen of the twenty countries with the highest economic risk exposure are classified as middle-income countries (World Bank 2005b).

To demonstrate the magnitude of future direct losses, reference losses have been defined for selected markets, using the concept of probable maximum loss (PML). The PML gives the maximum direct loss amount caused by a specific natural peril that is likely to be equaled or exceeded with a specified probability in a given year. It is computed using sophisticated catastrophe risk models. For example, a hurricane event in Jamaica occurring once every 100 years (that is, with a return period of 100 years or a 1 percent annual probability of occurrence) would cause

Figure 1.2 Average Annual Direct Losses from Natural Disasters Compared to GDP
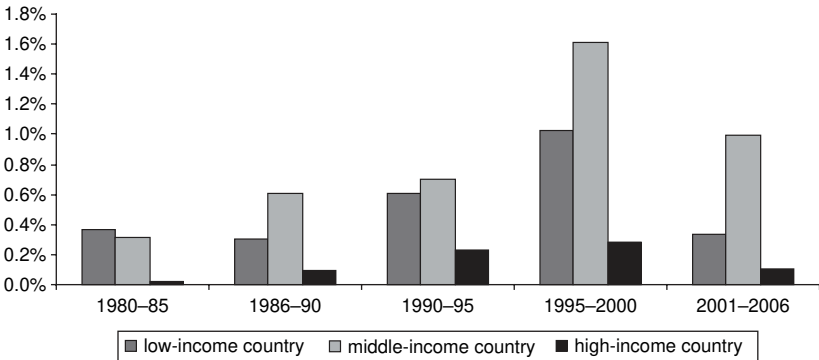
Natural disasters are: drought, volcanoes, waves or surge, earthquake, flood, extreme temperature, windstorm, based on CRED EM-DAT classification. World Bank country classification (2006). See Annex 1.
Source: Authors from CRED EM-DAT database, *Swiss Re (2007d), World Bank (2005b).*

direct losses of up to US$111 billion, or 121 percent of GDP. A major earthquake in Pakistan, with a 250 year return period, would cause US$31 billion of direct losses, that is, 28 percent of GDP. Annex 2 compiles a list of reference losses for almost 50 countries. These reference losses capture damage caused on buildings (residential, commercial, industrial) and infrastructure. It is noteworthy that most major losses are expected to be caused by earthquakes, except in islands that are particularly exposed to hurricanes.

Proactive Country Disaster Risk Management

Post-disaster financing strategies generally have high opportunity costs for developing countries. Budget allocations are diverted from priority development projects to fund emergency and recovery needs. Raising new domestic debt in an expensive post-event capital market may significantly affect the country's debt service, and raising taxes may discourage new private investments that are central to redeveloping the economy (Ghesquiere and Mahul 2007). The government may not wish to retain all possible losses, given the cost of risk transfer, but instead may retain only those that are below a tolerable fiscal cost threshold. In determining this threshold, the goal is to avoid disruption in the projected fiscal and macroeconomic performance while taking into account post-disaster funding provided by international donors. Finally, although donors have been generous in a number of cases, assistance has been highly dependent on the visibility of a given event in the international press, and donations usually arrive long after the event, making them an unreliable risk management instrument.

Disaster reduction and recovery is a critical part of the poverty reduction agenda. The increasing disaster-related risks pose a threat to development gains. The Hyogo Framework for Action (2005–2015), HFA, is the primary international agreement for disaster reduction. Its principal objective is to more effectively integrate disaster risk considerations into sustainable development policies, planning and programming.

In support of the HFA, the World Bank, in partnership with the United Nations, established the Global Facility for Disaster Reduction and

Recovery (GFDRR) in 2006 to facilitate comprehensive disaster prevention risk management, increased investments in prevention and preparedness, and risk financing. Several major donors have joined this partnership and GFDRR is becoming a major vehicle for financial and technical assistance in disaster risk management (see Box 1.1).

The World Bank and the GFDRR have been promoting a proactive and strategic framework for disaster risk management. The underlying principles are that both the loss of life and the economic impact of disasters can be reduced by advance planning and cost-effective investment (Pusch 2004). The proactive disaster risk management framework is based on five pillars and offers countries an operational template for gradually and systematically investing in upgrading their systems:

Box 1.1 GFDRR Financial and Technical Assistance

GFDRR financial and technical assistance uses a three track approach:

Track I, which is managed through the UN, targets knowledge sharing and advocacy. Examples include regional cooperation on disaster risk reduction in Central America, Sub-Saharan Africa, South-Eastern Europe, and South Asia, and partnerships with universities, academic institutions, and scientific organizations to promote disaster risk reduction in education, training, and research.

Track II supports the development of national strategies and capacity-building interventions. It provides ex-ante support, primarily through three-year technical assistance programs, to boost investments in risk reductions and risk transfer mechanisms. As of December 2007, it is helping to develop i) country risk financing strategies in 11 countries, ii) national strategies for disaster risk reduction in 24 countries, and iii) disaster prevention and preparedness projects in 7 countries.

Track III is a mechanism to support accelerated disaster recovery in low-income countries. A Callable Fund (a fund in readiness), to be operational soon, will accept donor funds after a specific event to bridge the gap between immediate relief efforts and longer-term reconstruction and development programs.

GFDRR is governed by a consultative group, a results management council, and a small secretariat at the World Bank.

Source: GFDRR (2007).

- *Risk assessment.* Risk assessment is the central pillar of the disaster risk management framework. Risk depends on the frequency and severity of the hazard, the people and structures exposed to those hazards, and their vulnerability. Risk assessment can be determined based on historical events, but sophisticated probabilistic risk models are often developed to simulate the economic impact of extreme events (see Annex 3). The development of ex-ante risk financing programs such as insurance and other risk transfer devices is critically dependent on the development of these probabilistic catastrophe risk models.

- *Institutional capacity building.* The effectiveness of a comprehensive disaster risk management system depends on the knowledge, awareness, and capacity of the stakeholders involved, including central governments, local governments, municipalities and local communities. Educational and development programs that strengthen the capability of government at all levels play a critical role in effective disaster risk management.

- *Risk mitigation investments.* Risk mitigation investments can help reduce risk by lessening the economic and human impact of a catastrophe when it occurs by hardening infrastructure. Priority should be given to soft infrastructure, such as strengthening and enforcing building codes, which provides great benefits at modest costs. Retrofitting public assets, strengthening infrastructure and constructing defenses, such as sea walls, can also help reduce loss.

- *Emergency preparedness.* Emergency preparedness increases people's ability to respond to a disaster effectively. Governments should adopt simple systems that can be applied to all hazards. This pillar includes planning and exercises, emergency communication systems, public awareness, and technical emergency response capacity.

- *Catastrophe risk financing.* A well-designed catastrophe risk financing program should enable a disaster-prone country to avoid any major financial disruptions following natural disasters by meeting in full its post-disaster funding needs without impacting long-term development objectives.

Toward a Country Catastrophe Risk Financing Framework

To help countries reduce their reliance on post-disaster external assistance, the World Bank supports a country risk financing framework, which is partly based on corporate risk management principles, but also considers economic and social factors such as the government's fiscal profile and the living conditions of the poor (Gurenko and Lester 2004, Ghesquiere and Mahul 2007). This risk management approach relies on the identification and assessment of the government's contingent liability in case of natural disasters, and on the financing of this liability using market-based financial instruments. By ensuring that sufficient liquidity exists immediately following a disaster, modern funding approaches can help speed recovery, ensure that scarce government funds are well used, and reduce the risk-enhancing effects of moral hazard. With sufficient liquidity following a disaster, key government officials can immediately focus on recovery and not be distracted by having to close short-term funding gaps. In addition, catastrophe risk management can assist countries in the optimal allocation of risk in the economy, which may result in higher economic growth, better mitigation, and more effective poverty alleviation.

The country catastrophe risk financing framework is based on three pillars:

- *Assessment of the government's contingent liability.* Governments in low- and middle-income countries are generally unaware of the full financial risks they face from natural disasters. The first step in understanding the government's contingent liability is to develop precise models that accurately reflect the country's risk exposure and the losses associated with various natural disasters. Second, a dialogue must take place regarding the roles and responsibilities of the government as well as individuals in the aftermath of a catastrophic event. The contingent liability of the government due to natural disasters is often implicit, as the law usually does not clearly define the financial responsibility of the government when a disaster hits the country. The government thus acts as a (re)insurer of last resort, without knowing precisely its catastrophe risk exposure. By understanding the full

exposure and the extent of public intervention in recovery efforts, it is possible to ascertain the government's contingent liability.

- *Promotion of risk transfer to competitive insurance markets.* The government can reduce its contingent liability by encouraging private, competitive insurance solutions for the transfer of private risk. This can be done by creating an environment that allows private insurers and reinsurers to offer competitive products and, possibly, through the establishment of catastrophe insurance programs based on public-private partnerships, including catastrophe insurance pools. This allows the government to reduce its contingent liability in the case of a natural disaster. The government can thus concentrate its financial support on the poor and disadvantaged. Such risk transfer is more likely to happen in countries where the domestic property insurance market is sufficiently developed, as in most middle-income countries.

- *Financing of sovereign risk.* The government can manage its remaining contingent liability arising from natural disasters by promoting the insurance of public assets and by protecting its budget against liquidity crunches through sovereign insurance.

The World Bank offers a complementary suite of products and services to assist countries develop tailor-made catastrophe risk financing strategies through an optimal combination of financial instruments (see Box 1.2). Several recent projects, sponsored or facilitated by the World Bank and other institutions, offer lessons that can be used to develop catastrophe risk financing solutions in other regions. A list of more than 30 catastrophe risk financing projects supported by donors and the World Bank is presented in Annex 4, and some of these programs are further described in Annex 5.

In cases where the domestic insurance market does not offer a sufficient supply of catastrophe insurance to consumers or businesses, or where demand for coverage is inadequate due to market imperfections, IFIs and donors can play an important role by working with governments and local institutions to create direct markets for catastrophe insurance. The process involves some or all of the following functions: i) financing or facilitating the development of catastrophe risk models; ii) mapping risk; iii) providing guidance to reform laws and regulations to encourage

Box 1.2 World Bank Group's Catastrophe Risk Products and Services

Sovereign catastrophe risk financing

The World Bank Group provides products and services that allow countries to secure immediate liquidity and budget support following a major natural disaster.

Contingent loan

The Catastrophe Risk Deferred Drawdown Option, CAT DDO, is a development policy loan that offers IBRD-eligible countries immediate liquidity up to US$500 million or 0.25 percent of GDP (whichever is less) following a natural disaster. It offers bridge financing while other sources of funding are being mobilized. Funds are disbursed when a country suffers a natural disaster and declares a state of emergency. Eligible borrowers must have an adequate macroeconomic framework in place at inception or renewal, and a disaster risk management program that is monitored by the World Bank Group.

Sovereign budget insurance

The World Bank Group provides advisory services to help countries access the international catastrophe reinsurance markets on competitive terms. The World Bank Group recently assisted 16 Caribbean countries in establishing the Caribbean Catastrophe Risk Insurance Facility (CCRIF), a Caribbean-owned, regional institution which offers parametric insurance against major hurricanes and earthquakes. A similar initiative is under preparation in the Pacific.

Insurance-linked securities

In 2006, the Government of Mexico, with the technical assistance of the World Bank Group, issued a catastrophe bond, the Cat-Mex bond, with a historically low interest spread. The cat bond transfers earthquake risk to investors by allowing the government to not repay the bond principal if a major earthquake were to hit Mexico. The World Bank Group is developing a multi-country catastrophe bond that would pool the risks of several countries and transfer the diversified risk to capital markets. As part of the reinsurance placement of the CCRIF, the World Bank Group arranged to place a portion of the catastrophe risk in the capital markets through a CAT swap. The World Bank Group has recently proposed other financial services, including the intermediation of weather derivatives between the member countries and the market counterparts.

Box 1.2 (*continued*)

Catastrophe property insurance

The World Bank Group works with member countries to create competitive insurance markets and increase catastrophe insurance penetration.

Property catastrophe insurance programs

The government of Turkey, with assistance from the World Bank Group, established the Turkish Catastrophe Insurance Pool (TCIP). The pool offers efficiently priced earthquake insurance to homeowners. The TCIP sold more than 2.7 million policies (i.e., 20 percent penetration) in 2007, compared to 600,000 covered households when the pool was set up. A similar catastrophe pool is being developed in Romania, Eastern Europe and Central America.

Agriculture insurance programs

The World Bank Group has provided technical assistance for the development of innovative agriculture insurance programs in several low- and middle-income countries. The Index-Based Livestock Insurance Program was established by the government of Mongolia to protect herders against excessive livestock mortality. More than 550,000 animals are currently covered under this program. The government of India, with technical assistance from the World Bank Group, established a Weather-Based Crop Insurance Scheme that currently protects more than 700,000 farmers against drought. Similar initiatives are ongoing in Malawi, Thailand, Ethiopia and other countries.

Specialist index reinsurer

The World Bank Group, in close partnership with the European commission, is supporting the creation of the Global Index Reinsurance Facility (GIRIF), a multi-donor trust fund linked with a specialized index-based reinsurance company, which will promote index-based insurance in developing markets.

Source: World Bank (2008).

or mandate the purchase of insurance; iv) providing technical assistance in the development of insurance policies and actuarial pricing methods; v) creating new insurance vehicles to provide coverage; vi) providing funding to cover startup costs; and, vii) supplying contingent financing. The objective should be to create self-sustaining systems that preferably

are not governmental organizations and that complement or facilitate the development of private insurance markets.

Donors can assist in the creation of catastrophe insurance pools that can offer policies issued in primary insurance markets, provide liquidity to governments following catastrophes, and facilitate the transfer of risk to global reinsurance and capital markets. Pools can be either single-country risk aggregators, such as the Turkish Catastrophe Insurance Pool in Turkey, or multiple-country regional organizations, such as the Caribbean Catastrophe Risk Insurance Facility in the Caribbean. By performing a risk-aggregation function, catastrophe insurance pools can enable low- and middle-income countries to reduce transaction costs, achieve diversification, and access risk transfer on more favorable terms than would be available to countries acting alone. IFI and donor support can help in coordinating and catalyzing the process, by supplying initial funding to cover startup costs, offering equity capital, and providing technical assistance.

Agricultural insurance programs can establish a mechanism whereby donors could help mitigate the effects of weather-based disasters, such as excessive rainfall, floods and drought on crops, and epidemics on livestock. For several reasons, such as lower monitoring costs and more transparent indemnity structure, index-based programs offer new opportunities for agricultural insurance programs. Index-based agricultural insurance programs are currently piloted in more than 15 countries, with the assistance of the World Bank and donors (see Annex 4). In addition to financial and technical assistance in establishing the programs, IFIs and donors can contribute by financing and facilitating the development of weather-monitoring systems, such as weather stations, and livestock-monitoring programs.

IFIs and donors can also play an important role in fostering ex-ante risk financing through tailored sovereign risk financing programs. Instead of providing post-disaster support for relief and rehabilitation, it is more efficient for IFIs and donors to arrange for funding ex-ante. These funds would provide immediate disaster relief following a catastrophe, whereas ex-post support usually involves a time lag of several months. Funding can be provided in the form of contingent loans, but the viability of this financing source will depend upon the fiscal condition and debt capacity

of the individual country under consideration. In many cases, it may be more cost-effective to provide funding through a layered program involving a catastrophe reserve fund, contingent credit, reinsurance, and other alternative risk transfer mechanisms (such as catastrophe bonds).

There are few successful catastrophe risk financing programs in developing countries, and the main challenge for IFIs and donors will be to mainstream programs in order to make them affordable, effective, and sustainable without heavy public subsidies. This requires a detailed analysis of the catastrophe insurance markets to identify imperfections that might impede the development of competitive catastrophe insurance solutions. It also requires clear efficiency and equity objectives for public intervention, and guidelines on how and when the public sector, backed by IFIs and donors, should intervene in catastrophe insurance markets.

Objectives

Public-private partnerships in catastrophe risk financing are often presented as an ideal approach, and donors increasingly support this model. For example, catastrophe risk financing mechanisms and their potential to help alleviate poverty have been discussed by international financial institutions like the World Bank (see, for example, Pollner 2001, Gurenko and Lester 2004, Ghesquiere and Mahul 2007), International Monetary Fund (see for example, Freeman, Keen and Mani 2003; Hoffman and Brukoff 2006), the Asian Development Bank (see, for example, ADB 2007), the Inter-American Development Bank (see, for example, Keipi and Miller 2005; Andersen 2005, Borensztein et al. 2007), etc.

This book analyzes the imperfections and inefficiencies that impede the emergence of competitive catastrophe risk markets in developing countries, and demonstrates how donors and international financial institutions can assist governments in middle- and low-income countries in promoting effective and affordable catastrophe risk financing solutions. It explores the rationale for public intervention in catastrophe insurance markets, and discusses the demand-driven and supply-driven market imperfections that can hamper the emergence of competitive catastrophe

insurance solutions in developing countries. Based on this analysis, it answers the following questions:

- Why should governments, assisted by donors and international financial institutions, intervene in catastrophe insurance markets?

- What are the risks of public intervention, and how can they be mitigated?

- When should governments, assisted by donors and IFIs, intervene?

- How should governments, assisted by donors and IFIs, intervene in the catastrophe insurance markets?

By answering the above questions, this book sets out guiding principles on how and when the public sector, with assistance from donors and IFIs, should intervene in catastrophe insurance markets. It also identifies key activities to be undertaken by the donors and IFIs for the emergence of sustainable and competitive catastrophe insurance and reinsurance markets in developing countries that would allow middle- and low-income countries to develop affordable and cost-effective catastrophe risk financing strategies, both at the macro (government) and micro (household) levels. These principles and activities are expected to inform good practice and ensure the achievement of desirable results in catastrophe insurance projects supported by donors and international financial institutions.

Market Imperfections and Catastrophe Insurance

T his chapter examines why the public sector, with the help of donors and IFIs, should intervene in the catastrophe insurance markets, and how public intervention could contribute to the emergence of affordable, effective, and sustainable catastrophe insurance solutions in developing countries. The chapter begins by examining the basic features of insurance markets, with an emphasis on the key players and the information flows that are required for the market to succeed. The discussion then turns to the pricing of catastrophe insurance, with an emphasis on why catastrophe insurance and reinsurance prices often seem unusually high. Next, the chapter discusses the various demand- and supply-side market imperfections that, by impeding the spread of catastrophe insurance coverage, have hindered the development of catastrophe insurance markets in most low- and middle-income countries.

Basic Features of Catastrophe Insurance Markets

Insurance markets tend to be quite complex, and sometimes flaws in various segments of the market can cause the entire market to become dysfunctional. An overview of the structure of the insurance market is provided, with special emphasis on catastrophe insurance, to provide a conceptual indication of the market functions.

Catastrophe Insurance Market Structure

Figure 2.1 shows the structure of an insurance market. The market exists to provide insurance coverage to buyers—individuals and business firms exposed to various types of risk, including the risk of natural and manmade catastrophes. Primary insurers provide coverage to buyers by issuing insurance policies and paying claims on insured losses. Generally, coverage provided by primary insurance is distributed to buyers through intermediaries such as insurance agents and brokers. In many countries, where non-life insurance markets are well developed, primary insurers also use direct selling channels, such as telemarketing and the Internet, and distribute insurance through banking institutions ("bancassurance"). Insurance distributors perform an important informational function for primary insurers by collecting information (on policyholder risk exposures and characteristics) that is used in the underwriting and pricing process. Insurance distributors also provide buyers with coverage advice and risk-management planning.

The primary insurers play a central role in insurance markets and conduct market research to design insurance policies that meet the needs of

Figure 2.1 Developed Insurance Market Structure
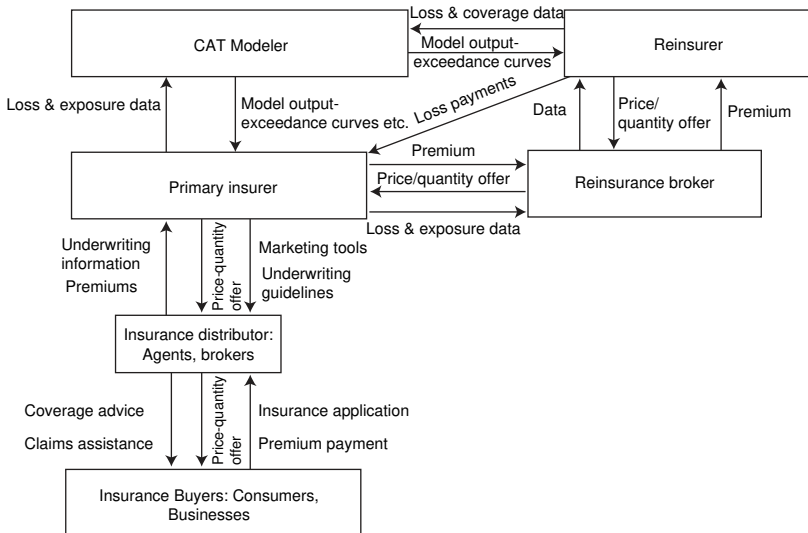
Source: Authors.

potential buyers. They obtain information from insurance distributors, and also directly from policyholders, that is used in pricing and underwriting the risks that are submitted by insurance distributors. Primary insurers also provide insurance policies and pay claims to buyers.

To assist in pricing, underwriting, and risk management in catastrophe insurance, the primary insurer often seeks the assistance of catastrophe modeling firms (CAT modelers). The insurer provides data on its risk exposures to the modeler, who simulates the occurrence of various types of catastrophes, based on specific risk profiles, and provides the results of the analysis to the primary insurer. The results of the analysis include probability distributions, which indicate the probabilities of losses of various magnitudes. Often, these are expressed as "exceedance probability curves," giving the likelihood that the losses will exceed various specified amounts.

Based on this analysis, the primary insurer typically seeks to reduce the risk exposure of his insurance portfolio by purchasing reinsurance, thereby transferring part of the risk to reinsurers. Reinsurance placements can be negotiated directly between the primary insurer and the reinsurer, but for many transactions, coverage is placed through a reinsurance broker. In much the same way that an insurance broker connects buyers and primary insurers, reinsurance brokers act as an intermediary between the primary insurer and the reinsurance market. The reinsurance broker's key role is to shop the primary insurer's coverage in the reinsurance market to obtain the best possible price and coverage terms. In addition, because of their knowledge of the market, brokers also frequently advise primary insurers on the design of their reinsurance coverage programs. If the transaction bypasses the broker, the primary insurer provides loss and exposure data directly to the reinsurer, receives a price-quantity offer, and pays the premium if the contract is accepted.

Equity Capital Requirements for Catastrophe Insurance

Insurers raise funds by issuing policies (collecting premiums) and raising equity capital from capital providers. The funds raised are invested in various types of assets, such as stocks, bonds, and other debt securities. However, in many developing countries, local securities markets are underdeveloped, so

that most assets are invested in government bonds or even in bank deposits (as in China). In fact, some governments require that assets of financial intermediaries be invested in government securities, a requirement which can create inefficiencies by impeding the development of securities markets and forcing insurers to hold sub-optimal portfolios. As a result, developing-market insurers often earn less investment income than do insurers in developed economies, raising the price of insurance.[1] Premium receivables from policyholders and agents and funds owed by reinsurers are also important assets for many insurers.[2]

Holding equity capital is important not only to guarantee the promise to pay claims, but also to reduce the cost of insurance to buyers. Equity capital serves as a cushion against unexpectedly large losses and enables the insurer to purchase less reinsurance to cover their losses. Although purchasing reinsurance is essential for most insurers, especially those with large catastrophe exposure, reinsurance tends to be expensive—the ratio of the price to the expected loss under the reinsurance policy tends to be significantly larger than 1 and has historically ranged as high as multiples of 6 times the expected loss for very infrequent events. Better capitalized insurers are able to conserve on the use of costly reinsurance, reducing the price of coverage to buyers. For a well-diversified property insurance portfolio, the net cost of reinsurance can be up to 10 percent of the premium income in non-catastrophe years.

Until coverage has been provided, premiums are held in reserves, which represent a liability owed by the insurer to the policyholders. As the coverage period runs on any given policy block, the premium reserve is drawn down, and the insurer becomes liable for claim payments. Some of these are paid immediately, but payment on other claims tends to be delayed pending loss adjustment, legal proceedings, and other events that must take place before loss payment can be made. The insurer's liability for unpaid claims, a sum set aside by the insurer based on the insurer's loss models, is called the loss reserve.

Insurers also hold equity capital to guarantee payment, in case claims are larger than expected.[3] Equity capital can be raised by issuing stock in capital markets, or, it can be obtained from potential policyholders or other sources in the case of a mutual insurer. After the company begins operations, additional equity capital is accumulated from retained earnings

(undisbursed premium payments) or subsequent issuance of stock. An insurer might also have access to contingent equity capital—capital that is provided by an outside source, contingent on a specified triggering event. Given the opportunity cost of holding a large amount of reserves in liquid, low-yielding assets, contingent credit can be a much more efficient way to ensure payouts caused by a low-frequency, high-intensity event are met.

Information Flows and Catastrophe Insurance Market Efficiency

Information flows are essential for insurance markets to properly function. Insurance intermediaries play an important informational role in the market—primary market brokers and agents gather data on the insurance buyers, and reinsurance brokers pass along information about the primary insurer to the reinsurers. Primary insurers also obtain direct data on insurance buyers through actuarial studies, and reinsurers likewise conduct their own analyses to supplement the information provided by reinsurance brokers. Accurate information is also essential in the claims settlement process.

In developed markets, adverse selection tends to be less severe for catastrophe insurance than other lines of property insurance business
    Insurance market failure is for the most part caused by breakdowns in the information flows. Informational asymmetries between insurers and buyers on the one hand, and insurers and reinsurers on the other, are primary causes of *adverse selection* in insurance markets. Adverse selection occurs when policies are incorrectly priced due to informational problems, so that high risk buyers are more likely to buy insurance or purchase larger quantities of insurance than would be purchased if policies were priced accurately. The result is that losses will be too high to be supported by the existing premium structure, leading insurers to lose money and either raise prices or withdraw from the market. In its most extreme form, adverse selection can cause the insurance market to break down entirely, so that no coverage will be available. However, even when information asymmetries are not so severe, adverse selection is a source of market inefficiency as prices tend to be higher than they would be if the information were accurate.

    In developed markets, adverse selection tends to be less severe for catastrophe insurance than other lines of property insurance business

because both parties generally have information about the assets at risk and the natural hazards. However, in low- and middle-income countries, where information is less accessible and reliable, the price of catastrophe risk coverage can be significantly higher. Uncertainty of actual loss causes insurers to set aside excess loss reserves at a high cost of capital, which is passed on through higher premiums. As information improves, uncertainty decreases, and the cost of insurance for low- and middle-income countries converges with premiums in developed markets.

Informational problems can also lead to *moral hazard*—situations where policyholders do not optimally manage and control risk, or claims settlements are excessive due to suboptimal loss-control expenditures, over-reporting of losses, or outright fraud. Moral hazard tends to occur when insurers have problems monitoring the behavior of policyholders, either because information is not observable or monitoring costs are excessive. Adverse selection and moral hazard create problems in insurance markets, even in developed countries with high levels of financial literacy and advanced financial systems.

The quality and quantity of underwriting and exposure information is one of the primary differences between insurance markets in developing and developed economies. The availability of underwriting information has increased exponentially in most developed countries over the past 20 years, even as the costs of collecting and processing data have declined. However, these advances in informational technologies have not yet found their way into most low- and middle-income country insurance markets. Thus, one market-enhancing strategy that could be adopted by IFIs is to foster exposure mapping and better informational management technologies in the developing world. Assistance is also needed in actuarial modeling procedures, including catastrophe modeling and more routine actuarial procedures.

Catastrophe Insurance Pricing

The role of insurers is to serve as risk recipients or warehousers and to diversify risk by pooling losses among many policyholders. The statistical foundation of insurance is the *law of large numbers*. Intuitively, the observed average loss (per policy) gets closer to the statistical expected loss

(per policy) as the size of the insured population increases. In other words, an insurer with a highly diversified risk pool can predict the average loss (per policy) accurately and thus charge the policyholder accordingly. This result is valid when a large number of relatively small, statistically independent risks are at stake, as in the case of automobile insurance.

Unfortunately, unlike automobile risks, the risks of natural disasters such as earthquakes and hurricanes are not easily diversifiable, because many policyholders are affected at the same time, violating the assumption of statistical independence among risks that provides the foundation for the law of large numbers. Moreover, deviations of the actual insurance loss from the expected insurance loss can be very large.

To credibly promise to pay for very large catastrophe losses, insurers must purchase reinsurance and hold equity capital. Insurers have also recently begun to use other types of risk-hedging instruments, such as catastrophe bonds, catastrophe swaps, and industry loss warranties (see Cummins 2007). Buying reinsurance and issuing bonds, swaps, options, and loss warranties can be considered *risk transfer* strategies, while holding equity capital is a *risk retention* plan for dealing with catastrophe risk. The optimal mix of risk transfer and risk retention depends upon current supply conditions and pricing in the reinsurance market, the availability and price of alternative risk transfer instruments, and the cost of equity capital. However, some combination of risk transfer and risk retention is necessary for the successful operation of the insurance company.

When large losses occur, they are absorbed partially by reinsurance and other risk transfer mechanisms, and partially by the insurer's equity capital.[4] In determining its risk-transfer and risk-retention strategy, the insurer typically tries to achieve a specified target solvency probability. For example, the insurer's risk transfer and retention program may be designed to enable the insurer to withstand an event that is expected to occur once in 200, 250, or 500 years, a period of time known as the *return period*. Return periods of 200, 250, and 500 years correspond to probabilities of occurrence of 0.005 (0.5 of 1 percent), 0.004 (0.4 of 1 percent), and 0.002 (0.2 of 1 percent). The amount of risk transfer and equity capital needed can be estimated using the concept of *probable maximum loss* (PML), defined as the largest likely loss from a specific catastrophic event for a given return period.

The catastrophe risk-financing strategy, which includes risk transfer and risk retention, is devised to achieve the target solvency probability at the lowest possible cost, consistent with the insurer's long-run survival. For example, if an insurer wants to cover a 1-in-200-year event without becoming insolvent, which corresponds to an implied financial rating of BBB+ (Standard & Poor's rating system), the insurer must secure a combination of risk-transfer and risk-retention capacity to withstand the PML for a 200-year return period. The amount of required risk-transfer and risk-retention capacity is a function of the volatility of losses, the correlation among losses from different policies, and the target level of solvency. Insurers and reinsurers are moving to more explicit marginal capital models, where the correlation of any new reinsurance contract they underwrite with the existing portfolio is taken into account. That is, new policies whose losses are highly correlated with the insurer's existing exposures consume more equity capital, and thus are priced higher than losses with low correlations with the existing portfolio (Cummins, Lin, and Phillips 2006). (See Box 3.1 and Annex 10.)

The price of catastrophe insurance in competitive markets is determined by the demand and supply of catastrophe insurance. When the demand exceeds the supply, insurance premiums tend to increase (hard market); when the supply exceeds the demand, that is, there is excess insurance capacity, insurance premiums tend to decrease (soft market). However, the price of catastrophe insurance (or insurance premium) is driven by some key elements, which can be identified through a decomposition of the technical insurance premium (see Figure 2.2).

The technical catastrophe premium formula below provides a good snapshot of the main drivers behind the determination of the price of catastrophe insurance:

$$\text{Technical Catastrophe Insurance Premium} = \text{Annual Expected Loss} + \text{Expense Load} + \text{Total Cost of Capital}$$

The *annual expected loss*, or pure premium, is equal to the expected loss per year averaged over a long period. The expected loss is equal to the expected loss frequency (the anticipated number of events per year) multiplied by the expected loss severity (the average value of each loss). The expected loss is determined using sophisticated actuarial modeling

Figure 2.2 Technical Catastrophe Insurance Premium Decomposition

Total Cost of Capital
Portfolio cost of capital
Frictional costs
Uncertainty costs

Expense Load
Startup costs
Underwriting costs
Costs of risk transfer
Administrative costs
Loss adjustment costs
Marketing and delivery costs

Annual Expected Loss
Expected loss frequency
Expected loss severity
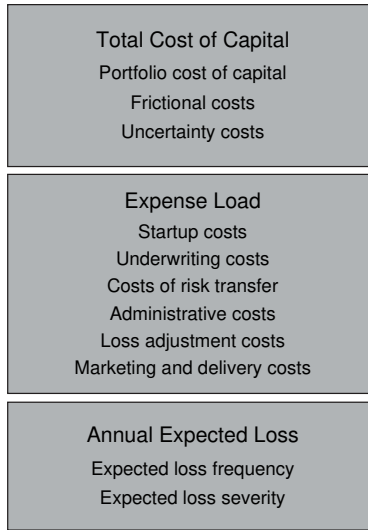
Source: Authors.
Note: Box sizes are not intended to reflect the relative sizes of the components of the premium.

techniques that take into account various factors, including the hetero-geneity among insured risks. Insurers also use advanced catastrophe risk models that simulate possible extreme losses based on the frequency and severity of the underlying peril (for instance, earthquake or hurricane) and the assets at risk (see Annex 3).

The *expense load* compensates the insurer for the non-loss expenses of providing insurance. This includes startup costs, which will be recovered (amortized) over a given period of time (say, five years). Development costs can be significant when a new line of insurance business is estab-lished, since the insurer needs to create an administrative apparatus, build a database, and develop or purchase complex catastrophe risk models to assess the risk profile of its portfolio. In addition to the startup costs, the insurer faces operational expenses, such as underwriting costs, marketing costs, delivery costs, claims adjustment expenses and monitoring costs.

The traditional risk-transfer mechanism in the insurance industry is reinsurance, but in recent years a variety of alternative risk transfer (ART) mechanisms have been developed, including catastrophe bonds, risk swaps, industry loss warranties, and sidecars. Transferring risks to third parties

using these risk-transfer mechanisms can be expensive, especially for lines of insurance subject to catastrophe risk. The costs of risk transfer include reinsurance premiums as well as premiums paid for other ART instruments.

All these expenses should be recovered through the expense load charged in the premium. For example, the average expense load for the U.S. property casualty insurance industry is about 25 percent of the overall premium. Expense ratios are similar in most other countries; the OECD reports that the non-life expense ratio in 2005 was 21 percent in France and 25 percent in Mexico (OECD 2007).

The *total cost of capital* is the amount charged to compensate the insurer for bearing risk. In any given year, the actual loss can be much larger than the average loss. The total cost of capital tends to be relatively small (for example, 5 percent of premiums or less) for lines such as private passenger automobile insurance, where loss volatilities and correlations are low and exposure to catastrophe risk is minimal. The total cost of capital is typically much larger in lines of insurance exposed to catastrophe loss, such as property insurance in geographical areas subject to hurricanes and earthquakes, where the actual loss can be many times larger than the expected loss. When providing coverage against low-frequency, high-intensity events, collecting only the expected loss component of the premium would not give the insurer adequate resources to pay for large cataclysmic events. Therefore, capital costs are highest for policies that cover large losses with low probabilities of occurrence, such as excess-of-loss reinsurance for property catastrophes.

The total cost of capital can be decomposed as follows:

Total Cost of Capital = Portfolio Cost of Capital + Frictional Costs
+ Uncertainty Costs

Insurers need to hold a large amount of capital to protect against insured natural disasters because of the potentially very large magnitude of these events. The total cost of capital needs to be sufficient to provide a fair rate of return on the insurer's equity capital. The fair rate of return, or *portfolio cost of capital*, compensates the insurer's owners for placing their capital at risk in the insurance enterprise. The portfolio cost of capital can be viewed as an opportunity cost; that is, by placing their capital at risk in the insurance business, the insurer's owners forego the opportunity to invest their

funds elsewhere in the economy. To attract capital, the insurance industry must be sure its investors receive a rate of return comparable to what they could earn in alternative investments of comparable risk.

The portfolio cost of capital is equal to the required rate of return on equity capital multiplied by the amount of capital allocated to catastrophe insurance policies. Even in low-risk lines of insurance, such as private automobile insurance, the cost of capital range from 15 to 18 percent (Cummins and Phillips 2005). Given the increased risk related to providing catastrophe coverage, the cost of capital is implicitly higher than these rates. The portfolio cost of capital is expected to be higher for developed countries with large and concentrated exposure bases that stress the capacity of the global reinsurance market. It is likely to be lower for developing markets because it allows (re)insurers to diversify their risk pool and bring down the overall cost of coverage.

The total cost of capital also captures various types of market imperfections that create *frictional costs*. Frictional costs include the government regulatory and tax costs imposed as well as agency costs (generated because managers of the insurer do not always act in the best interests of the owners). Other frictional costs emerge from informational asymmetries between capital markets and the insurer's management. For example, capital markets have less information about the insurer's exposure to catastrophe risk and the adequacy of its loss reserves than do the firm's managers. Hence, the capital market may charge a higher cost of capital to the insurer to provide a margin for the informational asymmetry. Informational asymmetries are likely to be particularly high in markets for catastrophe insurance and reinsurance, because such coverage is provided in a global marketplace, increasing the amount of information required to evaluate the insurer. The low-frequency and high-loss severity of catastrophic events increases the uncertainties in estimating loss probabilities, exacerbating informational problems. Frictional costs are highest for lines of insurance that increase the insurer's insolvency risk, either because of high loss volatility or high correlation with the insurer's existing portfolio of risks (Froot 2007). Such lines create capital costs in excess of the portfolio cost of capital and tend to be priced accordingly.

The total cost of capital also may include an additional margin to compensate the insurer for limited information or uncertainty associated with

writing a specific line of insurance. Insurers must charge extra to guard against the possibility that the probability or amount of loss might have been significantly underestimated. These *uncertainty costs* arise due to lack of information on the frequency and severity of loss-probability distributions. In lines of insurance such as private passenger automobile insurance in developed countries, the uncertainty load is minimal because large amounts of reliable data enable insurers to accurately estimate probability-of-loss distributions. For lines of insurance covering significant, sporadic events, and even more frequent events in countries where the quality of data is poor, the uncertainty costs can be a major component of the premium.

Box 2.1 Portfolio Cost of Capital

The portfolio cost of capital is derived from the return on the marginal surplus committed to support the variability of a new reinsurance contract. Following Kreps (1990), the underlying economic point of view of the reinsurer is considered. For any new contract to be added in his portfolio, the reinsurer should commit additional equity capital to support its volatility. Denote   , the random return of the existing portfolio, and   the expected return. The equity capital required to support the variability of the book of business is

where   is the value at risk function at an acceptable probability of default α, for example, 0.5 percent.   thus represents the equity capital needed to sustain losses occurring with a probability α or less. Consider a potential new contract with a random return   . The additional equity capital required by this contract is

In the absence of arbitrage opportunities, the yield rate on this additional equity capital must be (at least) equal to the risk-free rate in the capital markets. However, the cost of capital to insurance companies is generally considerably larger than the risk-free rate; that is, it includes the risk-free rate plus a risk premium to compensate capital providers for

(*Continued*)

Box 2.1 (*Continued*)

placing capital at risk in the insurance premium. Thus, the cost of capital, $c = y + \pi$, where π = the risk premium. Therefore,

This implies that

This represents the portfolio cost of capital to be charged on the new contract, in addition to the expected loss and expense load. If the random return of the new contract is marginal compared to random return of the existing book of business, then the difference in the values at risk is negligible and the cost-of-capital component of the contingency load will be small. However, contracts that are large in comparison to the existing portfolio or are highly correlated with existing risks will carry large contingency loads.

If the underlying risks are normally distributed and the return of the new contract is small compared to the return of the existing portfolio, the portfolio cost of capital increases with the degree of correlation or the variance of the return of the new contract. Thus, to the degree that developing market risks have low correlations with existing reinsurance portfolios and relatively low variances, such risks should have relatively low contingency loads.

Similar conclusions about the catastrophe loading have been developed using financial theory (Froot 2007). In Froot's model, the portfolio cost of capital is determined by three components the: i) covariability of insurance losses with the market portfolio of stocks and bonds; ii) covariability of incremental insurance policies with the insurers existing portfolio of risks; and, iii) asymmetry of insurance claims distributions. The second and third components are especially important for catastrophe insurance.

Source: Authors, from Kreps (1990) and Froot (2007).

Demand-Driven Market Imperfections

Low Non-Life Insurance Penetration

An analysis of the available data reveals that insurance is primarily a developed market phenomenon. Table 2.1 shows total non-life insurance

Table 2.1 Non-Life Premium Volume by Region (2006)

Region	Premium volume (US$ million)	Percent of total
North America	685,440	46%
Western Europe	492,117	33%
Eastern Europe	52,178	3%
Latin America & Caribbean	42,505	3%
Asia: Japan: South Korea, Taiwan	136,694	9%
Asia: Other	61,859	4%
Africa	14,200	1%
Oceania	20,102	1%
Total	1,514,094	100%

Source: Swiss Re (2007e).

premium volume in 2006 by region. The table shows that North America, Western Europe, and three developed economies in Asia account for approximately 88 percent of total world non-life premium volume.

Undeveloped or developing markets with large populations, including Latin America, other Asian countries, and Africa, account for only 8 percent of world non-life premium volume. The underdeveloped state of low- and middle-income non-life insurance markets makes it difficult to develop comprehensive risk financing strategies for government and private consumers. Outside assistance is required to help catalyze the expansion of these markets to provide sufficient catastrophe risk coverage in the future.

Two additional indicators of the development of insurance markets are *insurance density*, defined as insurance premiums per capita, and *insurance penetration*, defined as insurance premiums as a percentage of gross domestic product (GDP). Non-life insurance (which consists mostly of property insurance and automobile insurance) density and penetration for the various regions of the world are shown in Table 2.2. Insurance density is highest in North America, Oceania, and Europe, which have non-life insurance premiums per capita of US$2,072, US$891, and US$626, respectively.[5] In no other region do premiums per capita exceed US$100. Insurance density is lowest in Africa, at only US$15.30 per person, with South Africa accounting for 54 percent of total African non-life premiums. Insurance penetration is also highest in North America, Oceania, and Europe, which have penetration rates of 4.7 percent, 3.3 percent, and 3.0 percent of GDP, respectively. In the other principal regions of the world, non-life insurance penetration is in the range of 1.5 percent of GDP.

Table 2.2 Non-Life Insurance Density and Penetration (2006)

Region	Insurance density[a]	Insurance penetration[b]
North America	2,072	4.7%
Europe	626	3.0%
Latin America & Caribbean	75	1.4%
Asia	50	1.6%
Africa	15	1.4%
Oceania	891	3.3%
World Total	224	3.0%

Source: Swiss Re (2007e).

[a] Premium per capita in 2006 U.S. dollars.

[b] Premiums as percentage of 2006 GDP.

Although the industrialized countries in North America and Western Europe enjoy a high level of insurance penetration, many countries in Africa, Asia, and Latin America have limited access to non-life insurance, with hardly any catastrophe insurance available. Figure 2.3 shows the penetration of non-life insurance (expressed as a percentage of GDP) on the vertical axis, compared with the gross national income (GNI) per capita on the horizontal axis (with a logarithmic scale). The non-life insurance penetration, as a function of the GNI per capita, follows an exponential curve. The elasticity coefficient, calculated with all countries, is estimated at 0.3: this means that a 1 percent increase in the GNI per capita generates a 0.3 percent increase of the non-life insurance penetration. When calculated by income groups (low-income countries, middle-income countries and high-income countries), the elasticity coefficient seems lower for low-income countries and higher for high-income countries, although it is not always statistically significant.

The development of the non-life insurance market can be divided into three main stages: i) emerging markets, including Bangladesh, Pakistan and Nigeria, where GNI per capita is less than US$1,000 and the non-life insurance penetration is less than 1 percent (with the exception of Kenya and Lebanon); ii) take-off markets, where the GNI per capita is US$2,000–10,000 and the non-life insurance penetration varies from 0.5 percent to 3.0 percent; and, iii) mature markets, where the GNI per capita is higher than US$10,000 and the non-life insurance penetration can be up to 5.0 percent.

Figure 2.3 Non-life Insurance Penetration
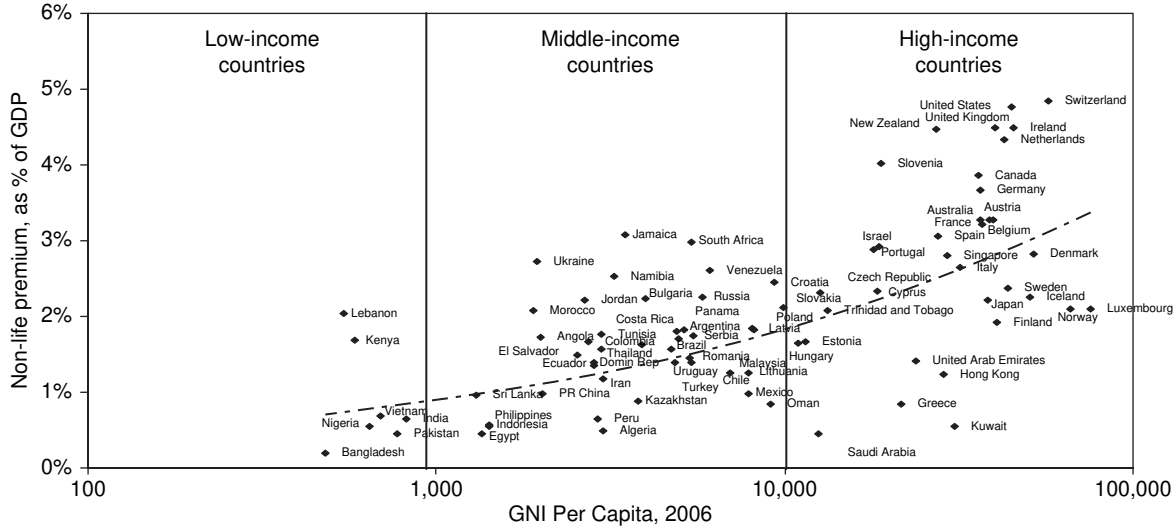
Source: Authors, from Swiss Re (2007e).

Although these statistics give a precise picture of the status of the non-life insurance markets worldwide, specific data on catastrophe risk insurance are generally not available. This makes it difficult to explore the role of catastrophe insurance in the financing of natural disasters, beyond some anecdotal evidence. As a first attempt, Figure 2.4 shows the estimated insured losses caused by natural disasters. Even though the data should be interpreted with caution due to the various sources of information, two main conclusions can be highlighted. First, as expected, insured catastrophe losses (as a percentage of the direct losses due to natural disasters) are higher in high-income countries than in low-income countries. Second, this proportion tends to grow over time in high-income countries and middle-income countries, but has remained stable at under 5 percent in low-income countries over the last decade.

Low Awareness of Catastrophe Risk Exposure

Low- and middle-income households and governments usually have limited understanding of their catastrophe risk exposure. Very few studies have provided country-specific catastrophe risk profiles, assessing not only the hazard exposure but also the economic risk exposure. Such studies are hampered by the lack of reliable (hazard and asset) data and the

Figure 2.4 Direct Losses From Natural Disasters Covered by Insurance (Percentage)
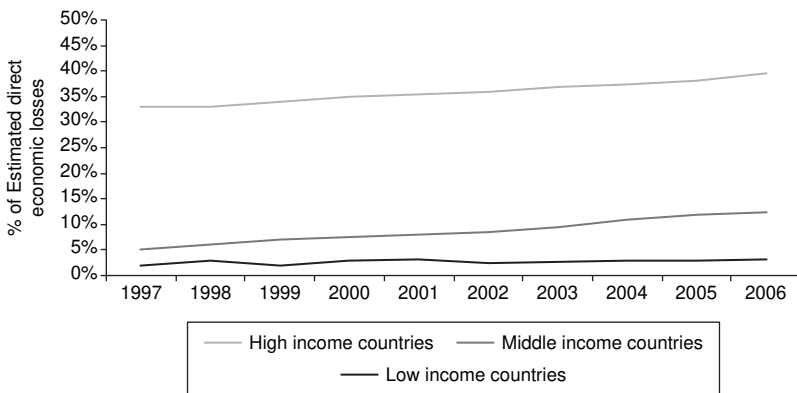
The direct losses from natural disasters (CRED definition) excludes: epidemic, insect infestation, slides, and wildfires.
Source: Authors' estimates, from Swiss Re (2007d), CRED EM-DAT, World Bank (2006a).

high cost of undertaking such studies using modern catastrophe risk modeling techniques.

Although poor households may be aware of their catastrophe risk exposure, catastrophe risk management may not be their priority as they face more pressing challenges. Their implicit discount rate is so high, for example due to the low life expectancy, that the net present value of potential catastrophe losses caused by very infrequent events becomes negligible compared to other recurrent losses.

Low Insurance Education

A commonly cited reason for the low demand of insurance, and particularly catastrophe insurance in developing countries, is the limited understanding of its benefits. Insurance is often perceived as a nonviable investment, because premiums are collected every year but indemnities are paid much less frequently. The general population views insurance coverage as the province of the rich. This is particularly true for disaster insurance, which, by definition, pays only when infrequent catastrophic events occur.

Insurance is a relatively complex financial product, especially in comparison with other basic financial products such as demand deposits and credit cards. Many households in developing nations are not financially literate, and insurance is an unfamiliar concept to many potential policyholders. As a result, the few insurance products that are currently available in low- and middle-income markets are not well understood by potential buyers. Policy exclusions and coverage limitations are often a source of confusion. As a result, potential buyers, even educated ones, sometimes prefer to retain risk than trust a third party like an insurance company.

Limited Ability to Pay

Although the limited ability to pay cannot be considered, strictly speaking, as a market imperfection, it contributes to the lack of demand for insurance and can be an equity rationale for public intervention.

In most developing countries, low incomes inhibit the development of insurance markets. In countries with GNI per capita of US$1,000 or less,

incomes for the vast majority of the population are absorbed by basic necessities such as food and housing. Where insurance is available, health insurance and life insurance are often given higher priority by buyers than catastrophe insurance. What little money is available will be devoted to the most immediate needs, such as medical care and health insurance. A recent analysis indicates that there is very limited provision of insurance in the world's poorest countries, although there is some reason to believe that microinsurance penetration will increase in the future, particularly for life and health insurance (Roth, McCord, and Liber 2007).

Weak Institutional Capacity of Governments in Disaster Risk Management

As a consequence of the limited awareness of their catastrophe risk exposure, very few countries have developed and implemented national disaster risk-management programs and institutions, at both national and subnational levels, to ensure effective planning and coordination of disaster management and emergency response events. When such programs are developed, they rightly focus primarily on risk-mitigation investments instead of developing risk financing strategies.

Post-Disaster Third-Party Financing

The availability of free or inexpensive post-disaster funding can discourage proactive ex-ante risk management on the part of disaster-prone countries and their populations, such as looking into market-driven risk-transfer solutions, including insurance, and developing risk-mitigation programs. Given the cost of risk financing solutions offered by the private markets, it may seemingly make sense for developing countries to rely largely on inexpensive ex-post aid and development banks' post-emergency lending. This poses a "Samaritan's dilemma" (Coate 1995), whereby ex-post disaster aid does provide financial relief but discourages programs that provide more efficient financial solutions and reduce the magnitude of losses from future events.

Post-disaster development lending from multilateral financial agencies plays an important role in middle-income countries, while support from

bilateral donors is generally dominant in low-income countries. Since the early 1980s, the World Bank alone has originated 528 loans for disaster recovery and reconstruction purposes for a total disbursement of more than US$40 billion (World Bank 2006a). Much of this assistance is recent, with about 43 percent of all disaster-related loans yet to close. Similar to donor aid, most of this lending has been provided in the aftermath of natural disasters, and has carried few incentives for countries to engage in proactive risk management (see Box 2.2).

Many low- and middle-income countries rely on assistance from the international community in the aftermath of a disaster. Although donors have been generous in a number of cases, assistance has been highly dependent on the visibility of a given event in the international press, making donor assistance an unreliable instrument for risk management. While immediate relief needs are met by the international community, donor assistance for recovery and rehabilitation generally takes several months to materialize. This financial support is usually earmarked for specific investment projects, with limited possibilities of financing budget

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Box 2.2 World Bank Project Reallocations After a Natural Disaster

When a country requests assistance after a natural disaster, World Bank country staff first examines the existing country portfolio and identifies loans from which funds can be reallocated for reconstruction. Over the past 20 years, funds from 217 projects have been reallocated. The importance of reallocation as an emergency response is highlighted by comparing it with emergency recovery lending: Since 1984, the Bank has made more than US$3,047 million available for natural disaster response through loan reallocations and has dedicated US$9,021 million toward disasters through emergency recovery loans. In a typical example, following the 2001 earthquake in Gujarat, 12 projects were restructured, providing a total of US$416 million for immediate reconstruction. Funding of US$10 million to US$130 million per project was taken from the original implementing agencies and given to another agency handling reconstruction, which changed the scope of the projects as well as their components and targeted sectors.

Source: World Bank IEG report (2006a).

outlays such as civil servants' salaries, other government obligations, and the immediate recovery costs.

The role of donor assistance in the financing of natural disasters in developing countries is depicted in Figure 2.5. Donor funding, as a percentage of total economic losses caused by natural disasters, decreased from 1992–1998, mainly due to the fact that economic losses increased faster than donor contributions for natural disaster relief. The ratio increased significantly from 2000–2003, reaching 10.5 percent in 2003. Although this illustrates the growing role of donor aid in funding natural disasters, these statistics show that donor funding is clearly insufficient to meet the growing disaster risk financing needs of developing countries. Given that insurance penetration has been very low and almost nonexistent in most developing countries, the vast majority of the economic losses from natural disasters have been absorbed by the countries themselves.

Low Business Volume

Most developing countries (with prominent exceptions such as China and India) do not provide attractive areas for geographical expansion for developed-market insurers. Further, in low- and medium-income countries, premium volumes tend to be very low, administrative costs are relatively high, and the lack of insurance infrastructure (such as distribution

Figure 2.5 Economic Losses from Natural Disasters Covered by Donor Assistance (percentage)
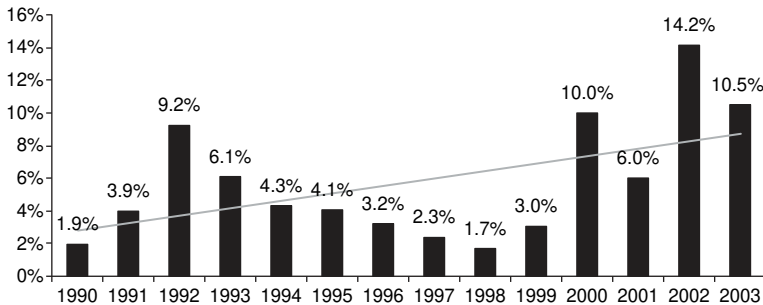
Source: OECD (2005), CRED, World Bank (2006a).
Note: Absolute amount of donor assistance earmarked for natural disasters is assumed to be one-third of total emergency and disaster relief (IMF 2003).

systems and investment alternatives) discourages most insurers from entering developing markets.

In many instances, the amount of potential revenues available would not be sufficient to justify the startup costs of entering low- and middle-income markets. Potential entrants would need to conduct costly research to determine market needs, to develop probabilistic risk models, and to design insurance policies that would be attractive to local buyers. Providing scaled-down versions of developed-market insurance policies generally is not an effective strategy. Introduction of inappropriate policies would likely lead to low persistence and renewal rates, reducing the effectiveness of insurance in mitigating risk. Hence, the fixed costs of entering new markets with viable products deter market entry by developed-market insurers.

Unstable Demand for Catastrophe Insurance

Reinsurance is based on relationships, as insurers view their business as a long-term partnership with their clients. Over time, insurers expect to recover their startup costs and, thanks to a better understanding of their clients' insurance needs, to provide effective tailor-made solutions. By covering the same client over a period of time, the insurer is able to smooth its earnings, offsetting losses in bad years with profits in good years.

The insurance market therefore differs from capital markets, which rely on anonymous financial transactions. In this context, insurers may be reluctant to start a business relationship with a government, since it is unlikely to offer a long-term commitment. Government budgets (including the purchase of sovereign insurance) are prepared on an annual basis and can change substantially from year to year, and changing political regimes may not represent stable partners.

Supply-Driven Market Imperfections

Limited Access to Capital Markets

Direct access to capital markets for domestic insurance companies and governments is still a work in progress, and there is scope to facilitate the

more rapid development of this risk conduit. The insurance securitization market (currently the main route for directly accessing capital markets) is underdeveloped for low- and middle-income countries, but there are encouraging trends. The catastrophe bond issued by the government of Mexico in 2006 demonstrates that middle-income countries can access capital markets on favorable terms, but this needs a strong institutional capacity in catastrophe risk financing.

International Reinsurance Capacity and Domestic Market Capacity

Like primary insurers, reinsurers must maintain equity capital to guarantee their promise to pay claims when losses are larger than expected. Since they generally reinsure the riskiest segments of primary insurer coverage portfolios, reinsurers are likely to need proportionately more equity capital than primary insurers. For various reasons, capital shortages often develop in reinsurance markets. For example, large loss shocks that deplete capital are likely to be followed by constraints on reinsurance supply. In past decades, new capital did not immediately flow into the reinsurance industry in sufficient quantities to offset the supply constraints. However, there is evidence that this is changing, as demonstrated by the large amounts of new capital that quickly flowed into the industry following the 2005 hurricane season (Hurricanes Katrina, Rita, and Wilma). See Cummins (2007, 2008). Although the market seems to be rebounding more rapidly than in the past, there are still apparent supply constraints following loss shocks. Loss shocks also create uncertainty about the accuracy of estimated frequency and severity of loss distributions, and capital is likely to be relatively expensive until some of the uncertainty is resolved (see Annex 8).

The evolving capacity of the global reinsurance industry is charted in Figure 2.6. At the end of 2007, the reinsurance premiums and capital of global reinsurers amounted to US$161.5 billion and US$161.3 billion, respectively.[6] However, only a fraction of global reinsurance premiums are related to catastrophe property losses. Although there is only limited data on overall market reinsurance premiums by line of business, the reinsurance portfolio of Swiss Re, one of the world's two largest reinsurers,

Figure 2.6 Global Reinsurance Capital
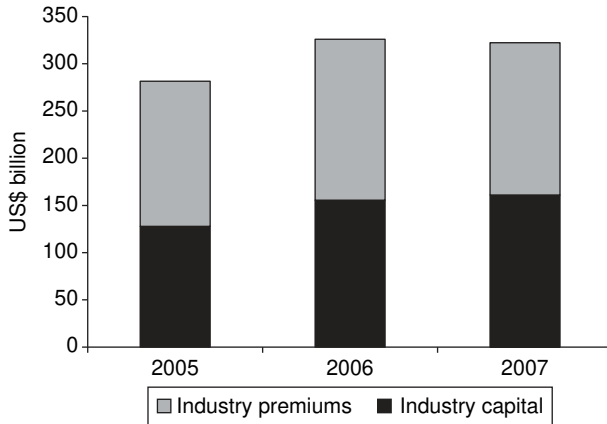
Source: Standard & Poor's, Global Reinsurance Highlights: 2007 Edition (London),Guy Carpenter, *2008a Reinsurance Review* (New York), authors' estimates.

offers some models for optimal business mix. In 2007, property reinsurance represented about 35 percent of Swiss Re's non-life premiums (Swiss Re 2008a), but only part of that represented catastrophe reinsurance. In the Americas, property non-proportional reinsurance, the type of reinsurance purchased to cover catastrophe property losses, amounted to 27 percent of Swiss Re's 2007 renewal premiums (Swiss Re 2007e). The overall capital available for catastrophe reinsurance, and particularly catastrophe excess of loss reinsurance, is estimated at 15 percent of the total amount of resources in the global reinsurance industry, i.e., approximately US$48 billion.

Some information on the magnitude of the excess of loss (XOL) reinsurance market is shown in Figure 2.7, which is based on unpublished data provided by Benfield and estimates by the authors. The figure shows that about US$175 billion in excess of loss coverage was purchased in 2007, representing an 8 percent increase over 2006. Europe (mainly Western European countries) and North America (mainly the USA) absorb nearly 75 percent of the catastrophe reinsurance capacity. Based on these figures, it seems that capacity would be adequate to cover most risks in developing countries, especially given the diversification potential of such risks to offset risks in peak markets.

Figure 2.7 Global Property Catastrophe Excess of Loss Reinsurance Coverage, By Region
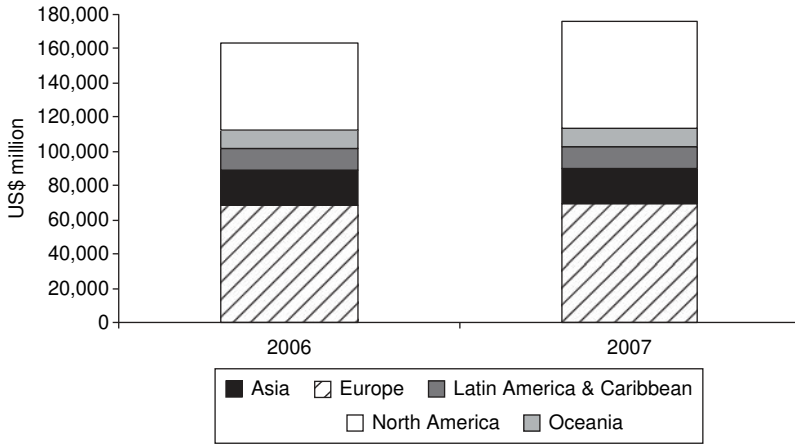
Source: Unpublished data from Benfield and authors' estimates.

The capital commitment made by reinsurance companies plays the important role of signaling to the market (mainly primary insurers) their confidence in the reliability of pricing and reserve estimates. When reinsurers commit less capital to the catastrophe risk market, they indicate that the price of risk is currently too high, which implies that premiums must increase until they are in line with the perceived risks. Excess capital committed to catastrophe insurance signals the opposite, which drives down premiums. It is also important to note that while equity provides a backstop to the technical reserves, reinsurers are expected to earn profits commensurate to the capital invested and the risks absorbed.

Although reinsurance prices and supply are cyclical, and periodic coverage shortages develop, the market appears to be becoming more efficient. In general, reinsurance markets responded efficiently to the unusually large hurricane losses of 2004 and 2005. For the most part, the 2004–2005 losses represented an earnings event rather than a capital event, meaning that earnings were reduced but capital was not significantly degraded. Significant amounts of new capital entered the industry in several new startup companies as well as capital issuances by established insurers. For example, in 2006, more than US$20 billion of additional capital was raised by new or existing companies. Catastrophe losses were

low in 2006 (US$12.3 billion). In spite of relatively high losses in Europe, overall insured catastrophe losses were also relatively low in 2007 (US$22.8 billion), especially in comparison with the insured catastrophe losses of US$46.2 and US$106.9 in 2004 and 2005 (Swiss Re 2008b). Accordingly, reinsurer capital continued to increase through retained earnings, and several reinsurers returned capital to shareholders through buybacks and dividends (Guy Carpenter 2008a). There was little issuance of new equity capital by reinsurers in 2007. Prices declined and the market remained relatively soft in 2008.

Prices of reinsurance increased for the 2006 renewals, as expected considering that the 2004–2005 events caused insurers and modeling firms to raise their expectations of future hurricane losses. However, the 2006 price increases and capacity shortages primarily affected hurricane-prone regions of the United States. Elsewhere in the world, price increases were more moderate, and severe coverage shortages did not develop (Guy Carpenter 2006c). However, reinsurance prices began to decline in late 2006 and the downturn continued during 2007 (Benfield 2007b). Guy Carpenter (2008a) estimates that reinsurance prices fell by approximately 9 percent during 2007, and that the soft market of 2008 is likely to continue at least through 2009, barring the occurrence of any major catastrophes. Thus, it seems that the underwriting cycle still exists but perhaps has shortened and become somewhat more moderate than in the past.

Capital also entered the reinsurance market through nontraditional financial instruments such as CAT bonds (see Box 2.3), catastrophic risk swaps, and industry loss warranties (see Annex 9). The catastrophe bond market set new records for total risk capital in both 2006 and 2007. As Figure 2.8 shows, nearly $7 billion in new risk capital was raised in the CAT bond market during 2007. Although no reliable figures are available, significant amounts of risk capital also were provided in the form of risk swaps and industry loss warranties. Risk swaps are agreements whereby reinsurers agree to swap risks to increase their diversification. For instance, an insurer or reinsurer with exposure to California earthquake risk may agree to a swap with a reinsurer exposed to Japanese earthquake risk. The agreement would obligate the California insurer to pay a specified amount of money to the Japanese firm if a Japanese earthquake occurred in return for the Japanese firm's agreeing to pay a specified amount to the California company in

Box 2.3 Catastrophe (CAT) Bonds

CAT bonds are part of a broader class of assets known as *event-linked bonds*, which trigger payments on the occurrence of a specified event. Most event-linked bonds issued to date have been connected to catastrophes such as hurricanes and earthquakes, although bonds also have been issued that respond to mortality events.

   Capital raised by issuing the bond is invested in safe securities such as treasury bonds, which are held by a special-purpose vehicle (SPV). The bond issuer holds a call option on the principal in the SPV with triggers spelled out in a bond contract, which can be expressed in terms of the issuer's losses from a predefined disaster, by hazard event characteristics, or by catastrophe location. If the defined catastrophic event occurs, the bond issuer can withdraw funds from the SPV to pay claims, and part or all of the interest and principal payments are forgiven. If the defined catastrophic event does not occur, the investors receive their principal plus interest equal to the risk-free rate, for example, London Inter-Bank Offered Rate (LIBOR), plus a spread above LIBOR. The typical maturity of CAT bonds is 1–5 years, with an average maturity of 3 years.

Source: Authors, from Guy Carpenter (2006c).

Figure 2.8 Catastrophe Bonds: Annual Number of Transactions and Issue Volume
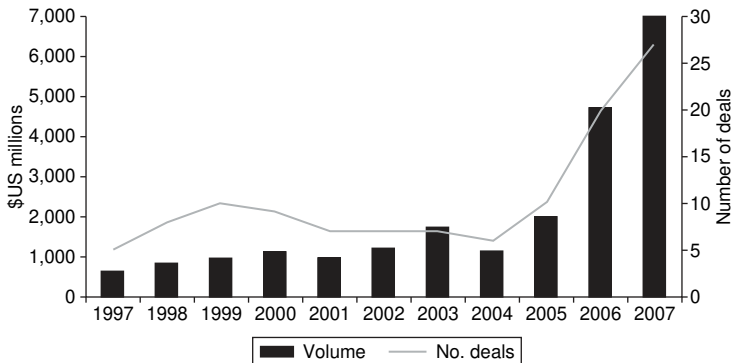
Source: Guy Carpenter (2008b).

response to a California earthquake (Takeda 2002). Industry loss warranties are a hybrid of conventional reinsurance and capital market risk instruments that also have grown rapidly in transaction volume over the past 10–15 years (McDonnell 2002).

Given the capacity of the global reinsurance industry and the relatively small demand for coverage in developing markets, the capacity of global reinsurers does not provide a significant constraint on the supply of reinsurance to low- and middle-income markets. In fact, reinsurance in such markets is valuable to global reinsurers for diversification purposes and hence should be priced lower than reinsurance on comparable risks in high-demand areas such as the United States. The main barrier to obtaining reinsurance for low- and middle-income countries is the lack of primary-market insurance penetration and the current inability in most such countries to package reinsurance programs in structures that are attractive to the global reinsurance market.

Because of low insurance density and penetration in developing markets, domestic insurance markets lack the capacity to finance large catastrophe losses. For example, the PMLs for Turkey and Mexico are US$35.9 billion and US$25.6 billion, respectively (see Annex 2). However, the total non-life premiums in Turkey and Mexico are only US$4.5 billion and US$7.7 billion, respectively (Swiss Re 2007e). Even if the insurance penetration in these countries were as high as in North America, non-life premiums in Turkey and Mexico would be only US$15 billion and US$36 billion, respectively, still basically too low to fund the PML, given that premiums are also needed to pay claims in other lines of business, such as automobile insurance. Thus, developing countries will be heavily dependent on international reinsurance markets to insure catastrophe losses.

New capital tends to flow quickly into the reinsurance industry, as shown in 2005, after Hurricane Katrina. Capacity should thus not be an issue, particularly in developing countries, provided data and models are available and reliable, the price is appropriate and there are adequate legal protections to allow international reinsurers to conduct business in a stable and competitive environment.

Reinsurance Cycles

Even if there were no impediments to increasing the supply of reinsurance and other hedging products to developing countries, primary insurers in these countries would face difficulties in dealing with the reinsurers.

Reinsurance markets experience periodical market fluctuations that cause coverage supply to be restricted and prices to rise sharply. The fluctuations in prices and supply in reinsurance markets are widespread and are generally referred to as the *underwriting cycle*. The cyclical fluctuations are usually triggered by crises such as unexpectedly large losses or investment shocks. For example, Hurricane Andrew in 1992, the terrorist attacks of September 11, 2001, and Hurricanes Katrina, Rita, and Wilma in 2005 sparked cyclical episodes in reinsurance markets. Because of the United States' importance in world reinsurance markets, these shocks created worldwide cyclical fluctuations even though the triggering events were localized in the United States.

The underwriting cycle refers to the tendency of property casualty insurance markets, including the market for catastrophe reinsurance, to go through alternating phases of "hard" and "soft" markets. In a *hard market*, the supply of coverage is restricted and prices rise, whereas in a *soft market*, coverage supply is plentiful and prices decline. The consensus in the economics literature is that cycles are driven by capital-market and insurance-market imperfections that prevent capital from flowing freely into and out of the industry in response to unusual loss experience (Winter 1994, Cummins and Danzon 1997, Cummins and Doherty 2002). Informational asymmetries between capital providers and insurers about exposure levels and reserve adequacy can result in high costs of capital during hard markets, so that capital shortages can develop. Hard markets are usually triggered by capital depletions resulting from underwriting or investment losses.

Evidence of cyclicality in the reinsurance market is provided by Figure 2.9, which shows Guy Carpenter's *rate on line* indices for catastrophe reinsurance. The rate on line is a pricing measure defined as the ratio of the premium for a reinsurance contract to the maximum possible payout under the contract. Rate on line indices are compiled by Guy Carpenter, the world's largest reinsurance broker, based on prices paid by its clients, which represent most of the world's primary insurers. The worldwide rate on line index is shown, along with country-specific indices for the United States, Japan, Australia and New Zealand, and Mexico. It is clear that prices are not only cyclical but also are highly correlated globally.

Figure 2.9 Catastrophe Reinsurance: World Rate on Line

Source: Guy Carpenter (2008a).

The peak in the rate on line in 1993 is the consequence of Hurricane Andrew in the United States, which caused US$23 billion in insured losses. Similarly, the upward trend observed in 2000–2003 was caused by the terrorist attack in the United States on September 11, 2001, where insured losses reached US$23.7 billion in 2007 dollars (Swiss Re 2008b). Following Hurricanes Katrina, Rita, and Wilma in 2005, which collectively resulted in about US$92.6 billion in insured losses, the world rate on line average index increased by 32 percent.

This worldwide average was mostly influenced by the extreme rate peaks experienced in those countries that absorbed the majority of the losses caused by the record storms in 2005. Rate increases in the United States and Mexico averaged 72 percent and 127 percent, respectively, compared with much smaller increases for the rest of the world. Because of minimal losses the following year, the world rate on line index declined by about 6 percent between 2006 and 2007, with declines of 9 percent and 14 percent in the United States and Mexico, respectively. Rates on line are more cyclical in Mexico than in developed markets, suggesting that reinsurance cycles in developing markets may pose a challenge for ex-ante risk transfer solutions.

Though not shown in the figure, the quantity of reinsurance available also fluctuates significantly over the course of the underwriting cycle, to such an extent that the demand for reinsurance is not fully met in some

years. Because the vast majority of reinsurance contracts are annually renewable, primary insurers typically cannot lock in predictable reinsurance pricing and supply over multiyear periods. Reinsurance multiples (measured as the ratio of the premium to the expected loss) tend to be highest for lowest probability, highest intensity events, so it is usually the top layers of reinsurance that are not covered when shortages develop.

The rate on line index shows the cyclicality of reinsurance pricing but does not reveal the extent to which price changes are affected by shifts in loss expectations versus those in loadings (that is, the expense and profit component of the premium). For instance, reinsurance prices rose following Hurricane Andrew in part due to revaluation of potential losses and in part due to higher profit loadings due to increased market uncertainty. Information on changes in loadings between 2007 and 2008 is shown in Figure 2.10, which plots the rate on line as a function of the *loss on line* for catastrophe reinsurance policies based on prices in 2007 and 2008. The loss on line is defined as the annual expected loss on a reinsurance policy as a percentage of the policy limit.

Figure 2.10 shows that prices declined significantly between 2007 and 2008 in response to relatively low catastrophe losses in 2007 and an accumulation of retained earnings by the world's leading reinsurers. The

Figure 2.10 U.S. Reinsurance Rate Online versus Loss on Line
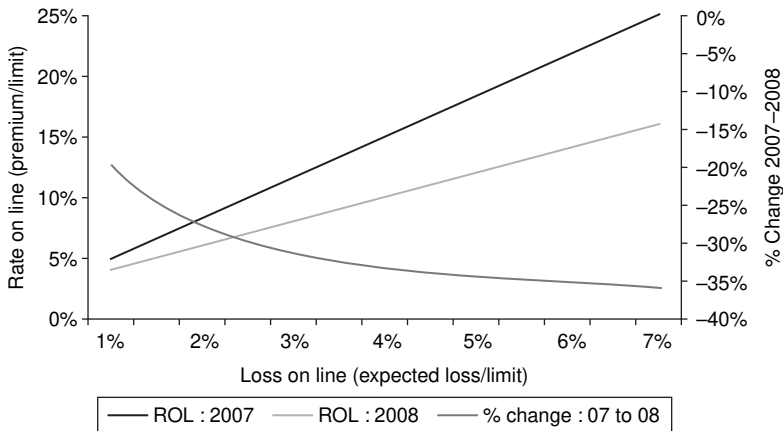
Source: Guy Carpenter (2008a)

price decrease was smaller for high layer contracts (less frequent, higher intensity events), i.e., those with low expected losses on line. For contracts with a 1 percent loss on line, the price decreased was about 20 percent, whereas for contracts with a 7 percent loss on line, the price decrease was 36 percent.

A comparison of the rate on line versus loss on line data for 2005 and 2006 show that prices increased significantly between 2005 and 2006 in response to losses caused by Hurricanes Katrina, Rita, and Wilma (KRW). The weighted average price increase between 2005 and 2006 was about 72 percent. The increases were largest for policies with low expected losses, which tend to provide coverage against large, infrequent events. For example, the price increase for reinsurance policies with 2 percent loss on line were about 120 percent, whereas the price increase for policies with a 20 percent loss on line averaged only 21 percent. Although rates on line declined between 2006 and 2007, even with the continued price declines in 2008, reinsurance prices remain higher than their level prior to KRW in 2005.

An increase in loadings means that reinsurance has become more expensive for primary insurers. Single-year price increases in the neighborhood of 70 percent or more are particularly problematic for primary insurers from developing economies, because reinsurance price increases are generally passed along to buyers in the primary market, raising premium prices. Because of low retention, and given the relatively low income levels in developing countries, substantial increases in insurance prices can pose significant problems for insurance buyers.

The existence of cycles and crises implies that the response of reinsurance markets to large-event losses is not necessarily fully efficient, in the sense that prices are not predictable and supply shortages may develop periodically. Both reinsurance premiums and coverage supply tend to vary significantly during the course of the underwriting cycle and are usually negatively correlated, as rising prices are often accompanied by reductions in the supply of coverage. Such fluctuations can be especially problematical for primary insurers in developing countries, which tend to be more financially fragile than insurers in more developed markets. The promotion of multi-year contracts may help domestic primary insurers to manage these better.

Adverse Selection, Agency Costs and Monitoring Costs

Adverse selection costs may impede the supply of reinsurance to developing countries. In most reinsurance transactions, the primary insurer ceding the risk (the "cedent") will likely have better information about the underlying risk than the reinsurer. Such informational asymmetries are especially pronounced when the cedent is a local insurer in a low- or middle-income country, given the limited underwriting data available on such insurers and markets. The greater the information asymmetry, the greater the cost of adverse selection to the ceding insurer. Since past reinsurance penetration in developing markets has been relatively low, many developing-market primary insurers do not have existing relationships with global reinsurers. Further, given the lower levels of financial infrastructure development, the amount of information generated by observing the primary insurer over a period of time is likely to be lower than for primary insurers from more developed economies. Hence, adverse-selection costs are likely to be relatively high for primary insurers from developing markets, raising the price and restricting the supply of reinsurance.

Because the reinsurer lacks full clarity of the risks they are underwriting, they will likely charge a higher premium. One way in which adverse-selection problems are mitigated in reinsurance markets is through implicit long-term contracting. That is, even though most reinsurance contracts cover a period of one year, there is an inherent understanding between the ceding company and the reinsurer that contracts will be renewed for multiple periods. Having a multi-period relationship eases informational problems, because it provides the opportunity for the reinsurer to learn more about the risk exposures and managerial skills of the ceding company.

Agency costs arise when the managers of a business enterprise take actions that are not in the best interests of owners. Managers may do things to minimize their volume of work or maximize their compensation, rather than working to take full advantage of the market value of the insurance enterprise. Managers may also engage in excessive consumption of perquisites, such as corporate jets, executive dining rooms, and so on, that degrade the efficiency of the insurer. In developed markets, market mechanisms exist to control agency costs, such as monitoring and disclosure mechanisms, and the market for corporate takeovers. These devices

either do not exist or are much less developed in low- and middle-income markets. Thus, such markets will likely require relatively high expenditures for monitoring and control mechanisms for insurance companies to operate efficiently and provide the necessary coverage at reasonable prices.

Limited Technical Capacity

Another important supply side impediment to the provision of reinsurance in developing countries is the limited technical capacity of the domestic insurance companies. To work with insurers, global reinsurers and reinsurance brokers need to have confidence that the primary insurers have the basic actuarial and technical expertise to design and price their products, measure their exposure to loss, and settle losses efficiently and without incurring excessive costs. Pricing non-life insurance, especially catastrophe coverage, requires a high level of sophistication in actuarial modeling, and insurers in many developing-market countries may not have non-life actuaries or may have actuaries with only rudimentary training and experience.

Reinsurers and their brokers expect a minimal level of sophistication in the presentation of data and the design of reinsurance programs. Insurers that have only limited experience with the development of reinsurance programs are likely to lack the expertise and experience required to deal effectively with global reinsurers and their brokers. The brokers can sometimes provide the needed expertise, at a cost, but will not be able to perform effectively if the underlying data are not available. Poorly designed reinsurance programs and failure to provide the requisite data can lead reinsurers to refuse to write the coverage or to offer coverage at a prohibitively high price.

Beyond the basics of actuarial science, catastrophe modeling requires technical expertise in statistics and various scientific fields, including seismology and meteorology. Such capabilities are expensive and time-consuming to develop in-house and probably beyond the resources of relatively small insurers in developing markets. Catastrophe models can be purchased from outside vendors, but doing so is expensive, especially if the exposure-mapping exercise has not been conducted for a particular country.

As shown in the case of the Mexican CAT bond and the Caribbean catastrophe insurance pool CCRIF (see Appendix 5), developing countries

may be able to transfer their catastrophe risk to securities markets through sophisticated financial instruments. Doing so requires the development of exposure maps and catastrophe-loss simulation models, which do not exist for most developing countries. The startup costs of developing such maps and models can be prohibitive for a small country and, given the premium volume in such countries, not likely to be cost-effective for the modeling firms to develop on their own.

Finally, the design and marketing of financial market instruments requires a high level of sophistication, on par with leading U.S. and European investment banks. Such expertise is generally limited in developing countries, and the transaction volume may be too low to motivate financial firms to become involved in developing the projects independently. And, once a proposed securities project has been designed, expertise is required at the domestic level to evaluate the cost effectiveness of the program relative to the alternatives.

Regulatory Impediments

The regulatory frameworks governing insurance markets in many low- and middle-income countries are underdeveloped since non-life insurance penetration is minimal. As a result, short-term market incentives and regulatory overlay can in some cases inhibit increased penetration of catastrophe insurance. For example, in Turkey, before 1999, insurers were subsidizing fire insurance with reinsurance commissions on earthquake insurance, where cartel pricing was applied. In addition, insurers would not provide stand-alone earthquake insurance policies. The government was legally obliged to provide soft loans to all house owners after an earthquake, regardless of financial status. This stalled the private market for catastrophe insurance.

In many developing countries, small insurers will not buy catastrophe insurance because of myopic risk-management practices; that is, they may not be fully aware of their true exposure to catastrophe risk or may expect a government bailout after the event. This makes it difficult for the more responsible competing insurers to purchase reinsurance because of price effects. In West Africa, all insurers adopt a reinsurance schedule specified by the common regulator, regardless of the exposure characteristics of their

individual policy portfolios. In Colombia, insurers are required under the Insurance Law to secure 15 percent of their exposure to natural disasters (mainly earthquake) through reinsurance and reserves. Catastrophe-risk models show that this would correspond to an event with a return period higher than 2,000 years, which is well beyond international standards, that is, the insurers are required to spend too much money on hedging catastrophe risk. In addition, such arbitrary regulatory requirements do not provide insurers with incentives to engage in exposure mapping, modeling, and risk management to hedge and mitigate catastrophe risk.

Informational Costs

Reinsurers are likely to be discouraged from aggressively seeking business in low- and middle-income countries because of a lack of data at the local level. Reinsurance underwriting and pricing are informationally intensive activities. Primary insurers in developing markets tend not to have the computing and communications infrastructure to produce sufficiently detailed and reliable data to be used by reinsurers in underwriting risks and pricing reinsurance coverage.

Insurance pricing and underwriting for the catastrophe lines of business have come to rely heavily on sophisticated catastrophe risk models. Such simulation models, which are available for most developed countries, rely on statistical, actuarial, seismological, and meteorological data and computer models to simulate the frequency and severity of catastrophic events such as hurricanes and earthquakes. In developed countries, detailed exposure maps have been developed that provide extensive data on the insurance industry's exposure to various types of catastrophe risk. The data includes information on the value of insured properties, the amount of insurance coverage, insurance contract details such as deductibles, the construction characteristics and damageability of insured properties. By using the models to simulate the impact of catastrophic events, insurers can obtain reliable estimates of their loss exposure under a variety of scenarios. Such information is used by insurers and reinsurers in pricing, underwriting, and risk management.

Although catastrophe models have been developed for a few low- and middle-income countries and regions such as Mexico, Turkey, and the Caribbean, such models do not exist for most developing nations. Moreover,

the historical records on catastrophe loss history and scientific data on the susceptibility to catastrophe losses of various regions are often lacking or limited in low- and middle-income countries, increasing the costs of developing catastrophe models. This lack of historical data and data on current exposures provides a major impediment to increasing the supply of insurance and reinsurance in developing countries.

The availability of models for perils and countries is shown in Appendix 7. Although Commercial earthquake models are available for most high- and middle-income countries exposed to earthquake risk, it should be noted that these models mainly refer to the hazard module (see Appendix 3). Data on the value of property and other assets exposed to catastrophe risk are much scarcer. Very few countries have a comprehensive database on their private and even public buildings and infrastructure, including location, construction type, and so on. This information is essential to assessment the economic impact of a natural disaster as well as for risk-management and risk-mitigation programs.

Box 2.4 Information Prerequisites for Reinsurers to Provide Weather Reinsurance

Insurers and reinsurers have strict data requirements for the development of commercial weather-based insurance products. The data used to design the underlying index must adhere to the following requirements:

    a. Third-party reliable and verifiable data (for instance, reliable and trustworthy daily collection, nearby backup station);

    b. Enhanced data (for example, integrity of recording procedure, consistency of observation techniques, daily quality control and cleaning, clean historical record to allow for proper actuarial analysis of the weather risks—more than 25 years of data, less than 1 percent missing data, less than 5 percent outliers);

    c. Legal and compliance qualification with local regulator;

    d. Clear tax requirements;

    e. Sufficient transaction size;

    f. Geographical diversification;

    g. Constant deal flow;

    f. Multiyear structures (5–10 years) are preferred.

Source: Authors, from discussions with reinsurers.

# Are Prices of Catastrophe Risk Transfer Instruments Excessive?

Catastrophe Reinsurance Prices Are High but Declining

Catastrophe reinsurance prices are sometimes considered "excessive," because reinsurance premiums are often much greater than the expected losses covered by reinsurance. Figure 2.11 shows the ratio of the rate on line to the loss on line (the catastrophe reinsurance *price multiple*) as a function of the loss on line for the U.S. catastrophe reinsurance market.[7] The results are shown annually for the period 2005 through 2008. For example, for a loss on line of 4 percent (that is, an expected loss of 4 percent of the policy limit), the multiple for 2008 was 2.5, that is, the cost of US$1 (expected) indemnity for this layer of reinsurance was US$2.50 in 2008.

The price of reinsurance is a decreasing function of the loss on line—the higher the expected loss, the lower the multiple. For example, for a 2 percent loss on line, the rate on line in 2008 was 6 percent, which represents a multiple of 3. For a 7 percent loss on line, the rate on line is 16 percent, representing a multiple of 2.3 in 2008.

Figure 2.11 also shows that the price of reinsurance varies significantly with the phase of the reinsurance underwriting cycle, where cyclical swings are triggered by large catastrophic events. Reinsurance multiples increased markedly between 2005 and 2006, with the largest

Figure 2.11 Catastrophe Reinsurance Multiple, U.S. Market
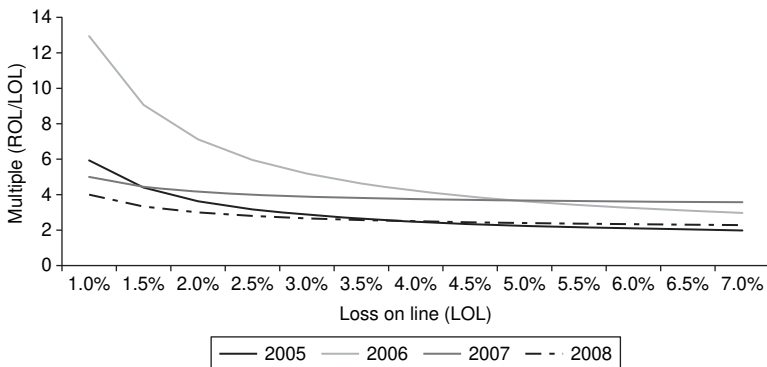
Source: Guy Carpenter (2006b, 2006c, 2008a).

increases affecting high layer (low loss on line) contracts. As new capital entered the industry in 2005 and 2006 and reinsurers accumulated retained earnings in 2007, prices gradually declined back to 2005 levels during 2007 and 2008.

As explained in the previous section on the premium decomposition, catastrophe insurance premiums are mainly driven by the cost of securing capital for extreme events. Events with high levels of loss on line tend to be smaller, more frequent events, whereas events with low levels of loss on line tend to be large and infrequent. Catastrophe losses fall into the low loss on line category and have higher pricing multiples than non-catastrophe losses, because they consume more equity capital. So long as the reinsurance market is reasonably competitive, catastrophe reinsurance prices are high but not necessarily "excessive," considering the stress such losses place on the equity capital base of the reinsurance industry.

CAT Bond Prices Are Comparable to Similar Corporate Bonds

As with catastrophe reinsurance, the cost of transferring risk through CAT bonds is often said to be excessive, based on pricing data from the early days of the CAT bond market in the late 1990s. Ratios of bond premiums to expected losses under the bonds were indeed high during this period, averaging between 6 and 7 (Cummins, Lalonde, and Phillips 2004). As more capital has flowed into the CAT bond market and investors have gained experience with these securities, prices have declined. CAT bonds are now priced comparably to excess-of-loss reinsurance.

The declining trend in CAT bond prices is illustrated in Figure 2.12, which shows the expected loss, the bond premium, and the ratio of premium to expected loss on a quarterly basis from 2001 through the first quarter of 2007. The data are averages for all outstanding CAT bonds at each point in time based on secondary market data (Lane Financial LLC, 2007). The pricing multiple for CAT bonds declined from about 6 in the first quarter of 2001 to about 2 in the first quarter of 2005. Thereafter, bond prices increased in response to the 2005 hurricane season, which resulted in the first publicly announced wipeout (total depletion of principal) of a CAT bond. Thus, there is clearly some cyclicality in the CAT bond

Figure 2.12 Catastrophe Bond Pricing
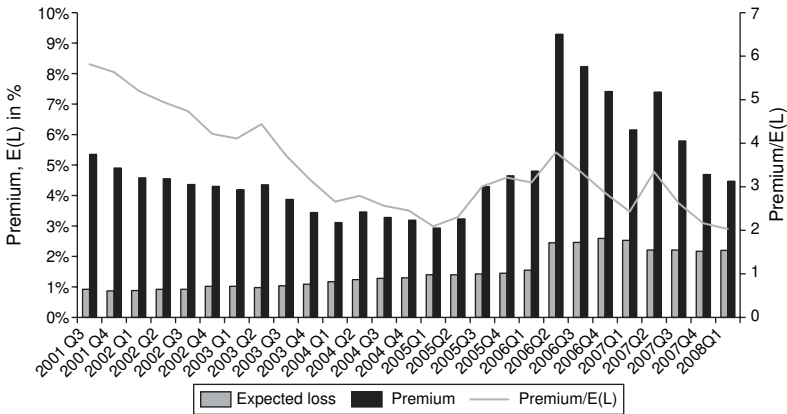
market, although it is less pronounced than the cyclicality in the reinsurance market. Following the 2005 hurricane season, the CAT bond pricing multiple peaked at about 3.8 in the second quarter of 2006, then declined to about 2.3 by the first quarter of 2007. Because the expected losses on CAT bonds hover at about 2 percent on average, it is no longer correct to say that CAT bond prices are excessive or more expensive than reinsurance.

Information on CAT bond spreads is also provided by comparing the spreads and expected losses on newly issued CAT bonds, based on data provided in Lane and Beckwith (2005, 2006, 2007b, 2008). The results are shown in Figure 2.13, which provides quarterly data for the period 2004, second quarter, through 2008, first quarter. The data are somewhat more volatile than those shown in Figure 2.12 because some of the quarterly observations are based on a limited number of issues. The ratio of the spread to the expected loss seems to provide a clear indication of the pattern of CAT bond pricing over this four year period; the ratio of the spread to expected loss averaged around 3.0 during the first five quarters and last three quarters, suggesting that bond returns are about three times expected losses during non-crisis periods. However, returns jumped following the 2005 hurricane season, averaging about 4.5 from the third quarter of 2005 through the second quarter of 2007. The price increases were caused by greater uncertainty following the

Figure 2.13 Catastrophe Bonds: Pricing of New Issues
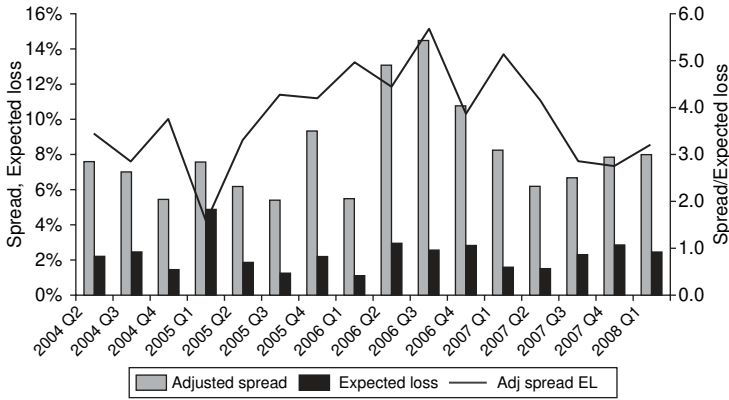
2005 hurricane losses as well as high demand for capital during this period. Despite high costs, supply and demand for bonds was strong during this period, with 107 tranches being issued.[8] Thus, even though CAT bond prices appear cyclical, these price movements do not seem to dampen the activity in the CAT bond market.

Another gauge of the rationality of CAT bond pricing is provided by a comparison of the price of CAT bonds, as measured by the bond premiums plus the interest return on the bonds, with yields on similarly rated corporate bonds. This comparison is shown in Figure 2.14, which plots the yields on BB corporate bonds and BB CAT bonds from the second quarter of 1997 through the fourth quarter of 2007. The results demonstrate that yields on the two types of bonds are generally comparable. CAT bond yields exceeded corporate bond yields early in the comparison period and toward the end of the period, with the latter reflecting the impact of the 2005 hurricanes. However, from 2001 through 2004, CAT bond yields were lower than yields on comparably rated corporates. For the period as a whole, the return on CAT bonds was about 1 percent above the return on BB corporates. This difference could reflect various factors such as a liquidity premium (most corporates are publicly traded whereas most CAT bonds are not) or the high volatility of the underlying risks. Overall, by this standard of comparison, CAT bonds appear to provide reasonably priced risk-transfer solutions.

**Figure 2.14 Pricing of Catastrophe Bonds and Comparable Corporate Bonds**
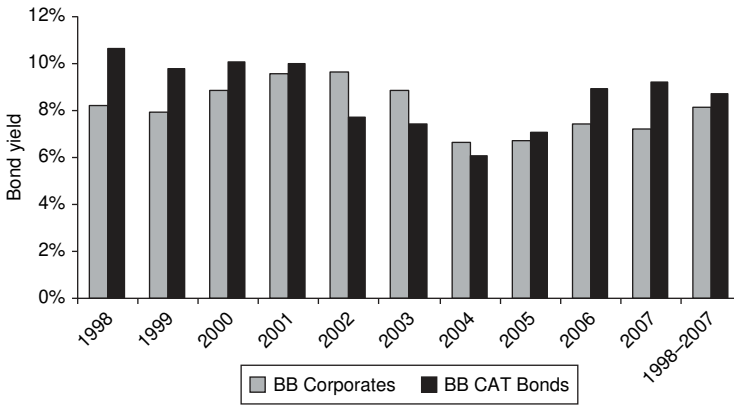
Cat Bond Prices Are Lower in Low- and Middle-Income Countries

Low- and middle-income country catastrophe bond pricing is lower than developed market coverage because investors try to build balanced portfolios with exposures to a variety of different perils and geographical areas. CAT bond portfolios tend to be heavily weighted toward U.S. windstorm and earthquake risk. As a result, investors are eager to acquire diversifying and non-peak exposures, primarily because these perils would favorably influence their concentration profiles and indirectly allow them to take on additional lucratively priced peak risk without violating allocation maximums.

The pricing of various types of CAT bonds is illustrated in Figure 2.15, which shows pricing multiples as a function of the expected loss for a sample of transactions completed during the period 2003–07. Peak perils are U.S. hurricanes and earthquakes; non-peak perils include European windstorms and Japanese earthquakes; diversifying perils include Mexican earthquakes, Australian earthquakes and hurricanes, Japanese typhoons, and European earthquakes; and multiple perils combine peak perils and non-peak perils in the same transaction.

Price multiples for peak peril transactions are higher than multiples for non-peak peril transactions (for the same range of expected loss). Multiple peril transactions tend to be priced somewhat lower in general, because they

Figure 2.15 Comparison of Peak, Non-peak, Multiple, and Diversifying Peril Transactions
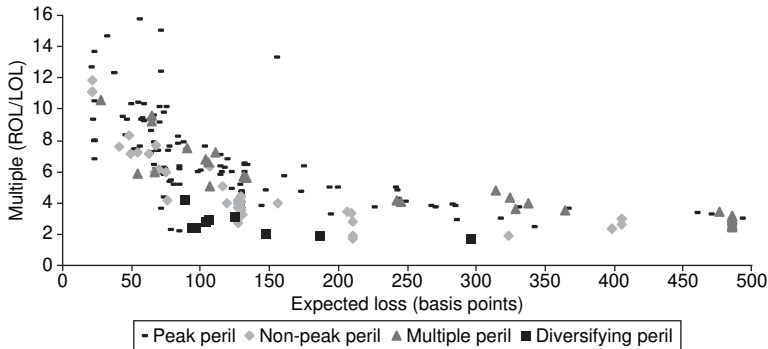
Source: Authors, from Swiss Re (2007d).
Note: Figure based on 240 CAT bond transactions, 1997–2007.

convey built-in diversification. Diversifying peril transactions, though less frequent than peak peril transactions, tend to have the lowest multiples.

Diversification of CAT bonds is increasing. In 2006, bonds were issued that securitized Mexican earthquake risk and Australian earthquake and wind risk. In May 2007, Swiss Re securitized earthquake risks of five Mediterranean countries (Portugal, Greece, Turkey, Cyprus, Israel) in a transaction called MedQuake. The three-year parametric bonds, with a 1 percent annual expected loss, were issued at multiples lower than 2. The multiples are even lower than 1.5 on the secondary market. This illustrates how catastrophe bond investors reward diversifying risks.

Summary: Insurance Markets and Market Imperfections

To function effectively, an insurance market requires the efficient operation of all links in the distribution chain. Imperfections, both on the demand side and the supply side, can reduce market effectiveness. Governments, with the assistance of donors and international financial institutions, can play a major role in correcting these imperfections through appropriate market-enhancing interventions.

Insurance markets require sophisticated financial infrastructure and are heavily dependent on information flows. Information on policyholder risk characteristics is transmitted from insurance intermediaries, such as

brokers and agents, to primary insurance companies that issue policies to individuals and businesses. Primary insurers in turn need to provide information to global reinsurers when they purchase reinsurance, which is usually accomplished through reinsurance brokers. Breakdowns in the informational flows at any point in the process can lead to serious market problems, such as incorrect pricing, inadequate loss reserves, insufficient equity capital, and poorly designed or inadequate reinsurance programs. Information breakdowns also can lead to moral hazard and adverse selection, which in extreme forms cause market failure. Low- and middle-income countries face more severe informational problems than do developed nations because of various deficiencies in the financial infrastructure.

The discussion in this chapter illustrates that the development of catastrophe insurance and reinsurance markets in low- and middle-income countries is impeded by a variety of demand- and supply side market imperfections summarized in Table 2.3, which also rates the severity of each market imperfection separately for low- and middle-income countries.

Most of the demand side market imperfections are rated in the highest severity category for low-income countries. This indicates the challenges faced by the countries themselves as well as by IFIs and donors in providing ex-ante risk financing solutions. The insurance system and related infrastructure often have to be developed from the ground up. Because any one of the demand side imperfections can block the spread of catastrophe insurance and reinsurance, having to confront multiple sources of market impediments is a particularly daunting task. However, programs in the Caribbean and new micro-insurance plans in various low-income countries (for example, livestock insurance in Mongolia or weather-based crop insurance in Malawi) demonstrate that it is possible to provide meaningful and cost-effective solutions.

For middle-income countries, most of the demand side imperfections are less severe than for the low-income countries. For instance, reasonably well-developed insurance markets exist in some middle-income countries, and the level of financial literacy among consumers tends to be higher. However, conditions vary widely among middle-income countries, and some will need more assistance than others in overcoming market imperfections.

Although low-income countries have severe demand side market imperfections, in some instances the supply side imperfections are less problematic. If the demand side imperfections could be overcome, the primary supply side imperfections affecting low-income countries—including limited technical capability of the domestic insurance industry, the low risk-bearing capacity of the local industry, and informational and agency costs—could be overcome. Overcoming these problems is an essential step in putting together risk-transfer programs that can be presented to

Table 2.3 Summary of Market Imperfections in Low- and Middle-Income Countries

Market imperfections	Challenges faced by donors		Comments
	LIC	MIC	
DEMAND SIDE			
Low non-life insurance penetration	H	M	Budget constraints and underdeveloped local insurance markets.
Low awareness of catastrophe risk exposure	H	M	Database and models need to be developed.
Low insurance education	H	M	Limited financial literacy.
Limited ability to pay	H	M	Health and life insurance have higher priority to buyers on limited budgets.
Weak institutional capacity	H	M	Need for institutional capacity building at national and sub-national levels.
Post-disaster assistance	H	H	Post-disaster assistance takes time to materialize and is usually earmarked to specific projects. Reliance on post-disaster assistance also creates a moral hazard problem by providing disincentives for disaster mitigation and risk management.
Low business volume	H	M	Private reinsurers do not want to invest when potential business volumes are expected to be low.
Unstable demand for catastrophe insurance	H	M	Government programs are unpredictable due to changing political leadership.
Inadequate government attention to catastrophe risk management	H	M	Catastrophe risk management often is not part of the political dialogue. IFIs and donors have a major role to play in raising government and public awareness.

(*continued*)

Table 2.3 Summary of Market Imperfections in Low- and Middle-Income Countries
(continued)

Market imperfections	Challenges faced by donors		Comments
	LIC	MIC	
SUPPLY SIDE			
Limited access to international capital markets	H	M	Recent experience (e.g., Mexico, Caribbean, India) supported by donors, shows that innovative solutions can facilitate access to international capital markets.
Insufficient domestic insurance capacity	H	M	Domestic insurance markets have limited financial capacity to be allocated to catastrophe insurance.
International reinsurance capacity	L	L	Capacity is increasingly available in low- and middle-income countries if programs are well structured and properly priced.
Reinsurance cycles	M	M	Less sensitive in developing countries than in high-volume developed markets when not correlated with peak risks in developed markets.
Agency & monitoring costs	H	H	Can significantly impact the cost of risk financing. Index-based products can lower these costs.
Limited technical capacity of the domestic insurance industry	H	M	Many domestic insurers lack actuarial, modeling, and financial skills to efficiently manage catastrophe risks. There is a need for capacity building.
Regulatory impediments	M	M	Arbitrary reinsurance rules may impede the adequate supply of catastrophe insurance or inflate the premium rates.
Informational costs	H	M	They can significantly increase the commercial (re)insurance premium through the uncertainty load.
Excessive CAT risk transfer pricing	M	L	Pricing is competitive when programs are well structured. It tends to decrease because of new capital inflow on reinsurance and capital markets.

Source: Authors.
Note: The challenges faced by donors are rated H (high), M (medium), and L (low).
LIC = Low-Income Countries; MIC = Middle-Income Countries.

international reinsurance and capital markets. Technical assistance may be needed to create domestic insurance and financial infrastructure to structure packages of risks that can be reinsured or securitized. If this step can be accomplished, the reinsurance placements and securitizations should be relatively successful. Once the foundation has been developed, risk transfer can be accomplished at a reasonable price and without significant exposure to supply constraints.

Risk-transfer placements from developing countries are generally quite small in comparison with developed-market transactions and are valuable to reinsurers and investors for diversification purposes. These placements cover off-peak perils and geographical areas where reinsurers and investors currently have little exposure. For some middle-income countries, some technical capability may already be present to assist in structuring packages of risks for transfer into global markets.

Reinsurance underwriting cycles have been severe for some developing countries, such as Mexico, which faced significant pricing volatility during the hard market of 2004 and 2005. This limits the ability of local insurers to respond effectively and consistently to demands for catastrophe insurance coverage. Technical assistance may be necessary in designing risk transfer solutions that mitigate the effects of pricing and availability swings associated with underwriting cycles.

Notes

1. For example, in China, insurers had 52 percent of their assets in low-yielding bank deposits in 2003. In part, this was due to regulation, although investment restrictions were gradually relaxed during the late 1990s. Mostly, it is due to the immaturity of China's financial markets, so that supplies of other types of assets are insufficient or subject to excessive return volatility (Sun, Suo, and Zheng, 2007). By contrast, insurers in the United States are almost exclusively invested in stocks, bonds, and other tradable securities.

2. These are also non-earning assets, that is, they typically are not invested and do not earn investment income, and such assets can create credit-risk problems arising from the possibility that policyholders or agents will default on their payment obligations.

3. In discussions of insurance programs, the term *reserves* is often used incorrectly to refer to a company's equity capital, that is, funds that are available to pay

unexpectedly large losses and not owed ex-ante to a particular creditor. Here, we adopt the correct accounting terminology, referring to premium and loss liabilities as reserves and the company's capital cushion as equity.

4. Equity capital is also called *surplus* or *policyholders' surplus* in the insurance industry.

5. The high non-life insurance penetration in the US is mainly driven by the fact that health insurance is provided by the private sector, whereas public social security programs exist in most European countries.

6. Industry capital is based upon data from Guy Carpenter (2008a), which provides total capital (including equity, retained earnings, and debt) for the Guy Carpenter Composite, consisting of the top 16 global reinsurers. Guy Carpenter estimates that the companies in the Composite account for 80 percent of industry premiums. Accordingly, as a rough estimate of total industry capital, we divided the Composite capital total by 0.8. Reinsurance industry premiums are from Standard & Poor's (2007). Premiums for 2007 are estimated based upon the estimate in Guy Carpenter (2008a) that premiums declined by about 9 percent in 2007 from their level in 2006. Allowing for some exposure growth, we reduced the Standard & Poor's (2007) premium total by 5 percent as our estimate of 2007 premiums.

7. Catastrophe reinsurance multiples are not available for other regional markets.

8. Figure 2.11 is based on tranches, whereas Figure 2.12 is based on bond issues, based on the reporting basis in the respective data sources for these figures. Many bonds issued over the past few years have had multiple trances covering various geographical regions or perils.

Principles for Public Intervention in the Catastrophe Insurance Markets

B ased on the insurance and reinsurance market imperfections identified in the preceding section, which present impediments to the implementation of sustainable and competitive catastrophe risk financing solutions, this chapter discusses how and when the public sector, with assistance from the donor community, should intervene. The emphasis is on the role that can be played by IFIs, such as the World Bank, operating in conjunction with governments, private institutions, and donors. Public intervention can be helpful in two broad areas. First, competitive private insurance and reinsurance markets can be fostered to increase the amount of affordable and cost-effective insurance coverage purchased by individuals and businesses to protect against catastrophe events. Second, sovereign insurance programs can be created to provide liquidity to governments to finance their immediate needs without adding significantly to sovereign debt or diverting funds from economic development projects.

The overall objective of any market intervention by the World Bank and donors related to catastrophe risk financing should be to reduce the vulnerability of developing countries to natural disasters by encouraging countries to develop sustainable, affordable, and effective risk financing strategies to deal with natural disasters. In the higher-level strategic context, projects supported by the World Bank and donors should meet the

objective outlined in Section IV of the Millennium Development Goals, underscoring the need "to intensify our collective effort to reduce the number and effects of natural and manmade disasters."

Risks of Public Intervention in Catastrophe Insurance Markets

The previous chapter explained why donors and IFIs should intervene in catastrophe insurance markets in developing countries, but these reasons are not sufficient for donor-supported public intervention. Such involvement comes at a cost; therefore it should be demonstrated that intervention will result in an improvement and that these benefits will exceed the costs. There is a risk that public intervention may be ineffective (that is, no efficiency gains are achieved) or even detrimental (that is, there are efficiency losses).

There are two main risks of public intervention in catastrophe insurance market. First, the government may want to develop public catastrophe insurance programs. As shown below, government is unlikely to implement the basic principles of efficient catastrophe insurance, leading to a financially unsustainable program that risks crowding out the private sector. Second, the government may be tempted to increase market penetration by offering insurance premium subsidies to lower the cost of insurance. Premium subsidies may distort the price signal and thus lead policyholders to under-invest in risk-mitigation activities or to invest in nonviable activities.

Public Catastrophe Insurance Programs

Establishment of efficient catastrophe insurance programs depends on the integration of four key components: risk assessment, risk pooling, risk segregation, and control of moral hazard (see Box 3.1). However, public catastrophe insurance programs run by governments are unlikely to follow these key principles, thus leading to unsustainable solutions.

Risk assessment is critical in enabling insurers to discover the true costs of risk. Sophisticated risk assessments inform insurers about the

policyholders' risk characteristics and help to control adverse selection by segregating or classifying heterogeneous risks into more homogeneous categories. However, segregation is sometimes viewed as socially unacceptable, because it may not be compatible with social and solidarity objectives. As a consequence, public insurance programs are likely to under-invest in controlling adverse selection through risk classification and to offer the same average premium rate to all policyholders. This leaves little incentive for

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Box 3.1 Basic Principles for Efficient Catastrophe Insurance

Risk assessment. Risk assessment is used to discover the true underlying cost of risk, which is pivotal to designing cost-effective catastrophe insurance programs. Risk assessment requires data collection and the application of statistical and actuarial modeling techniques. Catastrophe risk models can also be used to assess the risk of loss from disasters and improve government ability to mitigate the losses (see Annex 3).

Risk pooling. Insurance reduces the risk level to society by aggregating non-correlated risks. This makes the average loss more predictable and distributes the costs more efficiently. However, because pooling does not fully eliminate risk, insurers must maintain equity capital to absorb any variation around the expected loss. The amount of capital required is based on the independence of the risks; those risks that are correlated require more risk capital set aside than independent risks. The insurance industry has developed several techniques to make co-variant risk insurable: risk diversification over time, bundling catastrophe risk with other property risks (for example, fire), reinsurance, and so on.

Risk classification. Through appropriate data-collection and risk-underwriting techniques, insurers attempt to distinguish relatively high risk from low-risk applicants and then assign policyholders insurance premiums that accurately reflect their underlying risk characteristics. Insurance performs this function by segregating risks into the appropriate risk pools, that is, through risk classification. Risk classification and risk-based pricing reduce the chance of adverse selection, which occurs when high-risk policyholders over-consume insurance because their premiums are subsidized at pooled insurance rates. Charging risk-based premiums provides a market signal to policyholders about the

(Continued)

Box 3.1 (*Continued*)

cost of engaging in activities that generate the risk. This gives policy-holders incentives to invest in risk mitigation to lower their direct risk, and thus, their insurance premium (so long as any risk reduction is reflected in the insurance premium).

Control of moral hazard. The insurance industry has adopted a number of measures to reduce the impact of moral hazard, which occurs when policyholders change their behavior because the risk of loss is borne by someone else. To prevent moral hazard, insurers strive to align the policyholder's interests with the overall interests of the insurance pool. Commonly used tools to prevent moral hazard are deductibles and coinsurance, included as part of the insurance contract. Deductibles and coinsurance give policyholders the incentive to operate safely and engage in risk mitigation to avoid paying their portion of the loss. A final tool is the exclusion of some events from insurance coverage.

Source: Authors.

those with the greatest risk to lessen their exposure, while at the same time, makes insurance overly expensive for those with lower exposure.

Even if premium rates are appropriate on average, government-provided or government-backed insurance may provide cross-subsidies among classes of buyers, to promote equal treatment of all participants. For example, governments often undercharge buyers with high expected loss costs and overcharge buyers with low expected loss costs, because it is often politically unfeasible to charge citizens different rates. Providing insurance at sub-competitive prices or subsidizing high-cost insurance buyers creates moral hazard problems whereby policyholders under-invest in loss prevention or over-invest in high-risk activities or geo-graphical areas.

Insurers control adverse selection through various coverage-design feature, including deductibles, coinsurance, and policy exclusions. However, such coverage limitations may be viewed as inconsistent with the government's objective of offering broad coverage. For example, limiting

access of coverage by refusing coverage to citizens most at risk to disasters, or charging much higher premiums to reflect greater risks, may not be politically viable to a government attempting to establish catastrophe insurance coverage.

Under voluntary insurance, the failure to charge premiums that accurately reflect the underlying risks, based on government pressure to promote inclusion of all high-risk individuals, leads to a vicious circle of adverse selection. If the insurance industry is required (by law or decree) to charge equal rates to policy holders, this results in wealth redistribution from low-risk to high-risk policyholders, because low-risk policyholders are overcharged and high-risk policyholders are undercharged (subsidized).

To increase penetration of catastrophe insurance and depth of the market, governments may be tempted to require certain segments of the population to purchase coverage. Compulsory insurance may be viewed as a solution to adverse selection because it forces low-risk policyholders to remain in the insurance pool. It is also related to the principle of solidarity among citizens. Nevertheless, compulsory insurance may lead to a social sub-optimum because part of the population is forced to purchase catastrophe insurance.

However, because social or political constraints can prevent governments from controlling adverse selection through the application of sound insurance management practices, governments usually are ineffective in providing primary insurance coverage.

The efficient financing of natural disasters should thus rely on a public-private partnership between the private insurance, reinsurance industries, and governments. Figure 3.1 summarizes the public and private financing responsibilities. Governments, eventually backed by donors, should focus on:

- Stimulation of competitive private insurance markets (through the development of risk-market infrastructures and the financing of top layers of catastrophe risks);

- Provision of post-disaster loans and grants to the poor and disadvantaged; and

- Restoration of the lifeline infrastructure.

Figure 3.1 Public-Private Partnership in Catastrophe Risk Financing
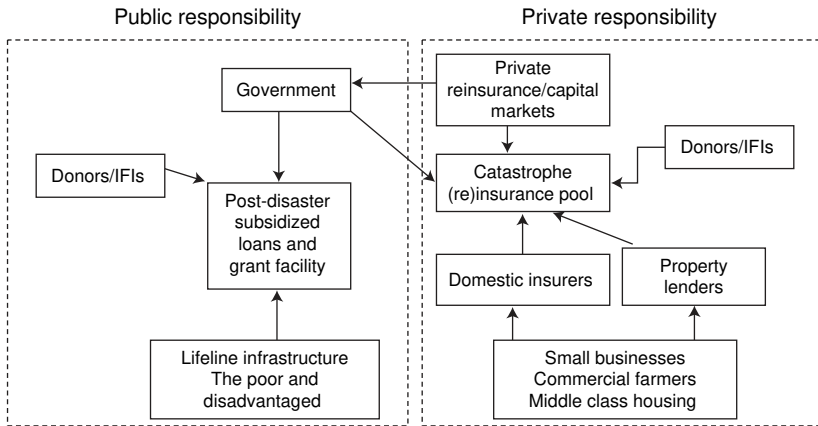
Source: Authors, from Gurenko and Lester (2004).

Insurance Premium Subsidies

Instead of actively managing catastrophe insurance programs, governments often choose to intervene in the insurance market to promote market development and penetration through financial incentives. Governments frequently subsidize catastrophe insurance, and particularly agricultural insurance products. Regardless of the form, government subsidies are usually designed to increase insurance penetration by lowering insurance premiums charged to the policyholders. Such public subsidies may be justified by the existence of market imperfections, but there is a risk that public intervention distorts the price signal and crowds out the private sector.

   In a well-functioning private insurance market, premiums should be risk-based and differentiated so that each buyer pays a premium sufficient to cover his or her own expected loss and expense costs as well as a profit loading to compensate the insurer for bearing insurance risks. With risk-based premiums, buyers bear the full costs of their risk-generating activities and thus have incentives to engage in risk mitigation and not to overindulge in risky activities. Subsidized catastrophe insurance induces overinvestment in structures in risky areas such as flood plains and coastal communities exposed to hurricanes. It also induces subsidized policyholders to buy more insurance than they would purchase under risk-based

insurance rates (Grace, Klein, and Kleindorfer 2004). These adverse-incentive effects increase the expected losses from catastrophes and impose costs on governments, taxpayers, and donors.

Two main types of insurance subsidies can be defined. *Market-enhancing insurance subsidies* are subsidies that enable or promote competitive insurance markets. These subsidies focus on the development of public goods and technical assistance that enhance the risk market infrastructure, such as data collection and management systems, catastrophe risk models and legal and regulatory framework. *Social insurance premium subsidies* are provided by governments as part of social safety net programs. The most common form of social premium subsidy is direct-premium subsidies that are proportional to the insurance premium that would be charged in a private insurance market.

Market-enhancing insurance subsidies aim to support a healthy and sustainable competition among insurance and reinsurance companies by reducing the startup costs and entry barriers. Such subsidies ultimately contribute to the reduction of the insurance premiums and therefore benefit the policyholders. Programs can be designed to address the market imperfections identified in the previous chapter, while avoiding market disincentives that lead to over-consumption of risky activities and higher loss costs.

Favorable subsidy programs include the provision of public goods that contribute to the development of insurance market infrastructure, such as data collection and management, development of catastrophe risk models, the creation of legal and regulatory frameworks, and so on. Other favorable subsidy programs include those that build the capacity of the domestic insurance industry and facilitate the transfer of risk to global (re)insurance and capital markets. Effective programs can also be created to educate the public about the benefits of insurance and to increase insurance literacy. Providing technical assistance and development aid to the domestic insurance industry is another form of subsidy that can improve the ability of domestic markets and institutions to finance catastrophe losses without leading to harmful disincentives.

The Turkish Catastrophe Insurance Pool is an illustration of a catastrophe insurance program with risk-based premium rates without public subsidies. Premium rates differ by risk areas (5 zones) and by type of construction (3 types). Likewise, for the Caribbean Catastrophe Risk Insurance Facility,

which provides sovereign insurance to Caribbean governments, the insurance premium reflects country-specific risk exposure. In agriculture, the livestock index-based insurance program in Mongolia and weather-based crop insurance program in Malawi provide insurance coverage where the herders and the farmers pay an actuarially fair premium without direct premium subsidies (see Annex 5). Most of the hail-insurance programs for crops are commercially viable without direct premium subsidies.

Social insurance premium subsidies tend to have highly distortional implications for the insurance markets and risk management behavior of the policyholders. They should be avoided and governments should offer separate safety net programs managed by the public sector. An example of a social insurance premium subsidy program is a scenario where 50 percent of the risk-based premium may be paid by the government, and the other 50 percent is paid by the policyholder. Experience shows that this form of premium subsidy is usually inefficient and increasingly expensive because direct premium subsidies tend to: i) be untargeted and available to all policyholders, whatever their ability to pay, because it is politically difficult to discriminate regarding the level of premium subsidies among the population; ii) be permanent, even though the government initially introduces them as temporary subsidies; iii) represent an increasing fiscal burden for the government, because the eligibility criteria are relaxed or the subsidy levels increase; and iv) mainly benefit policyholders located in high-risk zones.

The following two examples demonstrate the imperfections of social insurance premium subsidies. Proportional insurance-premium subsidy programs are widely used in crop insurance. In 2006, U.S. crop insurance premium subsidies were US$2.3 billion (60 percent of total crop insurance premiums),[1] meaning that farmers paid on average 40 percent of the total insurance cost. These subsidy programs mainly benefit large farmers (who insure a large value at risk) and farmers growing high-risk crops (whose risk-based insurance premium rate is higher than that for farmers with low-risk crops). In addition, these programs are largely captured by insurance companies. The GAO (2007) reports that during 2002–2006, U.S. Department of Agriculture crop-insurance subsidies resulted in underwriting profits of US$2.8 billion for the insurance industry. These gains represent an average annual rate of return of

17.8 percent over this 5-year period, approximately three times the rate of underwriting return on private market property casualty insurance during this period.

Another illustration of social insurance premium subsidies is India's National Agricultural Insurance Scheme (NAIS), a government-sponsored crop insurance program that protects Indian farmers against the adverse weather events and pest infestation. NAIS is heavily subsidized by the Indian country and state government and is designed as a social scheme, with limited risk classification.[2] Rates are capped at 3 percent for food crops nationwide—well below the actuarially sound premium rates. The lack of risk classification and premium differentiation does not give farmers incentives to change their farming practices or to shift to more viable crops. For example, groundnut farmers in states heavily exposed to drought risk should pay premium rates of more than 30 percent under actuarial pricing (World Bank 2007c) instead of the 3 percent cap legislated by the government. Since they pay only a 3 percent premium rate under NAIS, they have no incentive to invest in risk mitigation or to shift toward more drought-resistant activities. Although it is compulsory for borrowing farmers, this scheme is voluntary for non-borrowing farmers. As one would expect, the only non-borrowing participants in the NAIS are high-risk farmers because of a lack of price discrimination that allows them to receive coverage at a cost below the market price. As a result, the long-term average loss cost (the ratio of losses to the insured value) is 26.4 percent for non-borrowers, compared to 9.9 percent among borrowing farmers. Implicit premium subsidies represent approximately 75 percent of the actuarially sound premium rates.

Social insurance premium subsidies tend to have highly distortional implications for the insurance markets and risk management behavior of the policyholders. As such, they should be avoided and governments should offer separate safety-net programs managed by the public sector. However, when the public financial delivery systems face severe leakages or even corruption, the insurance industry delivery systems may be more efficient in providing assistance to poor households. In this case, social premium subsidies targeted to poor households may be justified, as part of a social safety net program rather than an insurance program.

Guiding Principles for Market Intervention

Recent interventions by IFIs, particularly the World Bank, in catastrophe insurance markets have mainly been "market-enhancing." The market-enhancing view recognizes that market failures can create suboptimal allocations of resources and that private sector coordination is not always effective (see Box 3.2). Public policy should facilitate the development of risk-market infrastructure that enables market-based solutions, such as the creation of public goods. Governments should avoid creating permanent new government institutions to substitute for private

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Box 3.2 Theories of Market Intervention

The *laissez-faire theory* of public policy maintains that any market-based equilibrium, however imperfect, still provides a more efficient allocation of resources within the economy than does an equilibrium involving government intervention. In the absence of distortion-inducing government intervention, the outcome of decentralized private sector activity will remain more efficient, even in a second-best sense, than a market equilibrium with government intervention. From this perspective, government intervention in markets results primarily in rent-seeking behavior of special interest groups seeking to bolster their allocation of societal wealth (Stigler 1971; Peltzman 1989). According to laissez-faire theory, calls for government assistance in providing catastrophe insurance may be viewed as opportunistic attempts to secure an ex-ante wealth transfer from taxpayers, and programs to provide liquidity to governments for disaster relief would be viewed as rent-seeking behavior by government officials.

The *public-interest theory* of intervention contests the laissez-faire view (Musgrave and Musgrave 1984). Public-interest theory suggests that the existence of market failures (such as adverse selection, moral hazard, economies of scale, externalities) can lead to a suboptimal allocation of resources, and that government intervention targeted at addressing these market failures can improve welfare. The challenge for public-interest theory is to narrowly define the market failure and devise a minimalist policy to correct this failure without creating additional

(Continued)

Box 3.2 (*Continued*)

distortions in the allocation of market resources. Proponents of public-interest theory, therefore, would maintain that the information asymmetries, limitations on financial infrastructure, and other imperfections associated with the market for catastrophe insurance may necessitate the role of the governments in "completing" the market for catastrophe insurance.

The *market-enhancing theory* takes a middle position (Lewis and Murdock 1996, 1999). It recognizes that market failures can create suboptimal allocations of resources and that private sector coordination is not always effective. This view holds that public policy should facilitate the development of the private market, for instance, by improving information flows, but should not create permanent new government institutions to substitute for private solutions. As an example, the market-enhancing view would suggest that a government-funded catastrophe risk mapping program would provide valuable information to the market on catastrophe risk zones, but that the provision of catastrophe insurance should be left to private institutions. At the same time, market-enhancing theory recognizes that government intervention can help facilitate the creation or enhancement of private institutions for solving market failures.

Source: Authors.

solutions, although government institutions can be invoked in very specific circumstances where risks are ill-defined and private market solutions are not available.

Although the experience of the World Bank and donors in encouraging country-specific catastrophe risk financing strategies is relatively recent, basic guiding principles can be drawn from past experience. These principles provide international financial institutions and donors with a framework to determine their roles in enhancing catastrophe insurance solutions. Below are five key guiding principles for public intervention in catastrophe insurance markets in developing countries. All rely on a close partnership between the countries, the donors and international financial institutions.

- **Principle 1. Promote catastrophe risk financing in the dialogue on disaster risk management with the middle- and low-income countries**

Given the clear fiscal and developmental implications of natural disasters for middle- and low-income countries, disaster risk management should become part of the wider dialogue with countries regarding macroeconomic stability and growth. The discussion should focus on all aspects of the five-pillar Disaster Risk Management (DRM) framework: risk assessment; emergency preparedness; risk mitigation; institutional capacity building; and catastrophe risk financing. The underlying principle is that both the loss of life and the economic impact of disasters can be reduced by advance planning and cost-effective investment. The DRM framework offers countries an operational template for gradually and systematically upgrading their capabilities for dealing with catastrophes.

Catastrophe risk financing solutions, including insurance, should be discussed within this context and should be considered as the last resort to finance the adverse impact of natural disasters that cannot be mitigated otherwise. Financing solutions should be designed to further induce policyholders to lessen their risks.

- **Principle 2. Enhance competitive catastrophe risk markets**

Financial vulnerability to catastrophe risk can be reduced by transferring risks to competitive insurance and reinsurance markets. Donors and IFIs should promote competitive insurance and reinsurance markets through the development of an enabling environment that will crowd in the private sector.

A strong and modern regulatory and supervisory framework is needed to make certain that insurers have the financial resources to pay claims as they become due, that contracts are enforced, and that insurers treat consumers in an equitable manner in their financial dealings. Regulation should be based on a set of rules that foster financial sector stability and public protection, while ensuring market competitiveness and efficiency. Finally, public awareness campaigns should be undertaken to overcome the widespread lack of insurance culture in middle- and low-income countries

and product development should be supported to assist insurers in devising products that better address consumer needs.

For political and social reasons, governments acting as direct insurers are unlikely to enforce basic insurance principles (for example, price discrimination) but they can act as a reinsurer or lender of last resort when private solutions are unavailable or inadequate. Effective and sustainable catastrophe risk financing solutions are therefore likely to involve collaboration between governments, donors and private industry.

Public-private partnerships in the financing of catastrophe risk should help enable competitive domestic insurance industries and facilitate access to international reinsurance and capital markets to generate affordable insurance solutions for private agents (for example, property insurance for homeowners) as well as governments (for example, sovereign insurance). These partnerships, supported by donors, should crowd in the private insurance and reinsurance industry and should be designed to be self-financing and self-sustaining, even though external financial support may be needed during inception to offset startup costs. These institutions should not compete with the private sector; on the contrary, they should create new business opportunities for the private insurance and reinsurance industry.

- • Principle 3. Use risk-based price signals to encourage catastrophe risk management

One of the important roles of competitive financial markets is the provision of price signals. In competitive markets, insurance premiums should be risk-based and differentiated, thus reflecting the underlying risk exposure. These draw attention to the catastrophe risk exposure of individuals, firms or governments, and allow them to evaluate the benefits of a disaster risk management program by comparing the cost of risk reduction investments with the resulting reduction in potential losses.

Identifying the true cost of risk through risk-based premiums can also help governments reduce their fiscal exposure by providing better forecasts of their contingent liabilities related to natural disasters. By fully understanding their exposure, governments can define the liabilities that

they are responsible for and those that private citizens are required to cover. Governments can then focus on limiting this liability through physical, institutional and financial mitigation efforts and can be directed in prioritizing these investments according to the risk-based price signals in the marketplace.

Actuarially sound cost estimates also can help governments to develop more cost-effective subsidy programs, because grants can be better targeted (for example, to catastrophe risks and/or to poorer households). Accurate actuarial premium estimation also can help insurance companies to build up adequate technical reserves and equity capital to cover their insurance risks.

- • Principle 4. Limit public subsidy programs to those that minimize distortions of risk-based insurance premiums

Market-enhancing insurance subsidies can be justified to finance public goods related to risk market infrastructure. Programs should focus on providing seed funding for development of essential services, such as data collection, risk modeling, product development, capacity building, and delivery channels.

Subsidies also can be justified for the financing of the catastrophe risk layers when private financial capacity is expensive or unavailable. In this case, governments, with the support of donors, could act as a reinsurer or lender of last resort, so long as the government can manage its catastrophe risk exposure. Subsidized risk capital, such as the capitalization of catastrophe (re)insurance pools, can be justified when it contributes to enhancing competitive insurance markets and creating new business opportunities for the private financial markets.

Direct insurance premium subsidies should be avoided, because they: i) distort the market price signal and thus give policyholders the wrong economic incentives; ii) tend to benefit high-risk policyholders to the detriment of low-risk policyholders; and, iii) are almost impossible to phase out in the long term. However, when the public financial delivery systems face severe leakages or even corruption, the delivery systems available through the insurance industry may be more efficient to provide financial assistance to the poor households. In this case, social premium

subsidies targeted to poor households may be justified, as part of a social safety net program.

• Principle 5. Develop customized catastrophe insurance solutions

Risk financing solutions typically need to be tailored to specific local conditions. The role of donors in the financing of natural disasters should be to promote the development of country-specific solutions based on local characteristics, including country risk exposure, the country's ability to diversify risks spatially and across time (for instance, debt level, tax base), the degree of development of the domestic insurance market, the access to international (re)insurance and capital markets, and so on. Cost-effective catastrophe risk financing, at both the micro (household, farmers) and macro (government) levels, cannot be addressed with one single financial product. At the micro level, products for households (such as property catastrophe insurance) and for farmers (such as crop insurance) should be customized. Likewise, sovereign insurance can help governments deal with the liquidity gap that may arise in the aftermath of a disaster.

Market-based insurance solutions should be promoted to transfer the risk of private assets (such as dwellings, agricultural assets) to the insurance industry. Catastrophe insurance pools can help the local insurance industry access the international insurance markets on cost-effective terms. Such solutions are particularly adapted for middle-income countries where the domestic insurance market is relatively developed (for example, Turkey, Mexico). In low-income countries, where the domestic insurance markets are likely to be underdeveloped, such risk-aggregation mechanisms may be premature (except maybe for agricultural risks), and the development of the primary insurance market should be given priority.

Cost-effective country risk financing strategies are likely to rely on a combination of post-disaster and ex-ante financial instruments through catastrophe risk layering. The first layer is a reserve fund to cover small and recurrent losses. Higher layers can be covered by insurance to protect critical public assets, contingent credit arrangements, budget reallocations, and reinsurance and alternative risk-transfer solutions such as catastrophe bonds.

Notes

1. The premium subsidy rate is decreasing with the coverage level: public subsidies account for 64 percent of the premium at 55 percent coverage level (that is, the yield guarantee is 55 percent of the long-term average yield) and for 38 percent of the premium at 85 percent coverage level.

2. The coverage levels offered to the farmers are determined based on the coefficient of variation of yields. Higher coverage levels are available for crops with lower coefficient of variation.

Roles for the Donor Community

D onors and IFIs should play a catalytic role in the development of innovative risk financing solutions for developing countries. Four key paths of intervention can be identified: convening power; promoter of public goods that permit the development of risk market infrastructure; provider of technical assistance for innovative catastrophe insurance solutions; and, financier.

Successful partnerships between the donor community and developing countries require a strong commitment from all parties. Governments should set up a *Catastrophe Risk Financing Cell* to promote catastrophe risk financing solutions through public-private partnerships. This cell would work in close collaboration with officials responsible for disaster risk mitigation and emergency preparedness. Donors and IFIs could help the government set up such a dedicated department, which would also jointly work with the private insurance and reinsurance industry to identify emerging risks and potential financial solutions. The cell would be the natural counterpart of the donor community in the promotion of effective, affordable and sustainable catastrophe risk financing solutions.

Public intervention in catastrophe insurance markets, supported by the donor community, should be country-specific. Low-income countries, where the domestic non-life insurance market is undeveloped, should focus in the short term on the development of sovereign catastrophe insurance

solutions and the promotion of public goods related to risk market infrastructure. These countries are usually not mature enough for the promotion of catastrophe insurance pools for private homeowners. Governments in middle-income countries, where the domestic non-life insurance market is more developed, should help the private insurance industry offer market-based catastrophe insurance solutions to homeowners and to small and medium enterprises, including the agricultural sector.

Convening Power

Using their in-depth knowledge of the client countries, relationship with donors, and reputation for impartiality in dealing with countries and the international reinsurance market, the World Bank and other IFIs can play a catalytic role in the development of efficient partnerships among countries, donors, and private markets for the financing of catastrophe risks. The establishment of the Caribbean Catastrophe Risk Insurance Facility illustrates how the World Bank and the Caribbean Development Bank used their power to bring together 16 Caribbean countries to form the facility and to recruit donors to contribute the startup costs (see Box 4.1).

Governments are often hesitant to purchase insurance from private agents for bureaucratic reasons. These bureaucratic reasons and the associated time-consuming efforts should not be underestimated. Most of the governments do not have a specialized risk financing department, which would be the natural counterpart, and therefore, several ministries can be involved in the final decision, making the dialogue even more difficult. For example, in the case of the CCRIF, the facility manager often had to explain the intricate details of the facility and the costs and benefits to various groups in several different country ministries in order to secure their participation. While IFIs are experienced in this type of dialogue with governments, private sector insurers are unfamiliar and will be less likely to divert scarce resources to such initiatives. Likewise, insurers may be reluctant to start a business relationship with a government since it is unlikely to offer long-term commitment because of annual budget exercises and changing political regimes.

Box 4.1 Caribbean Catastrophe Risk Insurance Facility

As the request of the CARICOM countries, the World Bank helped Caribbean governments to develop the Caribbean Catastrophe Risk Insurance Facility (CCRIF). The CCRIF allows Caribbean governments to purchase coverage akin to business interruption insurance that would provide them with immediate cash payment after a major earthquake or hurricane. This Caribbean-owned, regional institution is the first regional disaster insurance facility in the world. The CCRIF currently has 16 participating governments, with policies effective as of June 1, 2007, for a total premium volume of about US$20 million. The CCRIF is a Cayman-registered "mutual" insurance company capitalized by the international donor community and the World Bank, as well as participating countries themselves. The CCRIF was able to secure US$110 million of reinsurance capacity in addition to its own reserves. The development of a similar facility in other regions (including the Pacific island and Central American states) is currently under investigation. Extending the pool to small states beyond the Caribbean that face similar natural hazards would provide further opportunities for risk diversification, thus lowering the cost of insurance.

    See Annex 5 for a detailed description of the CCRIF.

Source: Authors, from World Bank (2007d).

Promoter of Public Goods

Donors can play a major role in financing public goods that contribute to the creation of a risk market infrastructure, which enables the development of competitive risk financing solutions. However, donors should ensure that public subsidies are used to create public goods that equally benefit all the stakeholders involved in the catastrophe risk markets, and ultimately the most vulnerable farmers and households, through the emergence of a competitive market. If these public subsidies were to be captured by private entities for commercial purpose, this may result in unfair competition among private insurers and reinsurers, possibly leading to the creation of a monopoly or cartel that would discourage private initiatives.

Data Collection and Management

Data collection and management is essential for the development of sustainable market-based risk financing products. Reliable historical data covering a period of at least 30 years is needed to enable markets to provide efficient and cost effective catastrophe insurance coverage. The availability, quality, and cost of obtaining such data is an important issue in many developing countries (see Box 4.2).

To help meet this general requirement, the World Bank has helped the governments of Ethiopia and Malawi to upgrade their weather station networks and install new weather stations. Tamper-proof weather stations must be established to ensure reliable readings on insured events. New hardware systems, such as automated weather stations, can improve accuracy and reduce direct human involvement in the recording process. Satellite

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Box 4.2 Data Quality Issues in Middle- and Low-Income Countries

In 2006, WMO carried out a survey to evaluate capacities, gaps and needs of the National Meteorological and Hydrological Services in serving different aspects of disaster risk management. One hundred and thirty-nine countries participated in the survey, and 90 percent indicated the need to strengthen their observing networks, their capacities for maintenance of standard hazard databases and metadata, maintenance of sectoral disaster loss data and methodologies for risk modeling to support development planning in different economic sectors. Given the pervasive nature of hydro-meteorological hazards and increasing levels of vulnerability, ability to manage these changes will require continuing and renewed commitment to maintaining the observing networks, basic data, and hazard forecasting capacities needed for identifying and managing risks. Specifically, at the national level, many challenges remain, including: i) the need for modernization and/or installation of new automated hydrometeorological instrumentation and observing networks; ii) data-collection and management systems; iii) technical capacity and resources for maintaining observational networks; iv) data rescue to translate massive amounts of paper-based records into digital form; v) ongoing quality control to ensure consistency and completeness of the records; and, vi) the capacity to archive large databases; and ensuring that the data are available to all users.

Source: WMO (2007)

instruments can provide estimates of rainfall and perhaps, in the long run, these instruments can become the main means of providing rainfall measurements for insured areas. Satellite rainfall estimates (RFE), covering the entire African continent in a grid (10 x 10 kilometers), are being pilot tested to provide an early warning system in Ethiopia (see Annex 5). Although tested for monitoring purposes in Africa, this RFE data has not yet been used as an underlying variable for risk transfer, primarily due to concerns about its short historical data length (the data set starts in 1995).

The World Bank Index-based Livestock Insurance Project in Mongolia assists the National Statistical Office of Mongolia in the enhancement of its annual livestock census. The government of Mongolia has been conducting an annual census of animals in Mongolia for 50 years. The procedures are well-established, and rules and regulations are in place to protect the integrity of the process. Nonetheless, there are potential problems with these data once an insurance product is developed with payment triggered by measured livestock mortality rates. New procedures and statistical techniques have been developed to improve the reliability of the data collected under the livestock census. However, the data may not be sufficiently reliable for the purpose of reinsurance, and alternative indexes, such as the vegetation condition index, are being investigated.

Catastrophe Risk Assessment Tools

Catastrophe risk simulation techniques are powerful tools to assess risk exposure, at both the micro and macro levels, and to help governments in framing comprehensive disaster risk management programs. Such tools were initially developed by risk-modeling firms for the insurance industry. It is not surprising that such models exist for most developed insurance markets but are missing for most low-income and some middle-income countries.

Insurance markets in low- and middle-income countries are generally smaller and more rudimentary than in the developed world, and resources may not be adequate to support the fixed costs and ongoing expenses of catastrophe risk models for many developing countries. This lack of adequate catastrophe risk models inhibits country risk management and mitigation programs. Without such models, governments are not fully aware of their specific exposure to natural disasters, which they generally underestimate.

Moreover, the lack of models limits the ability of governments and domestic insurers to access global reinsurance and capital markets because the market is reluctant to provide capacity when the underlying risks are not property assessed. Donors and IFIs can play a major role in supporting the development of catastrophe risk models for developing countries. They should also ensure that these models are made available to the local stakeholders, including the domestic insurance companies.

Examples of donors and IFIs supporting catastrophe risk models include country-specific catastrophe (hurricane and earthquake) risk models have been developed for the Caribbean region under the sponsorship of the Caribbean Catastrophe Risk Insurance Facility. The facility is now financing the development of flood models to offer better coverage to its participating countries. Likewise, catastrophe risk models for tropical cyclones and earthquakes are being developed for the South-Pacific islands. In India, donors financed the development of an agro-meteorological model to assess the impact of weather variability and climate change on crop yields (see Box 4.3). This model has been adapted for the insurance industry to help design weather-based crop-insurance products.

The World Bank recently began developing an open platform for catastrophe risk assessment in Nicaragua and Costa Rica, to be extended to other Central American countries. This model aims to produce the necessary data to allow decision makers to understand their financial exposure to natural disasters and to develop regional dialogue on comprehensive and integrated disaster risk management. The model will be made available to all stakeholders involved in disaster risk management, including the private insurance industry (see Box 4.4).

Such models are expensive to develop, and the private sector is usually reluctant to invest due to uncertainty about generating sufficient business to recover the development costs. Therefore, there is clearly a critical role for donors to finance the development of such models, because they increase the awareness of disaster risk management and, ultimately, help reduce the physical and financial vulnerability of developing countries to natural disasters.

Awareness and Education Campaigns

Donors can play a central role in increasing insurance education and awareness in developing countries. The average person in a low-income

Box 4.3 Drought Risk Assessment Model in India

At the request of the Indian government, the World Bank conducted a study to develop a robust analytical framework for simulating the long-term impacts of drought at the micro (drought-prone areas) and macro (state) levels. To create a framework, the Bank carried out a quantitative probabilistic risk assessment of the impacts under different scenarios, and assisted the government in the development of a forward-looking and anticipatory strategy for adapting to frequent drought events and conditions of water deficit.

A probabilistic drought risk assessment model was developed to estimate the economic impact of drought and to assess the effects of different drought mitigation strategies and climate change scenarios. Such models are well established to deal with rapid-onset disasters (for example, earthquakes, cyclones, and floods). However, the economic impact of drought is more complex than that of rapid-onset disasters because the impact of rainfall shortage on agricultural assets (for example, crops) is a complex hydrologic and agronomic phenomenon, and drought normally lacks the highly visible direct impacts associated with rapid-onset disasters. For slow-onset disasters, Indirect losses from drought are more difficult to quantify and identify. Because slow-onset disasters, such as drought, have different characteristics and are more difficult to quantify than rapid-onset events, it required an innovative risk assessment model using a different risk management paradigm than the one applied for rapid-onset disasters. This was the first time that latest catastrophe modeling techniques were used to address the impact of drought.

Source: World Bank (2006b).

country has limited financial education and an inadequate understanding of insurance. The problem is reinforced by a lack of confidence in the insurance industry. Information campaigns can contribute to the development of insurance markets by increasing the understanding of the insurance industry.

Legal and Regulatory Systems

Many developing countries lack the legal and regulatory framework to support the development of catastrophe insurance markets. Middle-income countries should focus on strengthening regulation and supervisory capacity.

Box 4.4 Central America Probability Risk Assessment

Central American Probabilistic Risk Assessment (CAPRA) initiative is an information platform for Central American countries to support decision making related to risk management of natural disasters: emergency preparedness, territorial planning, risk mitigation investments, and catastrophe risk financing.

CAPRA applies state-of-the art probabilistic catastrophe risk techniques to assess the impact of hurricanes, earthquakes, landslides, volcanic activity, and floods in Central American countries. This methodology provides a common language for catastrophe risk assessment and risk management and can be augmented to consider the future risks associated with climate change. Results of CAPRA's analysis will be disclosed in GIS (Geographic Information System) format, and will be available to the public on the internet.

CAPRA is based on an open and modifiable platform, which allows governments and institutions to supplement the model with previous and ongoing initiatives, avoiding duplication in the region. The platform is designed to be tailored to the needs of each user and will be first piloted in Costa Rica and Nicaragua.

The initiative is managed by CEPREDENAC and the World Bank, with financial support from the Global Facility for Disaster Reduction and Recovery (GFDRR).

Source: World Bank (2008).

Creative solutions to increase insurance penetration may be needed, such as establishing legislation that makes catastrophe insurance compulsory. In Turkey, for example, the government formally introduced a compulsory earthquake-insurance program through the enactment of the governmental Decree Law. The regulatory framework may also need to be amended to make catastrophe insurance more attractive for the insurance industry.

In low-income countries, product development should move in parallel with, or should precede, regulatory and supervisory developments. An example is the Mongolian livestock insurance scheme, where the insurance regulatory structure had to be developed to facilitate the introduction of a livestock mortality product that has the potential to be one of the largest sources of insurance premiums.

Provider of Technical Assistance for Innovative Catastrophe Risk Financing Solutions

The highly technical and specialized nature of catastrophe risk financing solutions necessitates the use of a wide spectrum of experts to tackle the actuarial, legal, fiduciary, and financial engineering aspects of catastrophe risk financing projects. IFIs, and especially the World Bank, with the funding support of donors, can contribute the technical expertise to effectively supervise and provide oversight to such projects.

IFIs and donors should assist countries in developing tailor-made catastrophe risk financing strategies through an optimal combination of financial instruments, including reserves; contingent debt; insurance/reinsurance; and insurance-linked securities (for example, catastrophe bonds). These financial tools would enable governments to secure immediate liquidity and budget support in the aftermath of a major natural disaster. Donors and IFIs should also work with governments to create competitive insurance markets and increase catastrophe insurance penetration. The following innovative catastrophe risk financing products can contribute achieving these objectives.

Index-Based Insurance Solutions

Index-based insurance solutions, such as parametric insurance, offer countries new opportunities to transfer their catastrophe risks to third parties. At the micro level, they allow domestic insurance companies to offer simple and transparent solutions to farmers to transfer weather risks (such as rainfall deficit, excess rainfall, low temperature). These parametric instruments should complement traditional indemnity-based insurance products. Likewise, at the macro level, they allow governments or domestic insurers to access international reinsurance capacity and capital markets (see Box 4.5).

While index-based insurance looks promising, it is not a perfect product. For example, the issue of basis risk, that is, the imperfect correlation between the actual losses and the indemnity payouts, should not be underestimated. Anecdotal evidence, both for households and governments, suggests that an imperfect understanding of these products' limitations causes

Box 4.5 Parametric Insurance in Middle- and Low-Income Countries

Parametric insurance products are index-based insurance contracts that make payouts based on the exact location and level of intensity of an adverse natural event (for example, wind speed, earthquake intensity, rainfall levels). Unlike traditional insurance settlements that require an assessment of individual losses on the ground, parametric insurance relies on an assessment of losses using a predefined formula based on variables that are exogenous to both the individual policyholder and the insurer, but have a strong correlation to individual losses.

The use of parametric insurance has been increasing since the early 2000s. Sovereign risk transfer mechanisms—such as the catastrophe bond issued by the government of Mexico in 2006; the catastrophe insurance contracts sold by the Caribbean Catastrophe Risk Insurance Facility in 2007; and the weather derivate contract between a leading reinsurer and WFP in 2006—are based on parametric triggers, like the wind speed for hurricanes or the rainfall level for drought (see Annex 5).

Micro insurance programs based on parametric triggers have been piloted in agriculture- and weather-based crop insurance products in Mexico, India, Malawi, Central America, etc. In India, more than 700,000 farmers purchased weather-based crop insurance linked to their crop loans in 2007.

The World Bank, in partnership with the European Commission, is supporting the creation of the Global Index Reinsurance Facility (GIRIF), a multi-donor trust fund linked with a specialized index-based reinsurance company, which will promote index-based insurance in developing markets. The European Commission allocated 25 million euros to the trust fund to promote the development of index-based insurance products in Africa, the Pacific and the Caribbean. This trust fund will finance capacity building activities (such as promotion and public awareness of index insurance, strengthening of legal and regulatory systems, improving data availability and catastrophe risk modeling, development of commercial capacity) and premium subsidies to specific index insurance agreements

See Annex 5 for more information.

Source: World Bank (2005a, 2007a, 2007c).

policyholders to complain, or to let their policies lapse, after being hit by a loss where no indemnity payouts were triggered. This risk could be mitigated by bundling index-based products and financial products with softer triggers that make small payouts for less catastrophe events.

Technical assistance in innovative insurance products should be carried out by independent experts, and not by the final risk carriers, in order to avoid any potential conflicts of interest or the creation of monopolies. Technical assistance provided by donors and IFIs should allow the clients to better understand their underlying risks and give them additional tools to better negotiate the insurance and reinsurance market. However, it is critical to involve the insurance and reinsurance industry in the early stages to obtain their advice, as they will be the ultimate risk carriers.

Risk Pooling Vehicles

Donors should support the creation of such national and regional risk aggregator vehicles. Besides the pooling benefits that allow participating countries to access catastrophe insurance on better terms, these pools provide a source of national or regional collective reserves. Setting aside reserves collectively is very attractive to countries, because they are often hesitant to deal individually with the insurance industry. Reserving collectively also contributes to reinforcing regional linkages and regional identity.

A central catastrophe risk aggregator vehicle is usually more efficient than holding capital on the balance sheets of individual domestic insurers or in government budgets. By pooling risks across countries or regions, catastrophe insurance pools generate diversification benefits that are reflected in reduced insurance premium. A risk aggregator creates greater portfolio diversification because payouts are more predictable, thereby decreasing the catastrophe load that companies are required to hold, which lowers premium costs. Moreover, managers of risk pools, because of the greater scale (based on amount of assets) of the risk pooled portfolio, are more likely to be able to negotiate favourable prices in international reinsurance and capital markets, thus transferring risk more efficiently. Catastrophe insurance pools should be designed to guarantee both affordable and stable insurance premiums and supply of coverage, although the premiums should reflect the risk exposure. The governments of developing countries would be unable to avail themselves of the offered protection if the premiums remain high.

Smaller developing countries may have limited capacity to spread catastrophe risk geographically. For example, a hurricane hitting Jamaica is

likely to affect the entire economy. In such cases, regional strategies should be promoted. The Caribbean Catastrophe Risk Insurance Facility is an illustration of a successful regional risk aggregator vehicle. Aggregator vehicles are particularly efficient for pooling risks that are common to all the participating countries and that can be easily tracked (for example, hurricanes in the Caribbean basin, tropical cyclones in the Pacific, earthquakes in Central America, droughts in Africa). By contrast, creating aggregator vehicles for localized disasters such as flash floods or landslides is often more challenging.

In addition to aggregation and scale, catastrophe insurance pools are able to self insure the first loss while transferring remaining risks to the market. This enables pools to accumulate reserves over time and to increase risk retention, allowing further reduction in insurance premiums. There is growing empirical evidence that catastrophe insurance pools have been able to diversify intertemporally to dampen the volatility of the reinsurance pricing cycle and offer stable premiums to the policyholders.

In large countries that have the capacity to spread catastrophe risks geographically, national catastrophe insurance pools should be promoted. An example is the Turkish Catastrophe Insurance Pool, TCIP (see Box 4.6). Other countries, such as Mexico, Colombia, China, and India, could also benefit from nationwide catastrophe risk diversification.

Insurance pools can help domestic insurers with limited capital and limited technical ability to start new lines of business, such as agriculture insurance. The government of Mongolia, assisted by the World Bank, supported the creation of a livestock insurance pool to allow domestic insurers to offer index-based livestock insurance to herders. The government developed risk market infrastructure, such as the adoption of a new insurance law, the strengthening of the animal census performed by the national statistical office (see Box 4.7).

Risk aggregator vehicles create new business opportunities for the private reinsurance market by providing a better structured insurance portfolio and reducing underwriting costs. The inputs that go into developing such facilities—including catastrophe risk modelling and strengthening of governments regulatory structures—serve as useful global public goods that lower the entrance costs for reinsurers to enter new markets.

Box 4.6 Turkish Catastrophe Insurance Pool

The Turkish Catastrophe Insurance Pool (TCIP) was established with World Bank technical and financial support in the aftermath of the 1999 Marmara earthquake. It offers efficiently priced earthquake insurance to homeowners. The World Bank provided the initial capitalization of the TCIP through a committed contingent loan facility of US$100 million, extended to US$180 million in 2004. The full risk capital requirements of TCIP are funded through commercial reinsurance (currently in excess of US$1 billion) and the build-up of surplus. The TCIP sold more than 2.5 million policies set at market based premium rates (i.e., 20 percent penetration) in 2007, compared to 600,000 covered households when the pool was set up.

  This pool enables the government of Turkey to: i) ensure that all property tax-paying domestic dwellings can purchase affordable earthquake insurance coverage; ii) reduce government's contingent fiscal exposure to recurrent earthquakes by guaranteeing funds for the rehabilitation of public infrastructure and by relieving pressure on the government to provide housing subsidies in the aftermath of an event; and, iii) transfer catastrophe risk to the international reinsurance markets.

  See Annex 5 for additional information.

Source: Gurenko et al. (2006).

Global reinsurers are constantly searching to increase risk diversification. By promoting local risk pools, reinsurers can achieve their aim of further diversification by providing coverage for new pools. Therefore, these vehicles crowd in the private reinsurance industry.

Risk Transfer Vehicles

Donors also can facilitate the pure transfer of catastrophe risks to international reinsurance and capital markets. At the micro level, the World Bank has helped domestic insurance companies to reinsure their weather-based crop insurance portfolio on the international reinsurance markets in India and Malawi (see Annex 5). At the macro level, donors and IFIs can help countries access innovative instruments to transfer their catastrophe risks to the reinsurance markets, the capital markets and the weather derivative markets (see Box 4.8). In particular, catastrophe

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Box 4.7 Livestock Indemnity Insurance Pool in Mongolia

A livestock insurance program was designed and implemented by the government of Mongolia, with the assistance of the World Bank and donors, to protect herders against excessive livestock mortality caused by harsh winters and summer drought. The Mongolian program involves a combination of self-insurance by herders, market-based insurance, and social insurance. The insurance program relies on a livestock mortality-rate index by species in a local region (*soum*). The insurance pays out to individual herders whenever the mortality rate in the *soum* exceeds a specific threshold. Under the program, individual herders receive an insurance payout based on the local mortality, irrespective of their individual losses.

A Livestock Insurance Indemnity Pool (LIIP) was established as a syndicate pooling arrangement that protects participating insurance companies against excessive insured losses, with excess-of-loss reinsurance provided by the government. Insurance companies build collective reserves and the government offers public reinsurance, backed by a US$5 million World Bank contingent credit facility. The viability of index-based livestock insurance is being piloted in 2005–2008 in selected areas across the country. In the second sales season (April–July 2007) about 600,000 animals were insured, representing 14 percent insurance penetration, for a total premium volume of US$120,000. The program is expected to be scaled up nationwide in the future.

See Annex 5 for additional information.

Source: Mahul and Skees (2007).

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bonds allow countries to secure multi-year coverage (usually between 3 and 5 years), while the reinsurance market usually offers only annual coverage, thus sheltering the countries against short-term price cycles.

The intermediation of donors and IFIs can help reduce due diligence concerns from market counterparts in dealing directly with some sovereigns and build capacity in the beneficiary countries, thus initiating the emergence of the innovative risk transfer mechanisms.

Financier

Donors and international financial institutions such as the World Bank can play several roles in financing catastrophe risk insurance programs

Box 4.8 Innovative Sovereign Risk Transfer Mechanisms

Following the successful example of Taiwan in 2003, the government of Mexico, with the technical assistance of the World Bank, issued a US$160 million 3-year **catastrophe bond**, Cat-Mex, to cover against the risk of earthquakes, as part of its risk financing strategy to secure US$450 million available in the aftermath of a disaster. The CAT bond was designed to transfer earthquake risk to investors by allowing the government to not repay the bond principal if a major earthquake hits Mexico. The World Bank is developing a **multi-country catastrophe bond** that would pool the risks of several countries and transfer the diversified risk to capital markets. The World Bank is currently working on a first transaction with two governments.

The World Food Programme (WFP) entered into a humanitarian aid **weather derivative contract** in 2006 with a leading European reinsurer. The contract provided contingency funding in case of extreme drought during Ethiopia's 2006 agricultural season. From March to October 2006, WFP and the government of Ethiopia monitored the drought index, built upon 26 weather stations in Ethiopia, on a daily basis and determined the contract value as the underlying rainfall data was recorded throughout the contract period. The contract was designed to provide a maximum payout of US$7.1 million for an annual premium of US$930,000 (13.1 percent premium rate) financed through a USAID grant. The contract did not trigger in 2006 and was not renewed in 2007.

The World Bank is working on intermediating index-based weather derivatives between low- and middle-income countries and market counterparts. The first pilot is expected to be for the Malawi government, where the World Bank plans to intermediate a rainfall-index linked derivative to provide protection against maize production shortfalls due to severe drought.

The Caribbean Catastrophe Risk Insurance Pool secured US$110 million **parametric reinsurance** (against hurricanes and earthquakes) on good terms before the 2007 hurricane season, in addition to its own reserves.

See Appendix 5 for additional information.

Source: World Bank (2008).

and solutions. Four efficient methods of financing include providing: i) seed funds; ii) contingent debt; iii) short term premium financing; and iv) serving as guarantor of future liabilities.

Seeder of Initial Capital and Reserves

National or regional insurance vehicles can facilitate the transfer of catastrophe risks to the international reinsurance and capital markets. Pools can reduce the contingent liability of governments, allowing them to focus on the poorest households in the aftermath of a disaster, and can also create new business opportunities for the private reinsurance industry. However, these pools need to build initial reserves to retain small losses that are expensive to reinsure and to protect the policyholders against reinsurance price cycles by retaining more risk when the market is hard and by transferring more risk when the market is soft. Although these entities should be run on a commercial basis, it will not always be on a profit-maximizing basis, which may inhibit the availability of private capital that can be used to initialize the structures. For example, pool managers may not be inclined to pay dividends on the seed investments, but instead reinvest those funds by increasing the reserve pool. This would serve the interest of the buyers of insurance (client governments) since it lowers the cost and quantity of risk transferred to the market, or it decreases the required long-term insurance premium rates. Donors can obviate this problem by providing the initial seed capital. However, insurance pools should be set up on an actuarially sound basis so that they will be self-sustaining in the long run.

Provider of Contingent Loans

Contingent loans offer governments the opportunity to smooth the budgetary impact of catastrophe losses by providing a source of emergency liquidity in the aftermath of a disaster, to be repaid over time. Such instruments are usually cheaper than insurance to finance intermediate losses (that is, working layers), but can be used only when there is a fiscal capacity in the government budget. These loans can also be an attractive backstop capacity for newly established catastrophe insurance pools, to help them build up capital during the first few years of operations. The World

Bank provides a new loan product, Catastrophe Risk Deferred Drawdown Option facility, which allows countries to secure immediate liquidity and budget support in the aftermath of a major natural disaster (see Box 4.9).

Provider of Premium Finance

To encourage development and achieve critical mass in some risk financing structures, it may be necessary to assist some participants with their premium payments. However, it is important for actuarially sound, risk-based premiums to be calculated for all plan participants. Temporary premium finance can help countries to overcome their liquidity problems during the first years of operation and was, for instance, provided to four participating islands of CCRIF as well as the TCIP, during its first years of operations, to provide assistance in paying its reinsurance premiums.

Enhancer or Credit Guarantor of Future Payments

The World Bank can also act as a credit enhancer, allowing World Bank clients to benefit from its AAA rating. As part of the catastrophe risk financing strategy of CCRIF, the World Bank placed a catastrophe swap in the capital market, thus allowing CCRIF to secure AAA capital.

Box 4.9 World Bank Contingent Loan

The Catastrophe Risk Deferred Drawdown Option facility (**CAT DDO**), offers IBRD-eligible countries immediate liquidity up to US$ 500 million or 0.25 percent of GDP (whichever is lower) if they suffer a natural disaster such as a hurricane or earthquake. It can be used as a line of credit to provide bridge financing while other sources of funding are being mobilized. Funds are disbursed when a country suffers a natural disaster and declares a state of emergency. The facility has a revolving feature and can be renewed for up to 15 years. Eligible borrowers must have an adequate macroeconomic framework in place at inception or renewal, and a disaster risk management program that is monitored by the World Bank.

   See Annex 5 for additional information.

Source: World Bank (2008).

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World Bank List of Economies

T able A1.1 classifies all World Bank member economies and all other economies with populations of more than 30,000. For operational and analytical purposes, economies are divided among income groups according to 2005 gross national income (GNI) per capita, calculated using the World Bank Atlas method. The groups are: low-income, US$875 or less; lower-middle-income, US$876–3,465; upper-middle-income, US$3,466–10,725; and high-income, US$10,726 or more. Other analytical groups based on geographic regions are also used.

Geographic classifications and data are for low- and middle-income economies only. Low-income and middle-income economies are sometimes referred to as developing economies. The use of the term is convenient; it is not intended to imply that all economies in the group are experiencing similar growth or that other economies have reached a preferred or final stage of development. Classification by income does not necessarily reflect development status.

In the lending category, IDA countries are those that had a per capita income in 2005 of less than US$1,025 and lack the financial ability to borrow from IBRD. IDA loans are deeply concessional—interest-free loans and grants for programs aimed at boosting economic growth and improving living conditions. IBRD loans are noncessional. Blend countries

are eligible for IDA loans because of their low per capita incomes, but are also eligible for IBRD loans because they are financially creditworthy.

Note: Classifications are in effect until July 1, 2007. The World Bank no longer classifies countries by indebtedness level.

Table A1.1 World Bank List of Economies

Economy	Region	Income group	Lending Category
Afghanistan	South Asia	Low-income	IDA
Albania	Europe & Central Asia	Lower-middle-income	Blend
Algeria	Middle East & North Africa	Lower-middle-income	IBRD
American Samoa	East Asia & Pacific	Upper-middle-income	n.a.
Andorra	n.a.	High-income: nonOECD	n.a.
Angola	Sub-Saharan Africa	Lower-middle-income	IDA
Antigua and Barbuda	n.a.	High-income: nonOECD	IBRD
Argentina	Latin America & Caribbean	Upper-middle-income	IBRD
Armenia	Europe & Central Asia	Lower-middle-income	IDA
Aruba	n.a.	High-income: nonOECD	n.a.
Australia	n.a.	High-income: OECD	n.a.
Austria	n.a.	High-income: OECD	n.a.
Azerbaijan	Europe & Central Asia	Lower-middle-income	Blend
Bahamas, The	n.a.	High-income: nonOECD	n.a.
Bahrain	n.a.	High-income: nonOECD	n.a.
Bangladesh	South Asia	Low-income	IDA
Barbados	Latin America & Caribbean	Upper-middle-income	n.a.
Belarus	Europe & Central Asia	Lower-middle-income	IBRD
Belgium	n.a.	High-income: OECD	n.a.
Belize	Latin America & Caribbean	Upper-middle-income	IBRD
Benin	Sub-Saharan Africa	Low-income	IDA
Bermuda	n.a.	High-income: nonOECD	n.a.
Bhutan	South Asia	Low-income	IDA
Bolivia	Latin America & Caribbean	Lower-middle-income	Blend
Bosnia and Herzegovina	Europe & Central Asia	Lower-middle-income	Blend
Botswana	Sub-Saharan Africa	Upper-middle-income	IBRD
Brazil	Latin America & Caribbean	Lower-middle-income	IBRD
Brunei Darussalam	n.a.	High-income: nonOECD	n.a.
Bulgaria	Europe & Central Asia	Lower-middle-income	IBRD
Burkina Faso	Sub-Saharan Africa	Low-income	IDA
Burundi	Sub-Saharan Africa	Low-income	IDA
Cambodia	East Asia & Pacific	Low-income	IDA
Cameroon	Sub-Saharan Africa	Lower-middle-income	IDA
Canada	n.a.	High-income: OECD	n.a.
Cape Verde	Sub-Saharan Africa	Lower-middle-income	IDA

(continued)

Table A1.1 World Bank List of Economies *(continued)*

Economy	Region	Income group	Lending Category
Cayman Islands	n.a.	High-income: nonOECD	n.a.
Central African Republic	Sub-Saharan Africa	Low-income	IDA
Chad	Sub-Saharan Africa	Low-income	IDA
Channel Islands	n.a.	High-income: nonOECD	n.a.
Chile	Latin America & Caribbean	Upper-middle-income	IBRD
China	East Asia & Pacific	Lower-middle-income	IBRD
Colombia	Latin America & Caribbean	Lower-middle-income	IBRD
Comoros	Sub-Saharan Africa	Low-income	IDA
Congo, Dem. Rep.	Sub-Saharan Africa	Low-income	IDA
Congo, Rep.	Sub-Saharan Africa	Lower-middle-income	IDA
Costa Rica	Latin America & Caribbean	Upper-middle-income	IBRD
Côte d'Ivoire	Sub-Saharan Africa	Low-income	IDA
Croatia	Europe & Central Asia	Upper middle-income	IBRD
Cuba	Latin America & Caribbean	Lower-middle-income	n.a.
Cyprus	n.a.	High-income: nonOECD	n.a.
Czech Republic	Europe & Central Asia	Upper-middle-income	n.a.
Denmark	n.a.	High-income: OECD	n.a.
Djibouti	Middle East & North Africa	Lower-middle-income	IDA
Dominica	Latin America & Caribbean	Upper-middle-income	Blend
Dominican Republic	Latin America & Caribbean	Lower-middle-income	IBRD
Ecuador	Latin America & Caribbean	Lower-middle-income	IBRD
Egypt, Arab Rep.	Middle East & North Africa	Lower-middle-income	IBRD
El Salvador	Latin America & Caribbean	Lower-middle-income	IBRD
Equatorial Guinea	Sub-Saharan Africa	Upper-middle-income	IBRD
Eritrea	Sub-Saharan Africa	Low-income	IDA
Estonia	Europe & Central Asia	Upper-middle-income	IBRD
Ethiopia	Sub-Saharan Africa	Low-income	IDA
Faeroe Islands	n.a.	High-income: nonOECD	n.a.
Fiji	East Asia & Pacific	Lower-middle-income	IBRD
Finland	n.a.	High-income: OECD	n.a.
France	n.a.	High-income: OECD	n.a.
French Polynesia	n.a.	High-income: nonOECD	n.a.
Gabon	Sub-Saharan Africa	Upper-middle-income	IBRD
Gambia, The	Sub-Saharan Africa	Low-income	IDA
Georgia	Europe & Central Asia	Lower-middle-income	IDA
Germany	n.a.	High-income: OECD	n.a.
Ghana	Sub-Saharan Africa	Low-income	IDA
Greece	n.a.	High-income: OECD	n.a.
Greenland	n.a.	High-income: nonOECD	n.a.
Grenada	Latin America & Caribbean	Upper-middle-income	Blend
Guam	n.a.	High-income: nonOECD	n.a.
Guatemala	Latin America & Caribbean	Lower-middle-income	IBRD

(continued)

Table A1.1 World Bank List of Economies *(continued)*

Economy	Region	Income group	Lending Category
Guinea	Sub-Saharan Africa	Low-income	IDA
Guinea-Bissau	Sub-Saharan Africa	Low-income	IDA
Guyana	Latin America & Caribbean	Lower-middle-income	IDA
Haiti	Latin America & Caribbean	Low-income	IDA
Honduras	Latin America & Caribbean	Lower-middle-income	IDA
Hong Kong, China	n.a.	High-income: nonOECD	n.a.
Hungary	Europe & Central Asia	Upper-middle-income	IBRD
Iceland	n.a.	High-income: OECD	n.a.
India	South Asia	Low-income	Blend
Indonesia	East Asia & Pacific	Lower-middle-income	Blend
Iran, Islamic Rep.	Middle East & North Africa	Lower-middle-income	IBRD
Iraq	Middle East & North Africa	Lower-middle-income	IBRD
Ireland	n.a.	High-income: OECD	n.a.
Isle of Man	n.a.	High-income: nonOECD	n.a.
Israel	n.a.	High-income: nonOECD	n.a.
Italy	n.a.	High-income: OECD	n.a.
Jamaica	Latin America & Caribbean	Lower-middle-income	IBRD
Japan	n.a.	High-income: OECD	n.a.
Jordan	Middle East & North Africa	Lower-middle-income	IBRD
Kazakhstan	Europe & Central Asia	Lower-middle-income	IBRD
Kenya	Sub-Saharan Africa	Low-income	IDA
Kiribati	East Asia & Pacific	Lower-middle-income	IDA
Korea, Dem. Rep.	East Asia & Pacific	Low-income	n.a.
Korea, Rep.	n.a.	High-income: OECD	IBRD
Kuwait	n.a.	High-income: nonOECD	n.a.
Kyrgyz Republic	Europe & Central Asia	Low-income	IDA
Lao PDR	East Asia & Pacific	Low-income	IDA
Latvia	Europe & Central Asia	Upper-middle-income	IBRD
Lebanon	Middle East & North Africa	Upper-middle-income	IBRD
Lesotho	Sub-Saharan Africa	Lower-middle-income	IDA
Liberia	Sub-Saharan Africa	Low-income	IDA
Libya	Middle East & North Africa	Upper-middle-income	IBRD
Liechtenstein	n.a.	High-income: nonOECD	n.a.
Lithuania	Europe & Central Asia	Upper-middle-income	IBRD
Luxembourg	n.a.	High-income: OECD	n.a.
Macao, China	n.a.	High-income: nonOECD	n.a.
Macedonia, FYR	Europe & Central Asia	Lower-middle-income	IBRD
Madagascar	Sub-Saharan Africa	Low-income	IDA
Malawi	Sub-Saharan Africa	Low-income	IDA
Malaysia	East Asia & Pacific	Upper-middle-income	IBRD
Maldives	South Asia	Lower-middle-income	IDA

(continued)

Table A1.1 World Bank List of Economies *(continued)*

Economy	Region	Income group	Lending Category
Mali	Sub-Saharan Africa	Low-income	IDA
Malta	n.a.	High-income: nonOECD	n.a.
Marshall Islands	East Asia & Pacific	Lower-middle-income	IBRD
Mauritania	Sub-Saharan Africa	Low-income	IDA
Mauritius	Sub-Saharan Africa	Upper-middle-income	IBRD
Mayotte	Sub-Saharan Africa	Upper-middle-income	n.a.
Mexico	Latin America & Caribbean	Upper-middle-income	IBRD
Micronesia, Fed. Sts.	East Asia & Pacific	Lower-middle-income	IBRD
Moldova	Europe & Central Asia	Lower-middle-income	IDA
Monaco	n.a.	High-income: nonOECD	n.a.
Mongolia	East Asia & Pacific	Low-income	IDA
Morocco	Middle East & North Africa	Lower-middle-income	IBRD
Mozambique	Sub-Saharan Africa	Low-income	IDA
Myanmar	East Asia & Pacific	Low-income	IDA
Namibia	Sub-Saharan Africa	Lower-middle-income	IBRD
Nepal	South Asia	Low-income	IDA
Netherlands	n.a.	High-income: OECD	n.a.
Netherlands Antilles	n.a.	High-income: nonOECD	n.a.
New Caledonia	n.a.	High-income: nonOECD	n.a.
New Zealand	n.a.	High-income: OECD	n.a.
Nicaragua	Latin America & Caribbean	Lower-middle-income	IDA
Niger	Sub-Saharan Africa	Low-income	IDA
Nigeria	Sub-Saharan Africa	Low-income	IDA
Northern Mariana Islands	East Asia & Pacific	Upper-middle-income	n.a.
Norway	n.a.	High-income: OECD	n.a.
Oman	Middle East & North Africa	Upper-middle-income	n.a.
Pakistan	South Asia	Low-income	Blend
Palau	East Asia & Pacific	Upper-middle-income	IBRD
Panama	Latin America & Caribbean	Upper-middle-income	IBRD
Papua New Guinea	East Asia & Pacific	Low-income	Blend
Paraguay	Latin America & Caribbean	Lower-middle-income	IBRD
Peru	Latin America & Caribbean	Lower-middle-income	IBRD
Philippines	East Asia & Pacific	Lower-middle-income	IBRD
Poland	Europe & Central Asia	Upper-middle-income	IBRD
Portugal	n.a.	High-income: OECD	n.a.
Puerto Rico	n.a.	High-income: nonOECD	n.a.
Qatar	n.a.	High-income: nonOECD	n.a.
Romania	Europe & Central Asia	Upper-middle-income	IBRD
Russian Federation	Europe & Central Asia	Upper-middle-income	IBRD
Rwanda	Sub-Saharan Africa	Low-income	IDA
Samoa	East Asia & Pacific	Lower-middle-income	IDA

Table A1.1 World Bank List of Economies *(continued)*

Economy	Region	Income group	Lending Category
San Marino	n.a.	High-income: nonOECD	n.a.
São Tomé and Principe	Sub-Saharan Africa	Low-income	IDA
Saudi Arabia	n.a.	High-income: nonOECD	n.a.
Senegal	Sub-Saharan Africa	Low-income	IDA
Serbia and Montenegro	Europe & Central Asia	Lower-middle-income	Blend
Seychelles	Sub-Saharan Africa	Upper-middle-income	IBRD
Sierra Leone	Sub-Saharan Africa	Low-income	IDA
Singapore	n.a.	High-income: nonOECD	n.a.
Slovak Republic	Europe & Central Asia	Upper-middle-income	IBRD
Slovenia	n.a.	High-income: nonOECD	n.a.
Solomon Islands	East Asia & Pacific	Low-income	IDA
Somalia	Sub-Saharan Africa	Low-income	IDA
South Africa	Sub-Saharan Africa	Upper-middle-income	IBRD
Spain	n.a.	High-income: OECD	n.a.
Sri Lanka	South Asia	Lower-middle-income	IDA
St. Kitts and Nevis	Latin America & Caribbean	Upper-middle-income	IBRD
St. Lucia	Latin America & Caribbean	Upper-middle-income	Blend
St. Vincent and the Grenadines	Latin America & Caribbean	Upper-middle-income	Blend
Sudan	Sub-Saharan Africa	Low-income	IDA
Suriname	Latin America & Caribbean	Lower-middle-income	IBRD
Swaziland	Sub-Saharan Africa	Lower-middle-income	IBRD
Sweden	n.a.	High-income: OECD	n.a.
Switzerland	n.a.	High-income: OECD	n.a.
Syrian Arab Republic	Middle East & North Africa	Lower-middle-income	IBRD
Tajikistan	Europe & Central Asia	Low-income	IDA
Tanzania	Sub-Saharan Africa	Low-income	IDA
Thailand	East Asia & Pacific	Lower-middle-income	IBRD
Timor-Leste	East Asia & Pacific	Low-income	IDA
Togo	Sub-Saharan Africa	Low-income	IDA
Tonga	East Asia & Pacific	Lower-middle-income	IDA
Trinidad and Tobago	Latin America & Caribbean	Upper-middle-income	IBRD
Tunisia	Middle East & North Africa	Lower-middle-income	IBRD
Turkey	Europe & Central Asia	Upper-middle-income	IBRD
Turkmenistan	Europe & Central Asia	Lower-middle-income	IBRD
Uganda	Sub-Saharan Africa	Low-income	IDA
Ukraine	Europe & Central Asia	Lower-middle-income	IBRD
United Arab Emirates	n.a.	High-income: nonOECD	n.a.
United Kingdom	n.a.	High-income: OECD	n.a.
United States	n.a.	High-income: OECD	n.a.
Uruguay	Latin America & Caribbean	Upper-middle-income	IBRD

(continued)

Table A1.1 World Bank List of Economies *(continued)*

Economy	Region	Income group	Lending Category
Uzbekistan	Europe & Central Asia	Low-income	Blend
Vanuatu	East Asia & Pacific	Lower-middle-income	IDA
Venezuela, RB	Latin America & Caribbean	Upper-middle-income	IBRD
Vietnam	East Asia & Pacific	Low-income	IDA
Virgin Islands (U.S.)	n.a.	High-income: nonOECD	n.a.
West Bank and Gaza	Middle East & North Africa	Lower-middle-income	n.a.
Yemen, Rep.	Middle East & North Africa	Low-income	IDA
Zambia	Sub-Saharan Africa	Low-income	IDA
Zimbabwe	Sub-Saharan Africa	Low-income	Blend

n.a. = not applicable.
Source: The World Bank (2006). See text references.

Reference Catastrophe Losses

Table A2.1 List of Catastrophe Direct Losses

		US$ Million			% 2005 GDP		
	Peril	PML 50	PML 100	PML 250	PML 50	PML 100	PML 250
Montserrat	HU	34	67	124	117.2	231.0	427.6
Cayman Islands	HU	1,082	2,994	5,937	77.8	215.2	426.8
Turks and Caicos Islands	HU	204	442	818	88.3	191.3	354.1
St. Kitts and Nevis	HU	249	609	1,295	62.3	152.3	323.8
St. Vincent and the Grenadines	HU	201	527	1,140	50.3	131.8	285.0
Haiti	HU	2,571	4,648	8,395	73.5	132.8	239.9
Grenada	HU	93	348	953	23.3	87.0	238.3
Montserrat	EQ	24	40	65	82.8	137.9	224.1
Jamaica	HU	4,734	10,746	19,245	53.2	120.7	216.2
Barbados	HU	1,081	2,830	6,025	38.6	101.1	215.2
Dominica	HU	158	331	614	52.7	110.3	204.7
Anguilla	HU	59	122	226	49.2	101.7	188.3
Honduras	EQ	3,085	7,592	14,836	38.7	95.2	186.0
Antigua and Barbuda	HU	418	832	1,424	46.4	92.4	158.2
Belize	HU	507	875	1,423	46.1	79.5	129.4
The Bahamas	HU	1,282	3,953	6,682	24.2	74.6	126.1
Haiti	EQ	628	1,255	4,322	17.9	35.9	123.5
Jamaica	EQ	3,507	5,502	10,760	39.4	61.8	120.9
Nicaragua	EQ	738	1,820	4,313	15.0	37.1	87.8

(*continued*)

Table A2.1 List of Catastrophe Direct Losses *(continued)*

		US$ Million			% 2005 GDP		
	Peril	PML 50	PML 100	PML 250	PML 50	PML 100	PML 250
Albania	EQ	2,973	4,640	6,448	35.5	55.4	77.0
Grenada	EQ	94	160	304	23.5	40.0	76.0
Ecuador	EQ	1,062	10,463	21,465	2.9	28.9	59.2
Macedonia, FYR	EQ	348	981	3,235	6.0	17.0	56.1
Antigua and Barbuda	EQ	175	299	502	19.4	33.2	55.8
Belize	EQ	172	317	604	15.6	28.8	54.9
St. Vincent and the Grenadines	EQ	85	126	212	21.3	31.5	53.0
Barbados	EQ	487	809	1,459	17.4	28.9	52.1
St. Lucia	EQ	158	226	356	19.8	28.3	44.5
Chile	EQ	3,812	20,428	50,587	3.3	17.7	43.9
St. Kitts and Nevis	EQ	56	88	168	14.0	22.0	42.0
Anguilla	EQ	15	23	49	12.5	19.2	40.8
Bermuda	HU	612	1,035	1,804	13.6	23.0	40.1
Guatemala	EQ	2,252	6,079	12,595	7.1	19.2	39.8
St. Lucia	HU	94	221	301	11.8	27.6	37.6
Trinidad and Tobago	EQ	628	1,255	4,322	5.0	10.0	34.6
El Salvador	EQ	1,770	3,770	5,364	10.4	22.2	31.6
Pakistan	EQ	15,215	25,537	31,009	13.7	23.1	28.0
British Virgin Islands	HU	168	351	641	6.7	14.1	25.7
Cayman Islands	EQ	33	113	269	2.4	8.1	19.3
Dominica	EQ	19	29	56	6.3	9.7	18.7
Philippines	EQ+HU	6,906	10,274	16,980	7.0	10.5	17.3
Trinidad and Tobago	HU	140	687	1,977	1.1	5.5	15.8
Turks and Caicos Islands	EQ	7	16	35	3.0	6.9	15.2
India	EQ+HU	34,000	50,090	107,615	4.3	6.4	13.7
Japan	EQ	—	—	500,000	—	—	11.1
Turkey	EQ	16,006	27,347	35,932	4.4	7.5	9.9
Peru	EQ	1,330	4,480	7,278	1.7	5.7	9.3
Ecuador	EQ	270	780	2,861	0.7	2.2	7.9
Colombia	EQ	1,390	3,250	9,595	1.1	2.7	7.8
British Virgin Islands	EQ	38	65	169	1.5	2.6	6.8
Indonesia	EQ	3,392	5,987	12,437	1.2	2.1	4.3
Mexico	EQ	12,190	17,001	25,555	1.6	2.2	3.3
Jordan	EQ	54	163	401	0.4	1.3	3.1
United States	EQ	—	—	300,000	—	—	2.4

(*continued*)

Table A2.1 List of Catastrophe Direct Losses *(continued)*

		US$ Million			% 2005 GDP		
	Peril	PML 50	PML 100	PML 250	PML 50	PML 100	PML 250
United States	HU	—	—	300,000	—	—	2.4
Venezuela	EQ	916	1,820	3,052	0.7	1.3	2.2
Belgium	WS	—	—	5,000	—	—	1.4
United Kingdom	WS	—	—	30,000	—	—	1.4
China	EQ	5,244	12,374	26,353	0.2	0.6	1.2
Japan	TY	—	—	50,000	—	—	1.1
Netherlands	WS	—	—	5,000	—	—	0.8
France	WS	—	—	15,000	—	—	0.7
Argentina	EQ	50	190	1,116	0.0	0.1	0.6
Germany	WS	—	—	15,000	—	—	0.5

EQ = earthquake; HU = hurricane; TY = typhoon; WS = winter storm; — = not available.
Source: Swiss Re (2007), EQECAT (2007), IADB (2006), World Bank (2007). See text references.

Catastrophe Risk Modeling

Introduction: Using Modeling to Manage Risk

The first step in any risk management process is quantifying the risk to be managed, usually through an analysis of historical loss information. However, the assessment of catastrophe risk differs significantly from traditional insurance risks such as automobile collision, fire, or life (mortality). These risks are characterized as high-frequency, low-severity (to the insurer, not to the insured) events, and usually affect only one or several risks per occurrence and historical data are usually sufficient to estimate the likelihood of future losses, in terms of both frequency and severity. However, the risk of natural disasters is low-frequency and high-severity. The severity is high because the causative events are large-scale earthquakes or meteorological phenomena affecting thousands of square kilometers, sometimes impacting hundreds of thousands of properties. And since the events are infrequent, historical data are usually insufficient to estimate future monetary losses. Risk assessment needs to be prospective, anticipating scientifically credible events that could happen in the future, but have not yet taken place.

Using current computer technology and the latest earth- and meteorological-science information, specialist consulting companies have developed models of earthquakes and other perils, such as hurricanes,

cyclones, and floods. These models are now deemed essential by insurers, reinsurers, and government agencies around the world to assess the risk of loss from catastrophic events.

Since model estimates of event severity and frequency, and of consequent losses, involve some uncertainty, models are usually constructed using probabilistic formulations that can incorporate this uncertainty into the risk assessment.

Methodology

A typical probabilistic earthquake risk model used by insurers has the five following components, as shown in Figure A3.1.

Stochastic module: The stochastic module describes the physical parameters, the location, and the frequency of stochastic events. It generates thousands of stochastic events based on historical data and experts' opinions.

Figure A3.1 Probabilistic Catastrophe Risk Model Modules
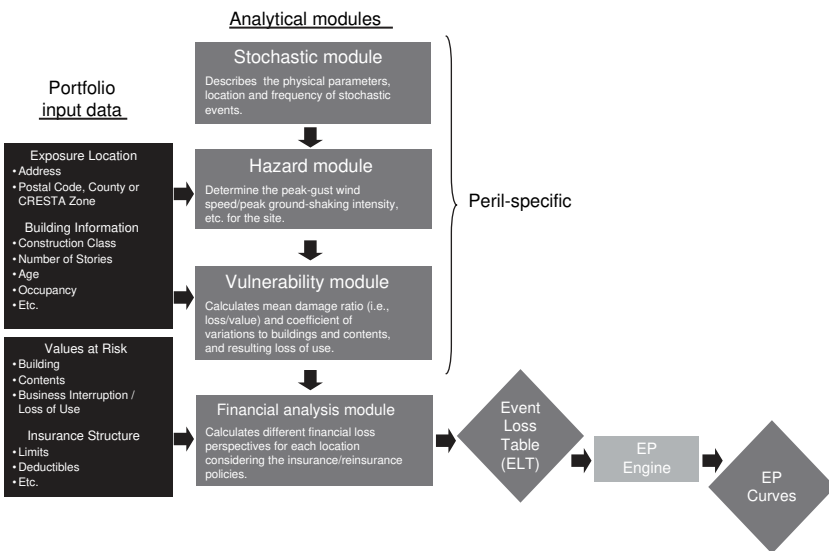
Source: Authors, from catastrophe risk modeling firms.

Hazard module: The hazard module defines the frequency and severity of earthquakes at a specific location within the region of interest. This is done by analyzing historical frequencies and reviewing scientific studies performed on the severity and frequencies in the region of interest. Relevant parameters used to define the hazard include location of earthquake faults, their geometry (length, depth, and angle of dip), recurrence frequency, and attenuation of ground motion (the amount of ground shaking at a specific distance from the earthquake source). In addition, conditions of site soils need to be included, because variations in local soils can either amplify or reduce the impact of ground shaking. Once the hazard parameters for each earthquake source are established, stochastic event sets are generated, which define the frequency and severity (hazard) of thousands of stochastic earthquake events. The hazard is defined via an instrumental ground-shaking measure such as peak ground acceleration, peak ground velocity, spectral acceleration, or a qualitative intensity scale, such as Modified Mercalli Intensity (MMI).

The assets at risk—which for an insurance portfolio represents the exposure location and the building information (for example, replacement value, type of construction)—are used in combination with the hazard module. Property location is essential, since distance from the insured property to each earthquake source greatly influences the level of ground shaking that can be expected in a future earthquake. And with the location established, local soil information can be incorporated to better estimate likely ground shaking.

Vulnerability module: Vulnerability is measured by the damage factor (D), which is the ratio of the repair cost and the total insured value (TIV). Depending on the type of structural system (for example, frame or walls), the method and time of construction, and the construction materials, specific vulnerability functions are defined. Vulnerability functions typically have been developed based on analysis of claims data from disasters throughout the world, engineering-based analytical studies, expert opinions, testing, or a combination of all of these. Vulnerability functions have been developed for structural damage, as well as for business interruption losses and damage to contents.

Financial analysis module: This module calculates different financial loss perspectives for each location considering the insurance/reinsurance policies. An important element of this calculation is the insurance

information, which is expressed through deductibles (d), limits (l), and total insured value (TIV). The quality of the insurance data can vary from crude to very detailed, which will affect the level of uncertainty in the estimation of losses. The gross loss at a property or group of properties is a function of damage and the insurance information, d, l, and TIV, relevant to the properties. This produces a probability distribution of loss. The mean, standard deviation, and the loss exceedance curve are estimated from the loss distribution. Net loss to a primary insurer and losses to reinsurers are further calculated based on the appropriate insurance information relevant to facultative reinsurance and treaties. In all cases, the relevant probabilistic information (for example, the expected loss of a treaty layer) is based on gross loss data and the relationship between the loss of interest (for example, treaty layer loss) and gross loss.

Risk Metrics

Risk management relies on accurate risk measures. Earthquake risk model outputs are specifically designed to quantify common measures of catastrophe risk used for insurance risk management. Models can produce loss estimates for one earthquake scenario (historical or hypothetical). Risk metrics for such events are *mean loss* and *standard deviation of loss*. Scenario results usually help an insurer understand the loss potential from a repeat of a historical earthquake or losses from credible future events.

However, for a complete picture of the risk, a probabilistic analysis is required. This analysis takes into account the losses and frequencies of occurrence of all foreseeable earthquake magnitudes on all faults and seismic zones affecting each site in the portfolio. One common risk metric is the *average annual loss*, which is an expression of the long-term (for example, 1,000 years) annual expected loss (AEL). It can be calculated for the entire portfolio, or by rating zone, asset class (for example, hospitals, schools, and so on), or individual risk. Hence it provides an idea of the relative risk, especially when the risk is normalized by dividing by the replacement cost to produce a rate (usually expressed per million) within the portfolio. The AEL is sometimes called the "pure risk"

Figure A3.2 Loss Exceedance Curve
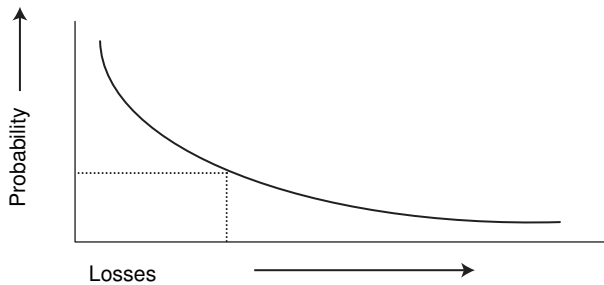
Source: Authors.

premium, and represents the minimum premium that must be paid by an insured to cover future losses. The actual premium is usually larger, to cover administrative costs and profit, and to provide a "risk charge" for the variance in year-to-year claims.

As noted above, actual claims losses will not occur in a uniform pattern. Some years may have few or no losses, followed by a severe event. And every 50–100 years, a major earthquake may cause enormous damage and loss. Because of this varying pattern of losses, the return period loss estimate (sometimes mistakenly called the PML or Probable Maximum Loss) is calculated. This risk measure is produced using the exceedance probability (EP), and represents the expected loss severity based on likely occurrence, such as the 1-in-50-year loss or the 1-in-100-year loss. An example of such a curve is shown in Figure A3.2. This curve quantifies the probability that the largest per occurrence loss, per year, exceeds a value x, as a function of loss.

Catastrophe Risk Financing Projects Supported by the World Bank and Donors

The following tables are current as of March 2008.

Table A4.1 Property Catastrophe Insurance for Homeowners

Project	Country	Date implemented	Status	Description	Volume	Donor/IFI role
Turkish Catastrophe Insurance Pool	Turkey	2000	Completed	Insurance pool offering earthquake indemnity-based insurance to middle-income homeowners. The pool can sustain a 1-in-250 year event through reserves and reinsurance capacity.	2.5 million homeowners (17% insurance penetration) insured under this program in 2006. The annual premium volume is $150 million.	1. Initial capacity building funded under a WB investment loan. 2. Contingent debt of $180 million to speed up the building of reserves. 3. Funding of the reinsurance premium (loan) the first two years.
Global Index Reinsurance Facility	World	n.a.	Under preparation	Multi-donor trust fund linked to a specialist index reinsurance company, which will promote (agriculture and non-agriculture) index-based insurance in developing countries.	n.a.	MDTF managed by WB, including EUR 25 million from the European Union for ACP countries for technical assistance and premium subsidies.
Catastrophe insurance	Romania	n.a.	Under preparation	Compulsory indemnity-based insurance against earthquakes, floods, and landslides, sold by insurers that are members of the Catastrophe Insurance pool.	n.a. (compulsory law to be enacted by the parliament)	Initial capacity building funded under a WB investment loan.
China Catastrophe Risk Assessment	China	n.a.	Under preparation	CAT risk assessment analysis for rapid-on set disasters, which may lead to the development of a national catastrophe insurance pool.	N/A	Technical assistance provided by WB

Table A4.2 Agricultural Insurance

Project	Country	Date implemented	Status	Description	Volume	Donor/IFI role
Index-based live-stock insurance	Mongolia	2005	Ongoing (pilot)	Index-based insurance program to protect Mongolian herders against livestock mortality. The program includes a voluntary commercial product, sold by domestic insurance companies, and a voluntary social product. A Livestock Insurance Indemnity Pool (LIIP) was set up to ring fence the livestock mortality losses. The LIIP reinsured by the government, backed by a $5 million IDA credit. The project has been piloted in three provinces since 2005.	In 2007, 3700 herders purchased insurance for about 600,000 animals (10% penetration rate) for a premium volume of $110,000.	1. Technical assistance financed by WB, Japanese grant (PHRD) and the Trust Fund First Initiatives. 2. $5 million contingent facility (IDA credit) to be triggered if the LIIP reserves are insufficient to pay all claims in a disaster year. 3. No direct premium subsidies

(*continued*)

Table A4.2 Agricultural Insurance (*continued*)

Project	Country	Date implemented	Status	Description	Volume	Donor/IFI role
Weather-based crop insurance	India	2003	Ongoing	The public crop insurance company AICI and private insurers (e.g., ICICI Lombard, IFCO Tokyo) sell weather- (parametric) based insurance product against drought and excess of rainfall.	700,000 farmers insured in 2007 for a total premium volume of US$30 million.	Non-lending technical assistance from WB Direct premium subsidies.
Weather insurance	Malawi	2005	Ongoing	Index-based weather insurance products for farmers to strengthen agricultural lending in Malawi.	In 2007 $300,000 of weather-related credit risk has been insured by Insurance Association of Malawi and reinsurance has been accessed for first time. The market is expected to grow rapidly in size in next few years as product is mainstreamed into Malawi agricultural credit system.	Non-lending technical assistance to Malawi private sector (MFI, banking, insurance) by WB.

| Weather insurance | Central America (Guatemala, Honduras, and Nicaragua) | 2008 | Ongoing | Supporting market development for agricultural weather insurance at farmer level, through three components: 1) public policy and regulatory framework; 2) information platform and weather data access to the industry; and 3) pilot projects for training purposes. | First transactions planned for 2008–9 agricultural season. Expected transactions of about $5 million for the first year, with increasing volumes as project scales up. | Non-lending technical assistance co-financed by Inter-American Development Bank (IADB), Central American Bank for Economic Integrations (CABEI), and the World Bank. The project is led by the Latin American Federation of Insurance Companies (FIDES), with the participation of insurers associations in each country. |
| Weather insurance | Thailand | 2007 | Ongoing | Index-based weather insurance for Bank for Agriculture and Agricultural Cooperatives (BAAC) farmer borrowers. | First Pilot Year (2007): $3,000 in premiums for $42,000 in sum insured. Market, especially for flood risk, is expected to grow rapidly due to large BAAC client outreach and stakeholder interest. | Non-lending technical assistance to General Insurance Association, Thai Re and BAAC by WB Product development research is being carried out for flood-index insurance for rice by WB. |

(*continued*)

Table A4.2 Agricultural Insurance (*continued*)

Project	Country	Date implemented	Status	Description	Volume	Donor/IFI role
Weather insurance	Ethiopia	2007	Ongoing	WB Financial Sector Capacity Building loan includes weather insurance component to focus on increasing infrastructure, training, and demand for index-based weather insurance components targeted to farmers.	$1 million loan over 5 years	Component of Financial Sector Capacity Building Project/Loan with the government of Ethiopia, with Technical assistance from WB.
Weather insurance (micro level)	Senegal	n.a.	Under preparation	Pilot drought index-based insurance for peanut producers	n.a.	Technical assistance from WB
Weather insurance (micro level)	Kenya	n.a.	Under preparation	Joint program with the Financial Sector Deepening Trust (FSDT) to provide weather insurance to farmers. Cooperative Insurance	n.a.	Technical assistance from WB. Financial support for project management and market research by the FSDT.

				Company is looking for partners in the financial sector to collaborate on rolling out weather insurance products. Working with the insurance company and FSDT in 2007, a test run of a pilot was carried out.		
Agriculture insurance	Nepal	n.a.	Under preparation	Technical assistance requested by the government of Nepal for the development of agriculture insurance (crop and livestock).	n.a.	Technical assistance from WB, funded by GFDRR
Agriculture insurance	Bangladesh	n.a.	Under preparation	Technical assistance requested by the government of Bangladesh for the development of index-based crop insurance (including flood).	n.a.	Technical assistance from WB, funded by GFDRR

Table A4.2 Agricultural Insurance (*continued*)

Project	Country	Date implemented	Status	Description	Volume	Donor/IFI role
Flood index insurance	Vietnam	n.a.	Under preparation	Flood index crop insurance product designed to hedge the crop loan portfolio of the agricultural bank VBARD.	n.a.	Project funded by ADB.
Index-based rice insurance	Indonesia	n.a.	Under preparation	Technical assistance requested by the government of Indonesia to pilot weather based rice insurance.	n.a.	Technical assistance from WB, funded by GFDRR

Table A4.3 Sovereign Catastrophe Risk Insurance

Project	Country	Date implemented	Status	Description	Volume	Donor/IFI role
Catastrophe bond	Mexico	2006	Completed	The sovereign disaster fund FONDEN issued a three year catastrophe bond, the Cat-Mex bond, to transfer earthquake risk to investors.	US$160 million catastrophe bond issued at a LIBOR + 2.35% (Class A) and LIBOR + 2.3% (Class B). This corresponds to a multiple of 2.5.	Technical assistance provided by the WB and the Trust Fund First Initiatives.
Weather derivative	Ethiopia	2006	Completed (First Phase)	Weather derivative purchased by UN World Food Programme (WFP) to secure contingency funding for livelihood-saving emergency relief operations to protect vulnerable populations in case of severe drought in Ethiopia.	First Phase (pilot): Parametric drought coverage of $7.1, protecting 60,000 vulnerable households, for a $930k premium through competitive tender (13% ROL).	First Phase: 1. Transaction arranged by WFP, with TA from WB. 2. Premium paid by USAID.
Caribbean Catastrophe Risk Insurance Facility	Caribbean	2007	Ongoing	The mutual insurance pool offers parametric insurance against earthquakes and hurricanes to Caribbean governments.	16 countries purchased insurance for a total of coverage of $500 million. Total premium volume is about $20 million.	1. Technical assistance financed by WB and Japanese trust fund (PHRD). 2. $47 million contributions from WB, UK,

Table A4.3 Sovereign Catastrophe Risk Insurance (*continued*)

Project	Country	Date implemented	Status	Description	Volume	Donor/IFI role
				The facility secured $110 million on the reinsurance and capital markets, which with its own reserves allows it to sustain a 1-in-1,000-year event.		Canada, and France will cover initial operating expenses (including reinsurance premium) and insurance payouts. 3. Insurance premiums of 4 OECS countries (St. Lucia, Dominica, Grenada, and St. Vincent & the Grenadines) and Haiti financed for three years through an IDA credit and an IDA grant, respectively.
Contingent credit facility	Colombia	2005	Ongoing	Contingent loan as part of a $250 million APL for Natural Disaster Vulnerability Reduction Program with the government of Colombia.	$150 million contingent debt to the government of Colombia, to be disbursed against a list of positive imports in the aftermath of a natural disaster (declaration of emergency by the central government)	Technical assistance provided by the WB.

| Catastrophe swap | Caribbean | 2007 | Ongoing | The World Bank Treasury has arranged for CCRIF to transfer a portion of the catastrophe risk to the capital markets through a swap transaction. | $20 million catastrophe swap in the top layer. | CCRIF paid fees for service to the WB treasury. |
| Catastrophe Risk Deferred Drawdown Option facility (CAT DDO) | IBRD clients | 2008 | Ongoing | Offers middle-income countries immediate liquidity up to USD500 million or 0.25% of GDP (whichever is less) if they suffer a natural disaster. It offers bridge financing while other sources of funding are being mobilized. Funds will be disbursed when a country suffers a natural disaster and declares a state of emergency. | More than 10 countries already expressed interest | Contingent loan offered by WB |

(*continued*)

Table A4.3 Sovereign Catastrophic Risk Insurance (*continued*)

Project	Country	Date implemented	Status	Description	Volume	Donor/IFI role
				Countries signing up for the facility must have a hazard risk management program in place that is monitored by the WBG and an adequate macroeconomic framework		
Pacific Catastrophic Risk Pool Initiative	South Pacific Islands	n.a.	Under preparation	Collective reserve fund backed by reinsurance against catastrophe losses (earthquakes, tropical cyclones) for Pacific islands.	n.a.	Technical assistance (feasibility study) provided by WB and funded by GFDRR.
Multi-Country Catastrophe Bond	WB clients	n.a.	Under preparation	Multi country catastrophe bond issued with SPV. The WB Treasury will be the arranger and the convening agent.	n.a	Catastrophe bonds issued on commercial terms. Technical assistance provided by WB Treasury and partly funded by GFDR.

| Central America Cata-strophic Risk Insur-ance Pool | Central American countries | n.a. | Under preparation | Collective reserve fund backed by reinsur-ance against catastrophe losses for Central American countries. Similar to CCRIF. | n.a. | Technical assistance (feasibility study) provided by WB and funded by GFDRR. |
| Weather derivatives | Ethiopia | n.a. | Under preparation | Developing a compre-hensive ex-ante country risk manage-ment framework for livelihood security in Ethiopia, including linkage to WB-supported Productive Safety Net Project, indexed contingent grants, and weather risk transfer component. | n.a. | Joint initiative between govern-ment of Ethiopia, WFP, WB and DFID |

(*continued*)

Table A4.3 Sovereign Catastrophic Risk Insurance (*continued*)

Project	Country	Date implemented	Status	Description	Volume	Donor/IFI role
Weather derivatives	Malawi	n.a.	Under preparation	Weather derivative contract to transfer the financial risk of national drought that adversely impacts national maize production and the government's budget. Part of Malawi's agricultural risk management framework for food security, complementing and enhancing price risk management tools the government has in its portfolio to financially manage this maize production risk using ex-ante market-based instruments and other investments (e.g., warehouse receipts, etc.)	First transaction planned for 2008/9 agricultural season, dry run in 2007/8. Expected transaction size: $10 million a year for 4 years.	1. Technical assistance from CRMG/ARD (WB). 2. Premium financing and Malawi weather network upgrade through donor budget support (DFID, USAID, EU)

Source for Tables A4.1–3: World Bank Catastrophe Risk Insurance Working Group.

Some Recent Catastrophe Risk Financing Initiatives Supported by the World Bank and Donors

Property Catastrophe Insurance Programs for Homeowners

With an increasing concentration of people and assets in high risk zones (for example, coastal areas), cities are becoming more vulnerable. This is especially true in developing countries due to poor land management and weak enforcement of building codes, when they exist. Property catastrophe insurance can financially shelter households against losses caused by natural disasters. Insurance is particularly effective when used in conjunction with risk-mitigation activities (for example, retrofitting) and better control of land use. Catastrophe insurance can also contribute to the enforcement of building codes through commercial arrangements with independent engineering firms that can be retained to certify the construction quality of new residential dwellings. The availability of property catastrophe insurance, for buildings that were built according to code, enables the government to preserve its resources to fund reconstruction of critical infrastructure and meet social obligations to the poor and disadvantaged after a disaster because the government would not need to significantly intervene in the housing sector. Even if the basic conditions for the emergence of an insurance market exist, there are two divergent theories for government intervention in catastrophe insurance markets.

The first argument for government intervention emphasizes the high cost and limited supply of private capital (Cutler and Zeckhauser 1999,

Froot 2007). According to proponents of this view, a shortage of risk-bearing capital leads to an inadequate supply of insurance capacity. This keeps prices high relative to projected losses for low-frequency, high-severity events, which is in turn socially suboptimal. Provision of government-subsidized insurance may be counterproductive, but proponents of government-sponsored insurance contend that government, with its vast capacity to tax and borrow, has an advantage over private insurers in bearing catastrophe risk. Unlike private insurers, governments do not need to hold explicit capital to pay off claims and avoid bankruptcy, since they can borrow the required funds. To free insurers from the costly burden of holding huge amounts of capital, proponents suggest that the government acts as a residual provider of reinsurance for "mega-catastrophes." Government-provided insurance should be priced to cover expected losses plus a reasonable risk premium to provide proper incentives for land use and other issues involving resource allocation. In certain cases, where the private market is not functioning properly, the government may be able to set economically justified premiums that are lower than those charged by the imperfect private insurance market.

The second argument emphasizes that the biggest barrier to an adequate supply of insurance, especially immediately after a catastrophe, is insurers' high level of uncertainty regarding the frequency and severity of future losses. After Hurricane Andrew, the Northridge earthquake, and the World Trade Center attacks, insurers were not certain that they could assess the risks they were being asked to assume. Without such knowledge, they were unwilling to commit capital by underwriting the coverage. In time, insurers usually are able to recalibrate their estimates and reenter the market. Proponents of this view argue that governments should intervene to supply insurance while insurers reassess risk after a disaster, but insurers argue that the government's role should be temporary.

There is little doubt that private insurance markets go through periods where they are capital-constrained, providing a possible rationale for government intervention. For many low- and middle-income countries, the most significant problem is the inadequate development of the domestic insurance market. Mounting uninsured losses from natural disasters have pressed governments in disaster-prone countries and regions to look for practical solutions for catastrophe risk management,

Box A5.1 Catastrophe Insurance Pools

Catastrophe insurance pools provide immediate post-disaster financing pro-portionate to incurred losses. Although the international community (donors, multilateral development banks) usually provides funds in the aftermath of natural disasters, the humanitarian aid offsets less than 10 percent of coun-tries' disaster losses. Moreover, ex-post reconstruction funding is generally slow to mobilize (4 –12 months) and is often allocated inefficiently.

Catastrophe insurance pools can be designed to guarantee both afford-able and stable insurance premiums, with supply of coverage, although the premiums should reflect the risk exposure. If the premiums remain high, governments of developing countries would be unable to avail themselves of the offered protection. To keep coverage costs down, developing coun-tries must be insulated from the volatility of the reinsurance pricing cycle, or this unpredictability must somehow be dampened.

Growing empirical evidence suggests that catastrophe insurance pools have indeed been able to diversify intertemporally to lessen the volatility of the reinsurance pricing cycle and to offer stable premiums to insured coun-tries. By pooling risks across individual countries or regions, catastrophe insurance pools generate diversification benefits that are reflected in reduced insurance premiums. Aggregation also allows small buyers to reach a critical mass, thus becoming more attractive to the reinsurance and capi-tal markets. By accumulating reserves over time, pools are able to increase risk retention, which allows further reduction in insurance premiums.

Source: Authors, from Gurenko et al. (2006).

and have spurred the formation of national and regional catastrophe insurance programs.

In countries with inadequate local catastrophe insurance markets, one option is for governments and IFIs to provide ex-ante disaster funding to create a market, as was done in Turkey, where the Turkish Catastrophe Insurance Pool (TCIP) was established in the aftermath of the Marmara earthquake in 2000, with assistance from The World Bank. The TCIP was established because Turkey's private insurance market had failed to provide adequate quantities of catastrophe property insurance for homeowners, particularly to protect private dwellings against earthquake risk. Turkey's insurers were also viewed as undercapitalized and poorly managed. Lacking

capital and technical capacity, sole reliance on the domestic market was not necessarily the best solution to the problem of providing catastrophe coverage throughout the country. The Turkish experience offers a model for how proxy direct insurance markets can be created.

The government of Turkey, with the help of the World Bank, investigated numerous successful national catastrophe risk management programs in eight different countries. The design and coverage features of these insurance programs vary, but the underlying rationale for their introduction has been the same: to address the challenges faced by the private insurance markets in insuring against the risk of natural disasters. Table A5.1 lists the best known of these programs. They include the Florida Hurricane Catastrophe Fund (FHCF), the California Earthquake Authority (CEA), the New Zealand Earthquake Commission (EQC), the CatNat program in France, the Taiwan Residential Earthquake Insurance Pool (TREIP), and the Japanese Earthquake Reinsurance Company (JER).

Table A5.1 Government-Sponsored Catastrophe Insurance Programs

Name of the fund	Country	Year established	Risk covered
Catastrophe Naturelles (CatNat)	France	1982	All natural disasters except windstorm, ice, and snow
Japanese Earthquake Reinsurance Company (JER)	Japan	1966	Earthquake, tsunami, volcanic damage
Earthquake Commission (EQC)	New Zealand	1994	Earthquake, tsunami, volcanic damage, landslide
Norsk Naturskadepool	Norway	1980	Floods, storms, earthquakes, avalanches, tidal waves
Consorcio de Compensacion de Seguros	Spain	1954	Earthquakes, tidal waves, floods, volcanic eruptions, cyclonic storms
Florida Hurricane Catastrophe Fund (FHCF)	USA	1993	Windstorm during a hurricane
Hawaii Hurricane Relief Fund (HHRF)	USA	1993	Windstorm during a hurricane
California Earthquake Authority (CEA)	USA	1996	Earthquake
Taiwan Residential Earthquake Insurance Pool (TREIP)	Taiwan, China	2002	Earthquake

Note: None of the above-mentioned insurance programs insures public infrastructure assets or provides or finances emergency relief services.
Source: Gurenko, et al. (2006).

A closer look at the above-mentioned national insurance programs reveals some major similarities. Most programs: i) tend to focus on providing coverage against a specific natural hazard; ii) tend to have a regional focus; iii) provide coverage mainly for dwellings and contents; iv) have premium rates that tend to reflect the characteristics of the risk, with an element of solidarity involved; v) as a rule, receive no direct government subsidies; vi) to various degrees, encourage retrofitting and safer construction practices by offering premium discounts, although mitigation is not typically their major focus; and, vii) rely on distribution and servicing capabilities of private primary insurance companies and their agents (Gurenko and Lester 2004).

Table A5.2 provides an overview of key design choices available to policymakers and insurance practitioners involved in the creation of national catastrophe insurance programs.

Based on this review, the Turkish government decided that the program would operate as a catastrophic risk-transfer and risk financing mechanism that limits the government's financial exposure to future natural disasters by absorbing up to US$1 billion of risk exposure from Turkish homeowners. Under the program, compulsory earthquake

Table A5.2 Catastrophe Program Design Variables

Program variables	Design choices
Management	Public/private
Governance	Public/private/mixed
Funding	Public/private/mixed
Insurance vehicle	Insurance pool/reinsurance pool/insurance companies
Coverage	Buildings; contents; business interruption
Lines of business	Residential/commercial (SMEs)
Rates	Flat/risk-based/mitigation incentives
Distribution	Insurance companies/alternatives
Retentions by insurance companies	Zero to risk-based solvency margin
Geographical coverage	National/regional/inter-country
Participation	Compulsory/voluntary
Reinsurance	Private/public mix

Source: Gurenko, et al. (2006).

coverage was introduced for all property tax-paying dwellings. The government aimed at creating a pool in which sufficient reserves could be accumulated over time, which would make the government less financially vulnerable to losses caused by future earthquakes. The key objectives for TCIP, defined by the government of Turkey, were to: i) ensure that all property tax-paying domestic dwellings have earthquake insurance coverage; ii) reduce government fiscal exposure to recurrent earthquakes; iii) transfer catastrophic risk to the international reinsurance market; and, iv) encourage physical risk mitigation through the insurance mechanism.

Creating a market for earthquake insurance in Turkey required two significant steps. First, an insurance institution had to be created to provide the coverage, and second, affordable and attractive earthquake insurance policies had to be designed and marketed.[1] TCIP is a public institution, but it is not part of the government so that its employees are not government employees. It was designed to be a self-sustaining insurance company with the capacity to pay claims arising from an earthquake with a return period of 300 years, that is, an earthquake with an annual probability of occurrence of 0.3 percent. For larger events, the Turkish government serves as reinsurer of last resort, covering all losses in excess of the 300 year return period. TCIP has all the components of a modern, efficient insurance company, and its creation involved designing business and information systems, training staff, conducting actuarial and risk-management analysis, and setting up a governance structure (Gurenko, et al., 2006).

Because TCIP is a public entity and did not obtain capital from private equity markets, providing the firm's initial equity capital was challenging. One possibility would have been for the government to put up the initial capital, with the funds to be paid back out of retained earnings over a period of time. This approach would have increased the government's sovereign debt liabilities and would not have achieved the program objective of reducing the government's fiscal exposure to earthquake risk. Accordingly, a creative solution was devised whereby TCIP's claims paying ability would be funded from three sources: i) self-retention to the extent supportable by the firm's equity capital; ii) reinsurance from the international reinsurance market; and iii) a contingent loan from the World Bank. Initially, TCIP relied heavily on reinsurance

and the contingent loan facility to fund its claims paying capability. Over time, as equity capital has accumulated, TCIP has been able to fund a higher proportion of the claims-paying capability from its retained earnings, and the contingent loan will soon be phased out.

The second step in establishing the proxy insurance market in Turkey was to design and distribute attractive and affordable insurance policies. It would have been possible to issue insurance as an add-on or "rider" to existing household property insurance policies. However, due to low market penetration of insurance in Turkey, among other factors, the decision was made to market the insurance as a free-standing, catastrophe-only policy. This required designing an attractive policy and conducting the necessary actuarial calculations to price the policy to be both affordable and self-sustaining, while permitting TCIP to generate retained earnings to reduce its reliance on reinsurance and the contingent loan.

The TCIP provides earthquake coverage with a limit of US$65,000 at an average annual premium of US$46. The policy covers only the dwelling (not the contents) and applies a minimum 2 percent deductible to the sum insured to avoid "penny claims" and to reduce administrative and reinsurance costs of the pool. Such a low insurance deductible makes TCIP coverage highly attractive for homeowners because they could likely make a claim after even minor events. Premium rates are based on the construction type (three types) and property location (five zones), and vary from less than 0.05 percent of insured assets for a concrete reinforced house in the lowest risk area to 0.60 percent for a house located in the highest risk zone.

To achieve substantial market penetration, it was necessary to overcome the resistance of Turkish homeowners to buying insurance and to blunt their mistrust of insurance companies and government-sponsored catastrophe programs. To do this, the government mounted a public relations campaign and also made the insurance compulsory for private dwellings on "registered land," which primarily means that the insurance is obligatory in urban areas but not in villages or rural areas.

Instead of setting up its own marketing organization, the government used distribution networks of the existing Turkish insurance companies, and all licensed companies were allowed to sell policies for a commission. Existing Turkish insurers were also enlisted to serve as claims adjusters, although care must be taken in such cases to prevent moral hazard, given

that the insurers have no financial stake in the amount of claims that are paid. Local insurers act as distributors of TCIP (they do not currently retain any fraction of TCIP's earthquake risk), in exchange for a sales commission (12.5–17 percent of written premium). These insurers also provide additional coverage in excess of that offered by the pool, such as coverage for household contents.

Since its inception in 2000, TCIP's penetration ratio has averaged 17 percent and is now in excess of 20 percent. In Istanbul, the penetration ratio is higher than 30 percent. Although penetration remains low, partly due to the difficulties in enforcing the compulsory insurance provision, there is now much more catastrophe coverage in Turkey than before the creation of TCIP. The majority of the coverage provided is for properties in areas with the highest exposure to earthquake risk (Gurenko, et al., 2006).

To place reinsurance coverage on primary insurers on favorable terms, it is necessary to provide the global reinsurers information on the distribution of exposures and the probability distribution of losses. In the case of Turkey, the World Bank played a catalytic role in providing technical expertise and solving information problems to foster the development of the catastrophe insurance market. For TCIP, the World Bank coordinated an effort by EQECAT, one of the world's three leading catastrophe modeling firms, and the brokerage firm Willis to model earthquake insurance in Turkey. The results were used by TCIP to structure its premium calculation, underwriting, and risk-management programs. The model results were also provided to the global reinsurance market. With high quality data on risk exposure, TCIP was able to obtain adequate reinsurance on favorable terms from global reinsurers. These terms have improved over time as the reinsurance market has gained experience with TCIP's exposure base and methods of operation.

TCIP's success also has brought worldwide recognition. To date, inspired by TCIP's example, more than a dozen countries—including China, Colombia, Greece, India, Iran, and the Philippines—have started technical and legislative work toward the preparation of catastrophe insurance programs. Romania is in the process of enacting a compulsory catastrophe insurance law and establishing a catastrophe insurance pool, which will allow homeowners to be insured against earthquake and flood risks.

Agricultural Insurance Programs

Agricultural business, including crops and livestock, is particularly exposed to the impact of natural disasters.

The volatility of farm income, due to climactic variability, has led governments to devise programs and policies to help stabilize agricultural income. More than 50 countries provide publicly subsidized agriculture insurance to stabilize farm income by reducing the farmers' exposure to production risks, mainly through private-public partnerships. In the past, experience with subsidized insurance programs has been disappointing and, in many aspects, disastrous.

Since the late 1990s, due to dwindling government subsidies to agricultural producers in emerging markets, there has been a renewed interest in agricultural insurance. Combined with other risk financing instruments such as savings and credit, insurance can enhance the business profitability of agriculture in developing economies. The emergence of insurance pools as well as index-based insurance, supported by the World Bank and donors, contributes to a revisiting of the potential role of agriculture insurance in economies where agricultural sectors become more profitable and commercially oriented.

The interest in using index-based agricultural insurance has grown in recent years, particularly to deal with the systemic component of agricultural production losses (such as those caused by a widespread drought). Index-based insurance offers advantages over traditional insurance that relies on individual losses, including lower monitoring costs and a more transparent indemnity structure. However, this type of insurance faces some challenges (such as basis risk), which makes it cost-effective only for specific crops, perils, and geographical areas (see Table A5.3).

These innovative products rely on the measurement of an objective and independent parameter that is highly correlated with the actual loss incurred by a farmer. Measurements such as rainfall or temperature are used as a proxy for such yield loss. Under parametric index insurance, payouts are based solely on the measurement of a particular parameter (for example, of rainfall recorded at a named meteorological station) according to an agreed payout scale (established in the insurance policy). Under aggregate index insurance, payouts are based on an index developed

Table A5.3 Advantages and Challenges of Index-Based Insurance

Advantages	Challenges
Less moral hazard The indemnity does not depend on the individual producer's realized yield.	**Basis risk** Basis risk is the risk that the insurance payout does not exactly match the actual loss.
Less adverse selection The indemnity is based on widely available information, so there are few informational asymmetries to be exploited.	**Precise actuarial modeling** Insurers must understand the statistical properties of the underlying index.
Lower administrative costs Does not require underwriting and inspections of individual farms.	**Education** Required by users to assess whether index insurance will provide effective risk management.
Standardized and transparent structure The uniform structure of contracts facilitates its exchange, possibly on secondary markets.	**Market size** The market is still in its infancy in developing countries and has some startup costs.
Versatility Can be easily bundled with other financial services, facilitating basis risk management.	**Weather cycle** Actuarial soundness of the premium could be undermined by weather cycles (such as El Niño events) that change the probability of the insured events.
	Microclimates Make rainfall or area-yield index-based contracts difficult for localized events (e.g., wind, hail).
	Forecasts Asymmetric information about the likelihood of an event in the near future will create the potential for intertemporal adverse selection.

Source: World Bank (2005a, 2007a).

from the aggregated statistics of farm production or yield in specified districts (for example, area yield statistics for crops, or mortality index for livestock). See Box A5.2.

About 20 index-based insurance programs have been implemented in low- and middle-income countries (see below). However, few are truly catastrophe risk insurance products, since they are designed to trigger indemnity payouts once every five to seven years, on average. Examples include weather-based crop insurance in India and Malawi, and livestock mortality index insurance in Mongolia.

A livestock insurance program was designed and implemented by the government of Mongolia, with the assistance of the World Bank and

Box A5.2 Index-Based Agricultural Insurance

Described below are three recently developed types of index-based agricultural insurance.

Area yield-based insurance is insurance wherein the indemnity is based on the realized average yield of an area, such as a county or district. The insured yield is established as a percentage of the average yield for the area. An indemnity is paid if the realized yield for the area is less than the insured yield, regardless of the actual yield on a policyholder's farm. This type of index insurance requires historical area-yield data.

Index-based livestock mortality insurance makes indemnity payouts when a livestock mortality index, as estimated in a given geographical area, exceeds a pre-determined trigger. This has been applied for mortality in Mongolia, where there is a high incidence of livestock losses due to extreme weather, and for some pasture and rangeland products in Canada and the United States.

Weather-based insurance is insurance wherein the indemnity is based on realization of a specific weather parameter measured over a pre-specified period of time at a particular weather station. The insurance can be structured to protect against index realizations that are either so high or so low that they are expected to cause crop losses. For example, the insurance can be structured to protect against either too much rainfall or too little. An indemnity is paid whenever the realized value of the index exceeds a pre-specified threshold (for example, when protecting against too much rainfall) or when the index is less than the threshold (for instance, when protecting against too little rainfall). The indemnity is calculated based on a pre-agreed sum insured per unit of the index.

Source: World Bank (2007a).

donors, to protect herders against excessive livestock mortality caused by harsh winters and summer drought. The Mongolian program involves a combination of self-insurance by herders, market-based insurance, and social insurance. Herders retain small losses; larger losses are transferred to the private insurance industry, and catastrophic losses are transferred to the government using a public safety net program. A syndicate pooling arrangement protects participating insurance companies against excessive insured losses, with excess-of-loss reinsurance provided by the government.

The insurance program relies on a livestock mortality rate index by species in a local region (*soum*). The insurance pays out to individual

herders whenever the mortality rate in the *soum* exceeds a specific threshold. The index provides strong incentives to individual herders to continue to manage their herds in a manner that minimizes the impact of major livestock mortality events. Under the program, individual herders receive an insurance payout based on the local mortality, irrespective of their individual losses.

The mechanism established to provide mortality coverage is the Livestock Insurance Indemnity Pool (LIIP). Through this pool, insurance companies build collective reserves and the government offers public reinsurance, backed by a US$5 million World Bank contingent credit facility. The viability of index-based livestock insurance is being piloted in 2005–2008 in selected areas to test the preparedness of private insurance companies to offer this product and the herders' willingness to purchase. In the second sales season (April–July 2007) about 600,000 animals were insured, representing 14 percent insurance penetration, for a total premium volume of US$120,000 (Mahul and Skees 2007).

Weather-based crop insurance was first piloted in India in 2003. Today, weather-based crop insurance is sold by three private insurance companies (IFCCO-Tokyo, HDFC-Chubb, and ICICI Lombard) and the government crop insurance company, AICI, to more than 700,000 farmers, for a total premium volume of about US$30 million.[2] Weather-based crop-insurance products are available for lack of rainfall (drought), excess rainfall, and low temperature. Some more innovative products, based on satellite images (for example, NDVI), have also been piloted in small areas. Companies have worked to make the product more accessible by enhancing the delivery system, training agents, and incorporating new technologies. Similar products have been piloted in Malawi since 2005. A prototype weather-based crop insurance policy is presented in Annex 6.

Although it is still too early to draw any final conclusion on the sustainability of these new programs (without heavy public subsidies) and their scalability, some preliminary guidelines can be formulated.

Thorough risk assessment is a precondition for the design of market-based risk financing solutions. Risk assessment that analyzes and quantifies production risks is a critical first step in the process of improving commodity risk management in developing countries. Very often, production risks and their financial impacts are underestimated or misdiagnosed, leading to

interventions that are inappropriate and ineffective for the market players. Risk assessment allows discovery of the true price of risk, which is essential in the design of financially sustainable market-based solutions.

Attempts to market stand-alone agricultural insurance directly to smallholder producers have not proven to be viable. Transaction costs (for example, delivery and training costs) are too high, which makes stand-alone insurance unattractive for farmers. Intermediaries (such as marketing groups, cooperatives, banks, mutual groups) that can aggregate risks and service the products at low costs can play a critical role in establishing market-viable solutions.

There is a strong link between insurance coverage and bank lending. Local financial institutions have a strong incentive to deepen agricultural insurance coverage, since lending to farmers is not profitable or sustainable when there is a pattern of repeated financial loss caused by weather-induced production or price shocks. High-capacity building requirements at the local level of insurance market intermediaries demonstrate the need for a permanent local partner that can assist risk management implementation. Local banks are well positioned to play that role and act as market intermediary. From a lending perspective, agricultural insurance can potentially help banks extend lending in the sector or reduce the cost, since insured customers are more creditworthy than non-insured customers. Finally, since local banks have to compete for clients, expanding the range of financial services is an advantage for market competitiveness.

Agriculture insurance should be part of a comprehensive agricultural risk-management framework. Early implementation work has demonstrated that an organization's responses to new knowledge and a proper assessment of risk lead to risk solutions that may not always involve financial products. New farming techniques, improved technology (for example, superior seeds), and risk-mitigation investments (such as irrigation, pesticides) should be considered first. Insurance can only finance the remaining risks that cannot be controlled with appropriate risk-mitigation techniques.

Insurance and reinsurance companies are interested in developing business in developing countries. Insurers and reinsurers support the pursuit of larger aggregators in developing countries in order to attain commercial sustainability. Working with the domestic insurance sector is an attractive

solution to the aggregation problem, and providers try to engage local banks and insurers as partners for delivery of agricultural insurance into a developing country economy.

Legal and regulatory issues are important. Insurance markets are regulated stringently in developed countries. In contrast, many developing countries lack the legal and regulatory framework to support trade in agricultural index-based insurance. Governments are usually willing to approve pilot activities and business development in these areas because they are eager to provide solutions to the important problems of agricultural production variability.

Capacity building needs are high. Attempts to build risk management capacity in organizations that have critical problems—such as poor communication infrastructure, institutional instability, underdeveloped marketing or financial skills, and weak managerial authority—are likely to be ineffective. The most fundamental prerequisite for successful implementation is that the institution involved must have a strong commercial incentive to improve risk management practices, expressed by a willingness to meet external project assistance with time and resources to jointly invest in the work.

International experience on weather-based crop insurance highlights the need for an efficient network of weather stations. The relevance and success of weather index insurance products are significantly influenced by availability of reliable weather data, a sufficient network of secured weather stations, and the presence of an objective validation scheme for verifying linkages between intended weather variables and observed yields.

Weather-based crop insurance offers promise, but mainly for selected hazards such as deficient rainfall or excess rainfall. Weather index insurance is effective only when basis risk (that is, potential mismatch between actual losses and indemnities) can be minimized. It is very difficult to design an effective weather index insurance product if losses are caused by a complex interaction between multiple weather variables. For these reasons, the primary focus should be on drought and excess rainfall in rainfed areas. A second focus could be for specific crop types and specific time windows during the growth cycles of vulnerable crops, including prolonged cold conditions for wheat or cotton. With regard to wind damages, these are typically localized and thus very difficult to capture

through an index at the field level, but such an index offers promise at a more aggregated level.

Weather-based crop-insurance products should balance simplicity that farmers and stakeholders can understand, with the complex dynamics that characterize water stress impacts on crop yield. Insurance products should be easy to communicate to farmers and stakeholders, perform well from an agro-meteorological perspective, and provide required protection for all stakeholders at an affordable level. An effective insurance product design should capture local conditions and environments, be simple to replicate in other locations and crops so that programs are scalable, and promote local ownership so programs are sustainable.

A public-private partnership may be the way forward. The role of public authorities is often critical for the successful implementation of risk financing strategies. Governments need to create an economic and legal framework that facilitates the emergence of competitive financial markets and that provides farmers with incentives to engage in risk management. They should support information and education campaigns on risk financing solutions, develop accurate and reliable agricultural data bases, and eventually act as the (re)insurer of last resort in the case of extreme events that cannot be transferred to the financial markets.

One can observe a dramatic increase in investments related to weather-based crop insurance programs among the international community since 2006 (see Annex 4). Several reinsurers have established their own dedicated teams in charge of agricultural index-based insurance. World Bank IFC has invested in a new Bermuda-based reinsurance company fully dedicated to index-based insurance. Donors (including USAID, DFID, Japanese Investment Funds, European donors) have been funding pilot activities in many developing countries. Multilateral agencies (such as World Bank, Asian Development Bank, Inter-American Development Bank) have provided both funding (as grants or loans) and technical assistance.

Given the increasing number of donors and IFIs involved in this business, there is a need for better coordination that would benefit the countries and facilitate the entrance of private insurers and reinsurers into these new business opportunities. Although the weather-based crop insurance business is growing at a rapid pace, it is still marginal compared to more traditional insurance programs. In India, for example, which is one

of the most advanced markets for weather-based crop insurance, the total sum insured under weather-based crop insurance was estimated at US$250 million and the total premium volume exceeded US$30 million in 2007, while the national crop insurance program, NAIS, generated a total sum insured of approximately US$5 billion.

Sovereign Risk Financing

Economic theory suggests that countries should ignore uncertainty for public investment and behave as if indifferent to risk (risk neutral), because they can pool risks to a much greater extent than can private investors (Arrow and Lind 1970). A direct consequence of the Arrow-Lind Theorem is that governments should *not* invest in ex-ante risk financing, such as insurance (so long as the insurance premium is higher than the expected indemnity payouts). In other words, there is *no* social cost of bearing catastrophic risk.

However, this theorem does not hold for developing countries that have limited borrowing capacity or inadequate ability to spread the losses among their taxpayers because of their small size (compared to the economic losses caused by natural disasters). Although ex-post-disaster funding can be an important part of a government's catastrophe risk management strategy, resources available through post-disaster programs are generally limited, particularly in the immediate aftermath of a catastrophe. In many cases, liquidity constraints greatly reduce governments' capacity to respond effectively to disasters, resulting in slower recovery. Poor post-disaster response leads to secondary socioeconomic consequences that often have a disproportional impact on the poor.

Thus, there is a social cost of bearing catastrophic risk, leading governments to behave as risk-averse agents. Given the social cost involved, governments of developing countries should be willing to pay more than the expected loss (or fair price) to transfer some of their risks to a third party through insurance or other risk financing instruments (Ghesquiere and Mahul 2007).

The optimal catastrophic risk financing of the contingent liability relies on the cost-effective combination of post-disaster and ex-ante financial

instruments. The first step to designing an efficient sovereign risk financing strategy is to determine the level of resilience the government wants to achieve—for example, whether it wants to be able to absorb a 1-in-50-year event or a 1-in-200-year event without jeopardizing the main public investment priorities (such as education, health). Experience and political reality tend to show that sovereign risk financing strategies should be devised to sustain a 1-in-150-year natural disaster.

A variety of instruments can be considered in the establishment of a risk financing strategy. These can be classified as ex-ante and ex-post risk financing instruments. Examples of ex-ante instruments include the building of financial reserves, signing contingent debt agreements, and the purchasing of insurance and alternative risk-transfer solutions. Ex-post disaster risk financing instruments include increasing tax revenue, reallocating funds from other budget items, accessing private domestic and international credit, borrowing from multilateral finance institutions, and so on. Developing countries also rely heavily on international disaster relief assistance. Although donors have been generous in a number of cases, aid has been highly dependent on the visibility of a given event in the international press, making it a fairly unreliable instrument for risk management.

The foundation of an ex-ante risk financing strategy includes the establishment of a reserve fund to cover small and recurrent losses caused by adverse natural events. This reserve fund should be financed by an annual allocation from the government budget. However, recent experience, such as the FONDEN in Mexico, shows that it is difficult to accumulate such reserves over time because, for various good reasons, reserves tend to be reallocated to other government's needs.

In this context, critical public assets, including lifeline infrastructure, should be insured to make certain that funds will be immediately available for their reconstruction after a disaster. The insurance of key public assets also contributes to greater financial discipline within the government, and provides an economic signal of the cost of natural disasters through the payment of insurance premiums. Costa Rica has recently asked the World Bank to provide technical assistance to help the public insurance company INS develop an insurance strategy for public assets.

A comprehensive ex-ante financing strategy, as depicted in Figure A5.1, involves the layering of various types of risk. Other potential

Figure A5.1 Catastrophic Risk Layering

Return period

		No coverage	
150-year	Insurance of public assets	Ex-ante financial parametric instruments (insurance, catastrophe bonds)	
		Post-disaster financing (credit line, budget reallocation)	
5-year	Reserve fund		
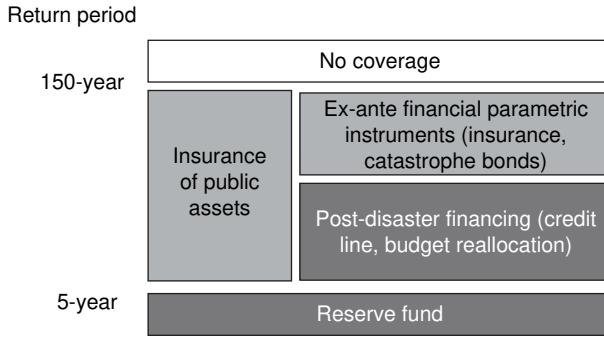
Source: Authors.

budget impacts caused by natural disasters, such as the reduction of fiscal revenue and relief and rehabilitation costs, could be financed through post-disaster financial instruments (when available) and innovative risk transfer instruments (such as parametric insurance, catastrophe bonds). This catastrophic risk layering is depicted in Figure A5.1.

The catastrophe risk layering approach described above does not include an important dimension of the problem: timing. In the aftermath of a disaster, immediate expenditure needs are high, but financial resources are rarely instantly available, creating a liquidity gap. Over time, more post-disaster resources become available, allowing the government to address its financial needs.

Although there is a wide range of instruments for financing long-term expenditures, the financing of short-term needs is more challenging. Figure A5.2 depicts potential financial gaps between the available budget and the financing needs after a disaster, and illustrates how ex-ante financing instruments can fill these gaps. Parametric insurance and contingent credit are particularly cost-effective in financing the liquidity gaps in the aftermath of a disaster.

Sovereign insurance programs against natural disasters are illustrated by the Caribbean Catastrophe Risk Insurance Facility, the Mexican catastrophe bond, the Colombian contingent credit facility, and the Ethiopian drought insurance program.

Figure A5.2 Timeliness of Financial Products

	Immediate hours/days	Short term 1–3 months	Medium term 3–9 months	Long term over 9 months
Financial needs for post-disaster operations	←————————→			
Relief		←————————————————→		
Recovery			←——————————————————→	
Reconstruction				
Financing tools		Donor assis. (relief)		Donor assis. (reconst.)
Ex post financing	Budget contingencies	Budget reallocation	Domestic/ external credit	Tax increase
Ex ante financing	Reserve fund	Parametric RT Cont. debt	Traditional RT	

Source: Authors, from Ghesquiere and Mahul (2007).
Note: RT = risk transfer instruments. Traditional RT instruments include indemnity-based insurance. Parametric RT instruments include parametric insurance (for example, weather-based insurance), parametric catastrophe bonds, and so on.

Caribbean Catastrophe Risk Insurance Facility

Based on their experiences during the 2004 hurricane season, the CARI-COM heads of government requested World Bank assistance to increase access to catastrophe insurance. The Caribbean Catastrophe Risk Insurance Facility (CCRIF) is the result of two years of collaborative work among the region's governments, key donor partners, and a team of experts from the World Bank. The CCRIF allows Caribbean governments to purchase coverage akin to a business interruption insurance that will provide them with immediate liquidity in case of a major hurricane or earthquake. The financial structure of the insurance instrument provides participating governments with coverage tailored to their needs at a significantly lower cost than if they were to purchase it individually.

The CCRIF functions as a mutual insurance company controlled by the participating governments. It was initially capitalized by the participating countries themselves, with support from donor partners. To understand CCRIF, consider a system through which several countries agree to combine their emergency reserve funds into a common pool. If each individual country were to build up its own reserves to sustain a catastrophic event,

the sum of these country-specific reserves would be much larger than the actual needs of the pooled countries in a given year. Considering that on average only one to three Caribbean countries are affected by a hurricane or an earthquake in any given year, a pool holding only the reserves for three potential payouts should be sufficient for the entire group of countries participating in the pool. Each year, as the pool is depleted, participating countries would replenish it in proportion to their probable use of the funds in the pool. The Facility works in a similar manner by combining the benefits of pooled reserves from participating countries with the financial capacity of the international financial markets. It retains some of the risks transferred by the participating countries though its own reserves, and transfers some of the risks to reinsurance markets, when cost-effective. Thanks to the risk-pooling benefits, the amount of reserves that CCRIF should retain to sustain a 1-in-200-year catastrophic event are 70 percent less than the total reserves each country would have to retain individually (World Bank 2007a). This structure results in a particularly efficient risk financing instrument that provides participating countries with insurance policies at approximately half the price they would pay if they approached the reinsurance industry on their own (see Box A5.3).

On June 1, 2007, 16 countries joined CCRIF: Anguilla, Antigua and Barbuda, Bahamas, Barbados, Belize, Bermuda, Cayman Islands, Dominica, Grenada, Haiti, Jamaica, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Trinidad and Tobago, and Turks and Caicos Islands. The total premium volume was about US$20 million, which purchased roughly US$450 million of (hurricane and earthquake) coverage.

CCRIF's risk placement was extremely well received by the reinsurance industry, which provided reinsurance capacity at a lower rate than anticipated. CCRIF was able to secure US$110 million of capacity on the international reinsurance and capital markets. As shown on Figure 2.6, the claims-paying capacity consists of four layers: CCRIF retains the first layer of US$10 million; reinsurers underwrite the second (US$15 million excess US$10 million) and third layers (US$25 million excess US$25 million); and the top layer (US$70 million excess US$50 million) is financed with reinsurance (US$50 million) as well as a US$20 million coverage through a catastrophe swap organized by IBRD Treasury. The average pricing multiple (premium divided by expected loss) of this transaction is 1.71, which

Box A5.3 Main Features of CCRIF

The Caribbean Catastrophe Risk Insurance Facility (CCRIF) allows CARICOM governments to purchase insurance coverage to finance immediate post-disaster recovery needs.

The facility acts as a risk aggregator. CCRIF allows participating countries to pool their country-specific risks into a single, better diversified portfolio, which results in a substantial reduction in premium cost of 45–50 percent.

Claims payments depend on parametric triggers. Index-based (or parametric) insurance instruments pay claims based on the occurrence of a predefined event rather than an assessment of actual losses. This measurement, made remotely by an independent agency, allows for transparent, low settlement costs and quick-disbursing contracts.

The facility was created with initial funding from donors. Initial funding allows the facility to cover startup costs, retain some of the risk, and access the reinsurance markets where it is most efficient.

The facility transfers the risks it cannot retain to the international financial markets. This is done through reinsurance and a catastrophic swap. The accumulation of reserves over time should lessen the facility's dependence on outside risk transfer and smooth the catastrophe reinsurance pricing cycle.

The facility maintains financial protection to survive 1-in-1,000-year events. Should the total insured losses exceed its claims-paying capacity, payouts will be prorated based on the total amount of expected claims compared to the remaining available funds.

CCRIF is established as an independent legal entity. It was created as an insurance captive managed by a specialized firm under the supervision of a board of directors composed of representatives from the donors and participating countries. This board is supported by the technical advice of a facility supervisor.

Participating countries pay an annual premium commensurate with their own specific risk exposure. Parametric insurance products are priced for each country, based on its individual risk profile. Annual premiums typically vary from US$200,000 to US$4 million, for coverage ranging from US$10 million to US$50 million.

Source: Authors, from World Bank (2007b).

is well below similar recent transactions. The cost savings enjoyed in the Facility are due to the fact that the transaction brings more diversification to the business portfolio of the reinsurers.

The US$20 million swap between IBRD and CCRIF is the first transaction to enable emerging countries to use a derivative transaction to access the capital market to insure against natural disasters. It is also the first time a diversified pool of emerging-market countries' catastrophe risk was placed in the capital markets. This allows CCRIF to cover losses for a series of events that have a probability of occurrence of once in 1,200 years or more, achieving a higher level of resilience than international standards (see Figure A5.3).

From June 1 to December 31, 2007, five earthquakes and two hurricanes were reported by CCRIF participants. Hurricane Dean, which passed through the Caribbean Basin on August 18–20, 2007, was the most significant of these events for CCRIF participants. Even though this hurricane generated losses on several islands, these losses remained below the attachment point of the policies purchased by the affected countries (see CCRIF report dated August 27, 2007). This event was a good test of the CCRIF operational mechanisms. The facility operated as planned, with all affected countries informed within 24 hours of the interim payout calculations resulting from the passage of the storm.

Figure A5.3 CCRIF Risk Financing Structure 2007–08
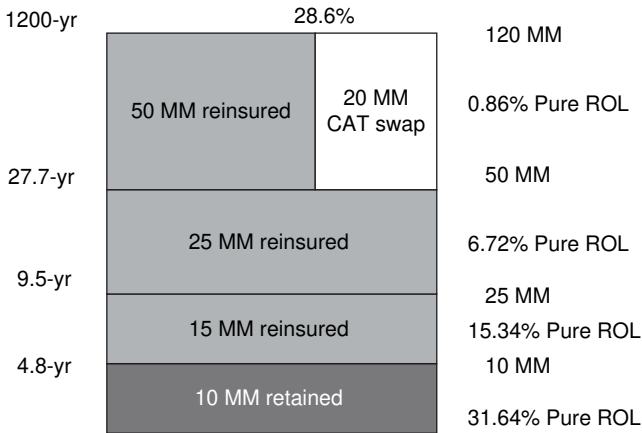
Source: World Bank (2007b).

In the light of Hurricane Dean and following inputs from different stakeholders, CCRIF has reviewed some of its operational procedures. The events following Hurricane Dean demonstrated the need for improved communication regarding the coverage provided and the operating mechanisms of the facility. CCRIF has retained Caribbean publicists for this purpose, and is working on a comprehensive communications strategy for the facility.

The CCRIF team is also considering lowering the minimum allowable trigger point of the insurance policy. The trigger point controls the amount of the deductible on the policy; it represents the threshold of predicted damage that needs to be reached in order to receive a payout from the Facility. Since Hurricane Dean, several participating countries have expressed interest in insuring more frequent events, even if this would translate into higher premiums or lower coverage. The team is studying the possibility of reducing the minimum available trigger point on CCRIF policies from a 20-year return period to a 15-year return period for its 2008 renewals. To allow for a further reduction of the attachment point on its policies, CCRIF is currently updating its catastrophe risk model. A new version of the model should be available for testing and calibration in early 2008. The CCRIF is also undertaking a feasibility study to extend its insurance coverage to catastrophic flooding events and is consulting with stakeholders on other possible risk-pooling mechanisms that may benefit from the pooled regional approach.

On November 29, 2007, a 7.4-magnitude earthquake occurred close to Martinique in the Eastern Caribbean. This event, which is reported to be a 1-in-50-year earthquake, triggered for the first time indemnity payments under CCRIF policies for St. Lucia and Dominica for a total amount of approximately US$1 million.

The CCRIF offers an efficient solution to the short-term liquidity gap faced by CARICOM governments in the aftermath of a major disaster. The liquidity gap is more pronounced in these small island states because, due to the limited geography of each island, the losses incurred during the passage of a major event overwhelm the government's ability to respond. Further work by the World Bank is already under way for a possible expansion of CCRIF to small island states in other regions, including Pacific island states.

Although financial instruments can be useful tools to limit the impact of adverse natural events, they should be considered as part of broader risk-management strategies, including risk identification and reduction. Much work is needed to prevent damage and losses in the first place, including strengthening emergency preparedness, enforcement of appropriate building codes, better application of territorial planning systems, and improving infrastructure to better withstand the effects of adverse natural events.

A clear benefit of the parametric instrument provided by CCRIF is that it avoids the usual moral hazard problem associated with insurance. Investments in risk mitigation do not affect the level of a payout, but will eventually reduce the cost of the annual insurance premium paid by a participating government because it needs to purchase less coverage. This keeps the incentives aligned to limit the impact of adverse natural events and to reduce the number and amplitude of disasters.

The renewal of the CCRIF insurance policies for the 2008-09 season was very successful, as all 16 participating countries renewed their insurance policy. Average insurance premiums decreased by about 10% because of a soft reinsurance market and the increased retention by the CCRIF. The conditions of the insurance policy have been slightly amended: the minimum attachment point for hurricanes has been reduced from 1-in-20-year return period to 1-in-10-year return period. The maximum aggregate limit has increased from USD50 million to USD100 million.

The Mexican Catastrophe Bond

The government of Mexico established a self-insurance fund, called FONDEN, in 1996 to finance emergency needs in the aftermath of a disaster. Initially, FONDEN was supposed to be funded by an annual allocation within the government budget. However, this budget allocation shrank over time and, as a consequence, the total expenses under FONDEN started exceeding its resources in 2002. The ministry of finance thus decided to develop a risk financing strategy for FONDEN, relying on market-based financial instruments. This would make FONDEN less dependent on the government for the allocation of post-disaster funds, which takes time since they usually have to be approved by the parliament. The government

decided to focus on major risks such as earthquakes, which could potentially cause up to US$10 billion of losses, if a major earthquake hit Mexico City.

In March 2006, Mexico purchased a US$450 million catastrophe coverage, of which US$160 million was issued a (binary) catastrophe bond, to cover against the risk of earthquakes. The Mexican earthquake bond, which has been sold to institutional investors in the United States and Europe, acts like an insurance policy for the Mexican government. Investors paid US$160 million into a single-purpose reinsurer created for the government of Mexico. If an earthquake of a specified magnitude occurs in designated areas of the country within the next three years, the government will be able to draw from these funds. If no disaster occurs during the life of the fund, the money will be returned to the investors. This is the first time a sovereign country has issued a catastrophe bond.

Catastrophe (CAT) bonds are an example of alternative risk transfer (ART) instruments that transfer catastrophic risk to the capital markets via the issue of a bond, where repayment of principal is contingent upon occurrence of a predefined catastrophe. The specified value limit of the CAT bond is paid out when a predetermined indemnity level, index, or parametric trigger occurs. The parametric trigger, based on scientifically measurable characteristics of a hazard (for example, wind speed, earthquake intensity), is the most frequent, CAT bonds are attractive because they protect investors from moral hazard and provide quick payments to issuers. Introduced in the mid-1990s, ART solutions mainly covered losses caused by wind and earthquake. Although it is still an experimental market, the annual stream of CAT bond issues more than doubled between 2006 and 2007, with a peak at US$7.7 billion in 2006 (involving 27 transactions).

Table A5.4 gives the main features of the notes issued under the catastrophe bond. The pricing multiple (the ratio of the bond premium to the expected annual loss) was about 2.5. This means that FONDEN pays as an annual premium 2.5 times the annual expected loss.

The price of this catastrophe bond is lower than the prices of similar bonds issued in recent years. This is a direct effect of the diversification benefit that this catastrophe bond provides in the investors' portfolio,

Table A5.4 Mexico Catastrophe Bond Contract Features

	Class A notes	Class B notes
Notional:	US$150,000,000	US$10,000,000
Covered Territory:	Zone B	Zones A and C
Annual Expected Loss:	0.96%	0.93%
Principal Reduction Mechanism:	Binary	Binary, first Zone to Trigger
Expected Rating (S&P):	BB+	BB+
Investor Spread (bps)	LIBOR + [235]	LIBOR + [230]
Multiple	2.45	2.47

Source: FONDEN (2006).

which is mainly concentrated in earthquake risks in California and Japan and hurricane risk in the Southeastern United States. The Mexican bond is especially valuable to investors for diversification purposes, because earthquake risk in Mexico is not highly correlated with these peak catastrophe exposures.

Contingent Debt

Contingent capital is an alternative risk transfer product through which capital funding is provided to the client after the occurrence of some specific risk-related loss, often on pre-loss financing terms. It is designed to provide immediate and less expensive capital to the client when it is most needed (for instance, after an economic loss) or most scarce (for instance, after a regional disaster). This is essentially a commitment by a capital provider to supply paid in capital on pre-agreed terms, if the buyer of the facility exercises that right on or before the expiration of the contingent facility. Just like a regular option, contingent capital can be characterized by the risk of underlying asset, exercise style, and strike price. Although this facility can potentially provide a country with lower cost capital relative to either a pure risk-transfer solution (such as insurance) or the accumulation of reserves, the major disadvantage is that, once disbursed, the contingent debt exacerbates the country's debt burden. The effectiveness of this facility thus depends on the country's

post-disaster financial profile, and, more specifically, on its post-disaster ability to service debt.

Colombia was the first country to secure contingent capital from the World Bank. Because of its location, Colombia is highly prone to natural disasters. The country sits astride the Andean mountain region and the Pacific "belt of fire," where high seismic potential combines with volcanic activity, and in the last 25 years, has suffered six major earthquakes. The government of Colombia and the World Bank designed a project that aims to reduce the state's fiscal vulnerability to adverse natural events by strengthening national capacity to manage disaster risk, using a US$260 million World Bank loan. This loan includes a US$150 million contingent credit line that would provide the government with immediate liquidity in the event of a major disaster in Colombia.

A similar instrument was designed for the government of Mongolia in 2005. Under the Index-Based Livestock Insurance program piloted with the assistance of the World Bank, the government of Mongolia is acting as a reinsurer of last resort for the pool of domestic insurers selling livestock insurance. A World Bank US$5 million contingent credit line has been made available to the government to protect against the contingent liability due to excessive livestock losses.

The World Bank is offering to their IBRD country clients a new contingent loan product, Catastrophe Risk Deferred Drawdown Option facility (CAT DDO). It offers middle-income countries immediate liquidity up to US$500 million or 0.25% of GDP (whichever is lower) if they suffer a natural disaster such as a hurricane or earthquake. It is like a line of credit that could provide bridge financing while other sources of funding are being mobilized. Funds will be disbursed when a country suffers a natural disaster and declares a state of emergency. Governments signing up for the facility must have a hazard risk management program in place that is monitored by the World Bank and an adequate macroeconomic framework.

Drought Insurance in Ethiopia[3]

In 2005, the government of Ethiopia initiated the Productive Safety Net Programme (PSNP) as the chief instrument to address food insecurity, with

a focus on asset building, especially productive community assets, and asset protection during shocks. In effect, PSNP shifts the emphasis from a system dominated by emergency humanitarian aid to long-term initiatives that address some of the major underlying causes of food insecurity.

In this context, the World Food Programme (WFP) entered into a humanitarian aid weather derivative contract in 2006 with a leading European reinsurer, Paris Re. The contract promised to provide contingency funding if extreme drought were to occur during Ethiopia's 2006 agricultural season. From March to October 2006, WFP and the government of Ethiopia monitored the drought index, built upon 26 weather stations in Ethiopia, on a daily basis and determined the contract value as the underlying rainfall data was recorded throughout the contract period. The contract was designed to provide a maximum payout of US$7.1 million for an annual premium of US$930,000 (13.1 percent premium rate) financed through a USAID grant. The payout would have been used to provide timely cash transfers to protect the livelihoods of up to 62,000 vulnerable households in Ethiopia. This experimental pilot transaction provided a small amount of contingency funding to hedge only a fraction of the overall risk in the country, however, the model was calibrated to address the potential losses suffered by up to 17 million Ethiopian farmers who risk falling into destitution as a result of extreme drought. The contract did not trigger in 2006 and was not renewed in 2007, nevertheless, the pilot demonstrated that it is feasible to use market mechanisms to finance drought risk in a developing country. It is possible to develop objective, timely and accurate indicators for triggering drought assistance and ex-ante resources can give governments and donors the incentive to put contingency plans in place, allowing earlier disaster response.

In 2007, WFP, World Bank and the government of Ethiopia began developing a broader drought risk management framework in the context of the PSNP to complement the future use of market-based instruments to manage catastrophic risk. Although PSNP offers a vehicle for delivering timely livelihood protection to the chronically food-insecure, the transiently food-insecure remain subject to the vagaries of the emergency relief system. Early and predictable assistance focused on the special needs of these households, to prevent asset depletion as well as increased levels of destitution, is central to the overall sustainability

of PSNP. Therefore, the second phase of PSNP (2008–2010) will introduce a drought risk financing component to the program. This approach proposes to facilitate predictable disbursement of resources for less foreseeable problems, in effect allowing the immediate scale-up of PSNP activities in response to localized, intermediate, or severe drought events. The concept is to coordinate a pool of contingent resources—eventually including index-based risk transfer products as piloted in 2006—that can be readily and appropriately allocated in the event that many more households become food-insecure, or existing beneficiaries require additional months of assistance following weather shocks. Donors are interested in scaling this facility beyond the PSNP areas of the country and expanding it to other risks in addition to drought.

The World Bank is helping the governments of Ethiopia and Malawi to upgrade their weather station networks and install new weather stations. Satellite data can also provide estimates of rainfall, yield or other losses. For example, Normalized Difference Vegetation Index (NDVI) data derived from satellites observing changes in greenness of vegetation has been used in Canada, Spain, Mexico and the US for forage, pasture and rangeland insurance. In the summer of 2007, the Millennium Village project, together with Swiss Re, pioneered the use of NDVI data combined with rainfall station data to transfer village-level drought risk via a weather derivative contract. Projects are also ongoing in Vietnam and Thailand to study whether flood risk can be indexed and reinsured using satellite-based remote sensed data. Satellite rainfall estimates (RFE) covering the entire African continent in a grid (10 × 10 kilometers), already the basis of early warning systems for the continent (e.g. FEWSNET), are being used by WFP, World Bank and the government of Ethiopia for drought risk financing in Ethiopia. Although tested for monitoring purposes in Africa, this RFE data has not yet been used as an underlying variable for risk transfer, primarily due to concerns about its short historical data length (the data set starts in 1995). In the future, these instruments will become a more mainstreamed and complementary means of providing rainfall or yield measurements for insured areas, particularly for national level (rather than farmer level) risk.

Notes

1. We abstract here from the legal and governmental changes required to set up the TCIP. The TCIP's earthquake insurance is legally compulsory for many urban Turkish homeowners, although the compulsion is not well enforced. For more details, see Gurenko, et al. (2006).

2. Although this number is large in absolute terms, it should be noted that there are about 110 million farmers in India. The major crop-insurance program in India is the (subsidized) area-yield crop-insurance program NAIS (National Agriculture Insurance Scheme), which covered almost 20 million farmers in 2007.

3. This section draws from Syroka and Wilcox (2006) and personal communications with J. Syroka.

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Prototype Weather-Based Crop Insurance Policy

T he growing period is decomposed into three phases. For each phase, agronomists and farmers determine the impact of lack of rainfall on crop yield losses and derive the threshold (trigger at which the contract starts paying), the limit (the trigger where the payout stops increasing), and the increment (monetary value for each millimeter of rainfall deficiency). See Figure A6.1.

Figure A6.1 Term-Sheet Features for a Weather-Based Crop Insurance Contract (Rainfall)

Product feature	Description		
Crop type	*Specific crop type or types for which the index is designed.*		
Index	*Description of the index type (for example, rainfall index)*		
Start of contract	[date] *The start of the contract is normally a specified calendar date*		
End of contract	[date] *Specific calendar date, or number of days after start of the contract*		
Phase	**1**	**2**	**3**
Duration (days)	[number]	[number]	[number]
Threshold (mm) *The amount of the meteorological measurement (e.g., rainfall, temperature) at which payout starts (also known as a trigger)*	[number]	[number]	[number]
Limit (mm) *The amount of the meteorological measurement at which maximum payout is made*	[number]	[number]	[number]
Increment (Rs/mm) *The amount of Rs to be paid out for each increment of the meteorological measurement above or below the threshold.*	[number]	[number]	[number]
Sum insured per phase (Rs)	[number]	[number]	[number]
Premium (Rs)	[number] *The premium payable*		
Reference weather station	[Name of reference weather station] *Nominated weather station, and supervisory authority. A secondary station is normally specified, as backup.*		
Maximum policy limit (Rs)	[number] *The maximum Rs amount which can be paid under the contract over all phases*		
Additional features of an index which may be relevant	Rainfall less than a given amount is not counted in the aggregate rainfall *(This feature recognizes that minimal amounts of rainfall cannot be used by plants.)*		
	Rainfall more than a given amount in 24 hours is not counted in the aggregate rainfall *(This feature recognizes that large rainfall in a single day will run off and not be available to plants.)*		
	Dynamic starting date *(The start date for an index can be designed to incept only after a given cumulative amount of rainfall has fallen—the amount normally required for planting.)*		

Source: World Bank (2005a, 2007a). See text references.

Commercial Catastrophe Risk Models

The following tables are current as of March 2008.

Table A7.1 Commercial Catastrophe Risk Models

Country	Earthquake	Flood	Landslide	Hurricane	Tornado	Hail	Wildfire	Windstorm	Winter Storm	Agriculture
					Hazard					
Anguilla	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Antigua and Barbuda	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Argentina	E	—	—	—	—	—	—	E	—	—
Aruba	E, A	—	—	R, A, E	—	—	—	—	—	—
Australia	R, A, E	—	—	R, A	—	—	—	—	—	—
Austria	R, E	—	—	—	—	R	—	R, A	—	—
Bahamas, The	A, E	—	—	R, A, E	—	—	—	—	—	—
Bahrain	E	—	—	—	—	—	—	—	—	—
Barbados	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Belize	R, A	—	—	R, A	—	—	—	—	—	—
Belgium	R, E	R	—	—	—	R	—	R, A, E	—	—
Bermuda	—	—	—	A, E	—	—	—	—	—	—
Brazil	E	—	—	—	—	—	—	E	—	—
Canada	R, A, E	—	—	—	R	R	—	A	—	—
Cayman Islands	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Chile	R, A, E	—	—	—	—	—	—	E	—	—
China	R, A, E	—	—	E	—	—	—	—	—	—
Colombia	R, O, E	—	—	E	—	—	—	—	—	—
Costa Rica	A, E	—	—	E	—	—	—	—	—	—
Cuba	—	—	—	R	—	—	—	—	—	—
Cyprus	E	—	—	—	—	—	—	E	—	—

Czech Republic	E	—	—	—	—	—	—	E	—	—
Denmark	E	—	—	—	—	—	—	R, A, E	—	—
Dominica	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Dominican Republic	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Ecuador	E	—	—	—	—	—	—	—	—	—
El Salvador	A, E	—	—	E	—	—	—	—	—	—
France	E	E	—	—	—	R	—	R, A, E	—	—
Germany	R, E	R, E	—	—	—	R	—	A, E	—	—
Greece	R, A, E	—	—	—	—	—	—	E	—	—
Grenada	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Guadeloupe (France)	R, A	—	—	R, A	—	—	—	—	—	—
Guatemala	A, E	—	—	E	—	—	—	—	—	—
Guam	R	—	—	R	—	—	—	—	—	—
Haiti	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Hawaii	R, E	—	—	R, A, E	—	—	—	—	—	—
Honduras	A, E	—	—	E	—	—	—	—	—	—
Hong Kong	E	—	—	R, A, E	—	—	—	—	—	—
Hungary	E	—	—	—	—	—	—	E	—	—
India	R, E	—	—	E	—	—	—	—	—	R
Indonesia	R, A, E	—	—	—	—	—	—	—	—	—
Ireland	E	—	—	—	—	—	—	R, A, E	—	—

(Continued)

Table A7.1 Commercial Catastrophe Risk Models *(continued)*

Country	Earthquake	Flood	Landslide	Hurricane	Tornado	Hail	Wildfire	Windstorm	Winter Storm	Agriculture
					Hazard					
Israel	R, A, E	—	—	—	—	—	—	E	—	—
Italy	R, A, E	E	—	—	—	R	—	E	—	—
Jamaica	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Japan	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Kenya	E	—	—	—	—	—	—	—	—	—
Lebanon	E	—	—	—	—	—	—	E	—	—
Liechtenstein	R	—	—	—	—	—	—	—	—	—
Luxembourg	E	—	—	—	—	R	—	R, A, E	—	—
Malawi	E	—	—	—	—	—	—	—	—	—
Malaysia	E	—	—	E	—	—	—	—	—	—
Malta	E	—	—	—	—	—	—	E	—	—
Martinique (France)	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Mexico	R, A, E, O	—	—	E	—	—	—	—	—	—
Monaco	E	—	—	—	—	—	—	E	—	—
Montserrat	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Netherlands	E	—	—	—	—	R	—	R, A, E	—	—
Netherlands Antilles	R, A, E	—	—	R, A, E	—	—	—	—	—	—

New Zealand	R, A, E	—	—	—	—	—	—	E	—	—
Nicaragua	E	—	—	—	—	—	—	—	—	—
Norway	E	—	—	—	—	—	—	R, A, E	—	—
Panama	A, E	—	—	—	—	—	—	—	—	—
Oman	E	—	—	E	—	—	—	—	—	—
Pakistan	E	—	—	E	—	—	—	—	—	—
Peru	A, E	—	—	A, E	—	—	—	—	—	—
Philippines	R, A, E	—	—	A, E	—	—	—	—	—	—
Portugal	R, A, E	—	—	R, E	—	—	—	E	—	—
Puerto Rico	R, E	—	—	—	—	—	—	—	—	—
Qatar	E	—	—	—	—	—	—	—	—	—
Romania	E	R	R	—	—	—	—	E	—	—
St. Kitts and Nevis	R, A, E	—	—	R, A, E	—	—	—	—	—	—
St. Lucia	R, A, E	—	—	R, A, E	—	—	—	—	—	—
St. Martin	R	—	—	R	—	—	—	—	—	—
St. Vincent and the Gren.	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Saudi Arabia	E	—	—	—	—	—	—	—	—	—
Singapore	E	—	—	—	—	—	—	—	—	—
South Africa	E	—	—	—	—	—	—	E	—	—
South Korea	E	—	—	E	—	—	—	—	—	—
Spain	E	—	—	—	—	—	—	E	—	—
Sweden	E	—	—	—	—	—	—	R, A, E	—	—
Switzerland	R, A, E	—	—	—	—	R	—	R, A	—	—
Taiwan, China	R, A, E	—	—	A, E	—	—	—	—	—	—

(Continued)

Table A7.1 Commercial Catastrophe Risk Models *(continued)*

Country	Hazard									
	Earthquake	Flood	Landslide	Hurricane	Tornado	Hail	Wildfire	Windstorm	Winter Storm	Agriculture
Thailand	E	—	—	E	—	—	—	—	—	—
Trinidad & Tobago	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Turkey	R, A, E	—	—	—	—	—	—	E	—	—
Turks & Caicos	R, A, E	—	—	R, A, E	—	—	—	—	—	—
United Arab Emirates	E	—	—	E	—	—	—	—	—	—
United Kingdom	E	R, A, E	—	—	—	—	—	R, A, E	—	—
United States	R, A, E	A, E	—	R, A, E	R, E	R, E	A	A, E	A, E	R
Venezuela	A, E	—	—	E	—	—	—	—	—	—
Virgin Islands (British)	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Virgin Islands (U.S.)	R, A, E	—	—	R, A, E	—	—	—	—	—	—
Yemen	E	—	—	E	—	—	—	—	—	—

Source: Authors, from personal communication with AIR Worldwide, EQECAT, and RMS.
E = EQECAT, A = AIR Worldwide, R = RMS, O = Other risk modeling firms, — = not available.

Review of the Catastrophe Reinsurance Market

Introduction

The 2004 and 2005 hurricane seasons created unprecedented losses for U.S. property insurers.[1] The insured losses from the largest 25 hurricanes on record in the United States are shown in Table A8.1.

Six of the top ten hurricanes, as measured by insured losses, occurred in 2004 and 2005. Total insured losses from the 2004–2005 events were US$67.9 billion, accounting for 46 percent of the total losses of the top 25 events. Because losses of this magnitude are not diversifiable based on the spread of risk in any one country, insurers are critically dependent on the global reinsurance market to provide coverage and pay claims. Although 2006 was a calm year for catastrophic events, it is clear that escalating insurance exposures and the recurrence of mega-hurricanes and other events will continue to expand the demand for reinsurance. This review includes information on the adequacy of markets for natural catastrophe reinsurance and examines how well the world reinsurance market responded to recent catastrophic events.

As Table A8.1 demonstrates, the frequency and severity of natural catastrophes have increased significantly in recent years. Further information on catastrophes is provided in Figure A8.1, which shows the annual insured losses from natural and manmade catastrophes over the period 1970–2006. The years 2004 and 2005 were the worst in recent history with regard to catastrophe losses. Hurricane Katrina, which made landfall

Table A8.1 U.S. Hurricanes—25 Largest Insured Property Losses (Billions of 2005 $*)

Rank	Hurricane	Year	Insured Losses $Billions
1	Hurricane Katrina	2005	66.3
2	Hurricane Andrew	1992	23.1
3	Great New England Hurricane	1938	9.6
4	Hurricane Wilma	2005	8.4
5	Hurricane Charley	2004	7.1
6	Hurricane Hugo	1989	6.7
7	Hurricane Ivan	2004	6.3
8	Hurricane Rita	2005	5.0
9	Hurricane Frances	2004	4.6
10	Miami Hurricane	1926	4.1
11	Hurricane Georges	1998	3.8
12	Hurricane Betsy	1966	3.7
13	Hurricane Jeanne	2004	3.4
14	Hurricane Allison	2001	2.9
15	Hurricane Opal	1995	2.9
16	Great Atlantic Hurricane	1944	2.5
17	Hurricane Floyd	1999	2.4
18	Hurricane Iniki	1992	2.4
19	Hurricane Fran	1996	2.1
20	Hurricane Frederic	1979	1.9
21	Galveston, Texas Hurricane	1900	1.8
22	Hurricane Celia	1970	1.7
23	Hurricane Carol	1954	1.6
24	Hurricane Hazel	1954	1.4
25	Hurricane Alicia	1983	1.2

Souces: A.M. Best Co., Insurance Services Office (ISO), Swiss Re (2007).
Note: Loss estimates vary. For example, the Florida Office of Insurance Regulation currently reports Hurricane Wilma's Estimated Gross Probable Losses at $10.9 billion.
* Inflation adjustment 1908 to 2005 made using the Construction Cost Index (CCI) (McGraw Hill). 1900 to 1907 based on CCI and overlapping CPI and McCusker inflation index (1860 to 1912).

on September 8, 2005, is the most costly natural catastrophic event in history, with projected insured losses of some US$66.3 billion (Swiss Re 2007). Prior to Katrina, the most costly natural catastrophe was Hurricane Andrew, in 1992, which cost insurers US$23.0 billion. Because Table A8.1

and Figure A8.1 are based on global catastrophic events, it is clear that the United States and other developed nations absorb most of the world's capacity for reinsurance against catastrophic events. However, this provides a potential opportunity for developing countries, which can offer a valuable source of diversification to the world's reinsurers, provided that the necessary insurance market infrastructure exists or can be developed.

The increasing costs of catastrophes have significantly stressed insurance markets. Insurance works best for high-frequency, low-severity events, which are statistically independent and have probability distributions that are reasonably stationary over time. Catastrophic events, and particularly mega-catastrophes such as Katrina, violate to some degree most of the standard textbook conditions for insurability. These are low-frequency, high-severity events that violate statistical independence by affecting many insured exposures at one time. Although considerable progress has been made in modeling natural catastrophes, Katrina exposed the limitations of existing catastrophe models in predicting losses for both personal and commercial risks, and caused modelers to launch new efforts to revise their databases and predictive techniques. Thus, the 2004–2005 hurricanes were truly paradigm-shifting events for insurance markets, equivalent in their impact to Hurricane Andrew and the World Trade Center (WTC) terrorist attack.

Figure A8.1 Worldwide Insured Catastrophe Losses (2006 Monetary Units)
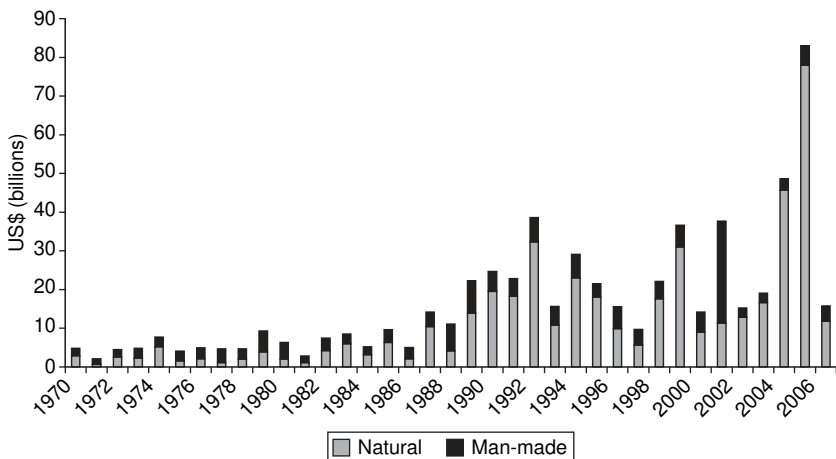
Source: Swiss Re (2007).

The Role of Reinsurance

The role of the insurer is to diversify risk. Insurance companies assume the risks of consumers and business firms and diversify the risk by insuring large numbers of policyholders. Insurance works best if the losses of individual policyholders are statistically independent, meaning that losses do not occur to large numbers of policyholders simultaneously and from the same cause. With statistical independence, the losses from a large pool of risks become highly predictable, allowing insurers to provide coverage without having to hold large amounts of costly equity capital relative to the quantity of insurance being underwritten. Insurance markets with large numbers of statistically independent risks, with moderate loss amounts per claim, can be characterized as **locally insurable** (Cummins and Weiss 2000). Examples of insurance markets where risks are locally insurable include automobile collision insurance and homeowners insurance for non-catastrophic events, such as ordinary fires.

Losses from mega-catastrophes do not satisfy the conditions of statistical independence and hence are not locally insurable. The problem is that a single event can cause losses to many insured exposures simultaneously, violating the fundamental underlying principles of diversification. However, risks that are locally *dependent* may be globally *independent* (for example, the risk of tornadoes in the American Midwest versus Australia). This provides the economic motivation for reinsurance markets and suggests that reinsurance for mega-catastrophes is of necessity a global market. As shown below, global reinsurance markets appear to be adequate to respond to catastrophic losses, even those as large as Katrina. Risks that are globally diversifiable through reinsurance can be characterized as **globally insurable**.

Violation of the conditions for insurability can create situations where risks are neither locally nor globally insurable. Events that are potentially extremely large relative to the size of insurance and reinsurance markets fall into this category. However, if other conditions are satisfied, such risks may be **globally diversifiable** through capital markets. Consider the example of events with low frequency and very high severity, where the covariances among the individual risks making up a portfolio are also relatively high. Examples of such risks are hurricanes that cause even more

damage than Katrina and earthquakes striking geographical regions with high concentrations of property values, such as the fabled "Big One" in California. Modelers have estimated that a US$100 billion event in Florida or California has a probability of occurrence in the range of approximately 1 in 100 (that is, a return period of 100 years). The capacity of the insurance and reinsurance industries may be inadequate to insure such events, but events of this magnitude are small relative to the market capitalization of securities markets. Thus, by introducing securitized financial instruments representing insurance risk, catastrophic events in the US$100 billion range are diversifiable across the financial markets, even though they may not be diversifiable in global insurance and reinsurance markets.

There is a fine line between loss events that are globally insurable and those that are globally diversifiable. Losses that once were considered uninsurable, such as Katrina, actually may turn out to be insurable in global markets. However, such events clearly create stress for global insurance markets and require innovative sources of capacity, such as catastrophe bonds and sidecars. Losses that once were considered unmodelable, such as large natural catastrophes, have moved into the realm of modelability due to advances in computing, data processing, and modeling technologies. Thus, it is not advisable to automatically rule out a primary role for private insurance and capital markets in solving problems of financing of catastrophic risk, even for the largest and most unpredictable events.

The Global Market for Reinsurance

The market for reinsurance is truly a global market, but the United States is by far the leading market both in the demand for reinsurance and in the amount of loss payments funded by reinsurers. In fact, the United States accounted for 87 percent of worldwide insured catastrophe losses in 2005 (Swiss Re 2006) and 61 percent in 2006 (Swiss Re 2007).

The world's 40 leading reinsurers are shown in Table A8.2, with rankings based on 2006 net premiums written. Reinsurers from 12 different countries are represented on the top 35 list, and the country with the largest number of companies on the list is Bermuda. Bermuda rose to

Table A8.2 Top 40 Global Reinsurance Groups

| Company | Country | Ranked by Consolidated Net Premium Written (US$ Millions) | | 2006 Cumulative Market Share |
		2006	2005	
Munich Re	Germany	25,433	22,603	15.0%
Swiss Re	Switzerland	23,841	20,558	29.0%
Berkshire Hathaway Re	U.S.	11,576	10,041	35.8%
Hannover Re	Germany	9,354	9,191	41.3%
Lloyd's	U.K.	8,445	6,567	46.3%
SCOR	France	4,885	2,692	49.1%
Reinsurance Group of America Inc.	U.S.	4,343	3,863	51.7%
Everest Re	Bermuda	3,876	3,972	54.0%
Partner Re	Bermuda	3,690	3,616	56.2%
Transatlantic Holdings Inc.	U.S.	3,633	3,466	58.3%
XL Re	Bermuda	2,960	5,013	60.0%
Tokio Marine & Nichido Fire Insurance Co.	Japan	2,783	2,789	61.7%
Korean Re	Korea	2,350	1,947	63.0%
Odyssey Re	U.S.	2,161	2,302	64.3%
Converium	Switzerland	1,852	1,783	65.4%
Scottish Re Group Ltd.	Bermuda	1,842	1,934	66.5%
ACE Tempest Re	Bermuda	1,797	1,777	67.6%
Sompo Japan Insurance Inc.	Japan	1,788	1,804	68.6%
Mitsui Sumitomo Insurance Co. Ltd.	Japan	1,724	1,713	69.6%
Caisse Centrale de Réassurance	France	1,509	1,476	70.5%
AXIS Capital Holdings Ltd.	Bermuda	1,529	1,491	71.4%
General Insurance Corp. of India	India	1,455	1,121	72.3%
Arch Capital Group Ltd.	U.S.	1,365	1,658	73.1%
Endurance Specialty Holdings Ltd.	Bermuda	1,328	1,323	73.8%
Mapfre Re	Spain	1,299	1,082	74.6%
White Mountains Re	Bermuda	1,290	1,304	75.4%
Toa Re Co. Ltd.	Japan	1,286	1,211	76.1%
PARIS RE (4)	Switzerland	1,254	1,362	76.9%

(continued)

Table A8.2 Top 40 Global Reinsurance Groups *(continued)*

Company	Country	Ranked by Consolidated Net Premium Written (US$ Millions)		2006 Cumulative Market Share
		2006	2005	
QBE Insurance Group Ltd.	Australia	1,213	1,190	77.6%
Platinum Underwriters Holdings Ltd.	Bermuda	1,177	1,718	78.3%
Aioi Insurance Co. Ltd.	Japan	1,132	1,152	78.9%
RenaissanceRe Holdings Ltd.	Bermuda	1,078	1,166	79.6%
Aspen Insurance Holdings Ltd.	Bermuda	1,029	1,129	80.2%
IRB-Brasil Resseguros S.A.	Brazil	910	650	80.7%
WR Berkeley	U.S.	893	720	81.2%
Deutsche Rück	Germany	879	697	81.8%
NIPPONKOA	Japan	791	831	82.2%
Transamerica Re (AEGON)	U.S.	771	727	82.7%
Amlin Group	U.K.	738	526	83.1%
Imagine Reinsurance Holdings Ltd.	Bermuda	656	516	83.5%
World Total		169,975	153,042	

Source: Standard & Poor's Global Reinsurance Highlights — 2007 (S&P 2007).

prominence as a reinsurance market following Hurricane Andrew in 1992 and has continued to increase in importance due to the island's proximity to the United States, sophisticated infrastructure for the operation of financial institutions, limited regulation of insurance companies, and absence of income tax. Hence, Bermuda's prominence is primarily due to restrictive regulatory and tax regimes in other jurisdictions such as the United States.

The world's non-life insurance premiums are broken down by country of reinsurance supplier (country of domicile of the reinsurer receiving the premiums) in Figure A8.2. Germany and the United States each account for more than 20 percent of world premium volume; other leading countries include Switzerland, Bermuda, the United Kingdom, and Japan. Because Figure A8.2 is based on the world's total non-life insurance premiums, regardless of country of origin of the ceding insurer, it does not fully reveal the importance of global reinsurance markets to insurers in developed countries with high exposure to catastrophe losses. For example, the overall numbers tend to understate the importance of Bermuda as a source of reinsurance for U.S. insurers.

Figure A8.2 Global Reinsurers—Net Premiums Written by Country, 2005
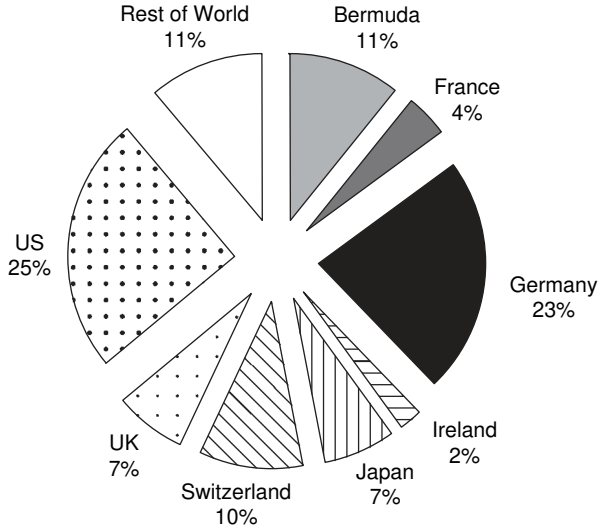
To provide an indication of the degree of globalization, the reliance of U.S. insurers on foreign reinsurance is elucidated in Table A8.3, which shows the number of foreign (non-U.S.) jurisdictions with which U.S. insurers transacted reinsurance business during 2001–2005. U.S. insurers did business with reinsurers domiciled in approximately 100 countries in each year and purchased reinsurance from more than 2,000 different non-U.S. reinsurers in each year. Total ceded reinsurance premiums, to both affiliated and unaffiliated foreign insurers, grew steadily over the period and reached US$62 billion by 2005. Putting this number in perspective, total net written premiums for U.S. property casualty insurers amounted to US$433.5 billion in 2005. As the premium totals suggest, U.S. insurers are also heavily dependent on non-U.S. reinsurers for their financial strength. As Table A8.3 shows, U.S. insurers had US$123.9 billion in recoverables from alien reinsurers in 2005, equal to 28.6 percent of total policyholders' surplus.[2]

The relative importance of non-U.S. reinsurers and U.S. professional reinsurers as sources of supply for reinsurance coverage for U.S. insurers is shown in Figure A8.3. The figure shows the percentage of total reinsurance premiums ceded by U.S. insurers to U.S. professional reinsurers

Table A8.3 Dependence of U.S. Insurers on Alien Reinsurance

Year	No. Alien Jurisdictions	No. Alien Reinsurers*	Ceded Premiums	Net Recoverables	Policyholders Surplus	Recoverables/ Surplus
2001	98	2,287	37,317	80,662	374,364	21.5%
2002	96	2,290	46,169	93,937	376,019	25.0%
2003	102	2,344	53,509	102,362	353,849	28.9%
2004	100	2,330	53,102	106,661	402,264	26.5%
2005	105	2,321	62,062	123,938	433,600	28.6%

Source: Data on alien reinsurance from Reinsurance Association of America (2006); data on policyholders surplus from A.M. Best Company (2005, 2006e).
Note: Monetary statistics are in millions of U.S. dollars, not adjusted for price level changes.
*Number of alien reinsurers assuming reinsurance from U.S. insurers.

Figure A8.3 Reinsurance Premiums Ceded: U.S. Professional Reinsurers vs. Alien Reinsurers
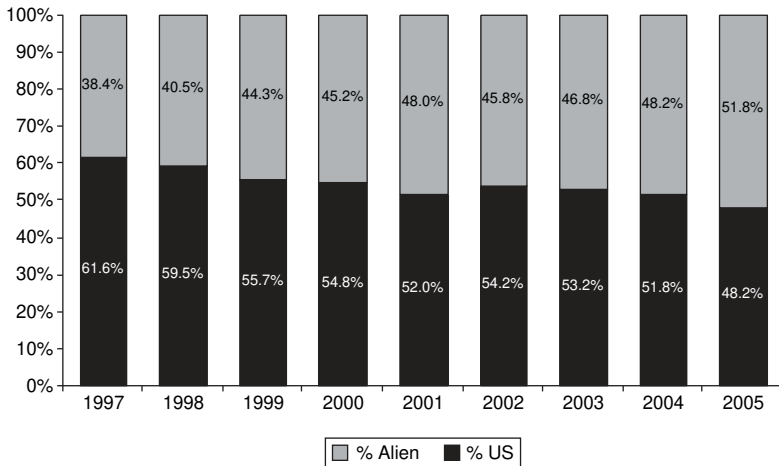
Source: Reinsurance Association of America (2006).

and alien reinsurers from 1997 to 2005. The percentage of reinsurance ceded to alien reinsurers increased significantly during this period, from 38.4 percent in 1997 to 51.8 percent in 2005. Figure A8.4 shows that Bermuda and off-shore Caribbean jurisdictions accounted for 52 percent of reinsurance cessions by U.S. insurance companies in 2005, and Germany, Switzerland, and the United Kingdom accounted for another 41 percent.

Figure A8.4 Premiums Ceded to Alien Reinsurers, by Jurisdiction, in 2005
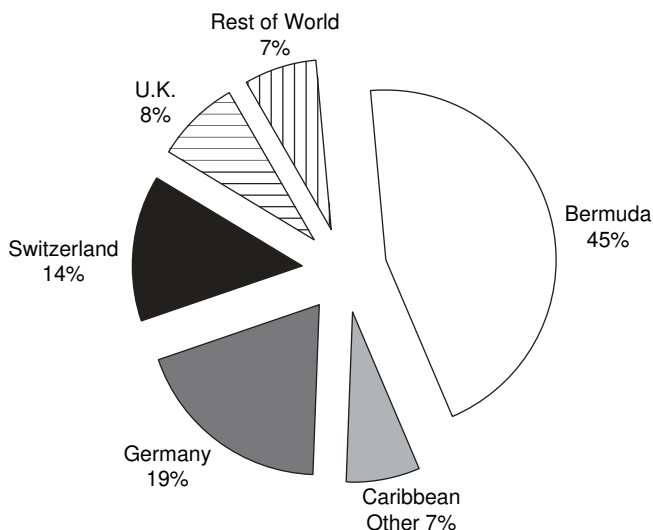
Source: Reinsurance Association of America (2006).

These results provide further evidence of the globalization of the market for reinsurance.

Insurance and Reinsurance Market Response to Mega-Catastrophes

Insurance markets are subject to cycles and crises triggered by shifts in the frequency and severity of losses as well as by investment shocks. The underwriting cycle refers to the tendency of property casualty insurance markets to go through alternating phases of "hard" and "soft" markets. In a hard market, the supply of coverage is restricted and prices rise, whereas in a soft market, coverage supply is plentiful and prices decline. The consensus in the economics literature is that cycles are driven by capital market and insurance market imperfections that prevent capital flowing freely into and out of the industry in response to unusual loss events (Winter 1994, Cummins and Danzon 1997, Cummins and Doherty 2002). Informational asymmetries between capital providers and insurer

management about exposure levels and reserve adequacy can result in high costs of capital during hard markets, so that capital shortages can develop. Insurers are reluctant to pay out retained earnings during soft markets because of the difficulty of raising capital again when the market enters the next hard market phase, leading to excess capacity and downward pressure on prices.

Hard markets are usually triggered by capital depletions resulting from underwriting or investment losses. The three most prominent hard market periods since 1980 resulted from the commercial liability insurance crisis of the 1980s, catastrophe losses from Hurricane Andrew in 1992 and the Northridge earthquake in 1994, and the WTC terrorist attack of 2001. The 1980s liability crisis was triggered by an unexpected increase in the frequency and severity of commercial liability claims, accompanied by a sharp decline in interest rates in the early 1980s; the catastrophe and terrorist crises were driven by catastrophic losses of unexpected magnitude. Each crisis not only depleted insurer capital, but also caused insurers to reevaluate probability of loss distributions and reassess their exposure management and pricing practices.

The existence of cycles and crises implies that the response of insurance markets to large event losses is not necessarily fully efficient in the sense that prices are unpredictable and supply shortages may develop periodically. However, in general, the market has functioned well in response to losses from mega-catastrophes, and evidence below shows that the market's ability to sustain catastrophic losses and to recover quickly from catastrophic events has improved significantly since the 1990s. Thus, the cycle may have moderated somewhat, at least with respect to mega-catastrophes.

Hurricane Andrew in 1992 and to a lesser extent the Northridge earthquake in 1994 were paradigm-shifting events for insurance and reinsurance markets. The magnitude of losses from Andrew in particular took insurers by surprise, and they drastically underestimated the financial impact of the hurricane even after the event took place. There were 13 insurance company failures in 1992 and 1993, primarily attributable to Hurricane Andrew, and three additional failures in Hawaii due to Hurricane Iniki, which also made landfall in 1992 (A.M. Best 2006b).

Catastrophe modeling firms responded to Hurricane Andrew by greatly enhancing the sophistication of their catastrophe modeling systems and

making greater efforts to collect data on insurer loss exposures, especially in catastrophe-prone geographical areas. Insurance companies responded by developing improved loss estimation, underwriting, and risk management capabilities. The capital market responded by supplying significant amounts of new equity capital to restore insurance industry capacity, and several new companies were formed, most prominently in Bermuda. New capital also entered the industry following the WTC terrorist attacks in 2001, although most of the added capacity was not used to provide terrorism insurance coverage. Hence, even prior to the 2004 hurricane season, there was evidence that insurance and capital markets were responding appropriately to mega-catastrophes and developing the capability to handle such events more efficiently in the future.

In general, insurance markets responded efficiently to the hurricane losses of 2004 and 2005. For the most part, the 2004–2005 losses represented an earnings event rather than a capital event, meaning that earnings were reduced but capital was not significantly degraded. New capital entered the industry in several new startup companies as well as via capital issuances by established insurers. Prices of reinsurance increased for the 2006 renewals, as expected considering that the 2004–2005 events caused insurers and modeling firms to increase their expectations of future hurricane losses. The 2006 price increases and capacity shortages primarily affected hurricane-prone regions of the United States. Elsewhere in the world, price increases were more moderate, and severe coverage shortages did not develop (Guy Carpenter 2007). However, reinsurance prices began to soften in late 2006 and early 2007 (Benfield 2007b). Thus, it seems that the underwriting cycle still exists but perhaps has shortened and become somewhat more moderate than in the past. This section provides additional information on the market response following the 2004–2005 storm losses. These two years are emphasized because they represented a paradigm-shifting loss, whereas 2006 losses were significantly lower (see Figure A8.1).

In contrast to prior years, when insurers suffered significant catastrophe losses, 2004 and 2005 were relatively good years for U.S. property casualty insurers. The industry-wide combined ratio for 2004 was 98.1 percent, implying that insurers earned an underwriting profit overall, for the first time since 1978. The industry-wide combined ratio for 2005 was

100.7 percent, significantly less than the average combined ratio of the past 20 years (106.8 percent). A combined ratio near 100 percent implies that insurers essentially broke even on underwriting, even though catastrophe losses boosted the overall combined ratio by 8 percentage points (A.M. Best Company 2006e). U.S. insurers earned operating profits of US$40.5 billion in 2004 and US$48.4 billion in 2005. By contrast, the U.S. insurance industry sustained operating losses of US$2.7 billion in 1992 (Andrew) and US$12.5 billion in 2001 (WTC).

One possible conclusion regarding insurance industry performance based on 2004 and 2005 experience is that insurers were fortunate in the sense that the 2004–2005 hurricane losses occurred in years that were otherwise favorable for insurance markets with regard to both underwriting and investment earnings. However, the performance of 2004–2005 was attributable to more than just good luck. To a significant extent, it appears that insurers have learned how to manage both the underwriting cycle and their exposure to various types of risk much more effectively than in the past. Insurers have introduced and continued to refine sophisticated exposure management models. In addition, underwriting standards have been significantly tightened, and insurers have placed more emphasis on capital allocation and rate of return targeting in various lines of insurance. The result has been a significant increase in the industry's ability to sustain large loss shocks without major disruptions to insurance markets. However, there are clearly repercussions from large loss events, including reduced reinsurance supply and rising reinsurance premiums. These changes reverberate through primary insurance markets in the form of price increases and coverage restrictions.

Reflecting the improved risk management in the industry, only four U.S. insurance companies failed as a result of the 2004–2005 storms, although one of them was the third-largest homeowners insurer in Florida (A.M. Best 2006a). In addition, four Bermuda reinsurers entered into runoff after ratings downgrades, resulting from 2004–2005 hurricane losses, making it difficult for them to retain existing customers and attract new business. Nevertheless, the 2004–2005 storms did not result in significant market disruptions due to insurer or reinsurer insolvencies.

In general, reinsurance markets responded efficiently to the storm losses of 2004–2005. As would be expected, losses of the magnitude experienced

in 2004–2005 had an impact on reinsurers' operating results. However, the effects were not as disruptive as were prior events such as Hurricane Andrew and the WTC terrorist attacks. Moreover, substantial new capital entered the industry, placing the industry in a strong position to finance future catastrophic events.

U.S. reinsurers had combined ratios of 106.7 in 2004 and 144.8 in 2005, which included, respectively, catastrophe losses of 8.3 percentage points in 2004 and 34.6 percentage points in 2005. However, including investment income, U.S. reinsurers posted positive net income in both 2004 and 2005 (A.M. Best Company 2006a). As shown in Figure A8.5, U.S. reinsurers weathered the 2004–2005 storms without significant deterioration in key leverage ratios. The liabilities-to-surplus ratio declined in 2005. The ratio of reinsurance recoverables to surplus increased in 2005, but remained below its peak level attained in 2002.

The combined ratio for the global reinsurance industry is plotted in Figure A8.6 for the period 1988–2006. As expected, the combined ratio peaks in 1992, 2001, and 2005, in response to Andrew, the WTC terrorist attacks, and the Katrina-Wilma-Rita hurricane season, respectively. The combined ratio also shows the cyclicality of the global reinsurance market. Figure A8.6 shows that global reinsurers were profitable in 2004

Figure A8.5 U.S. Reinsurers: Leverage Ratios
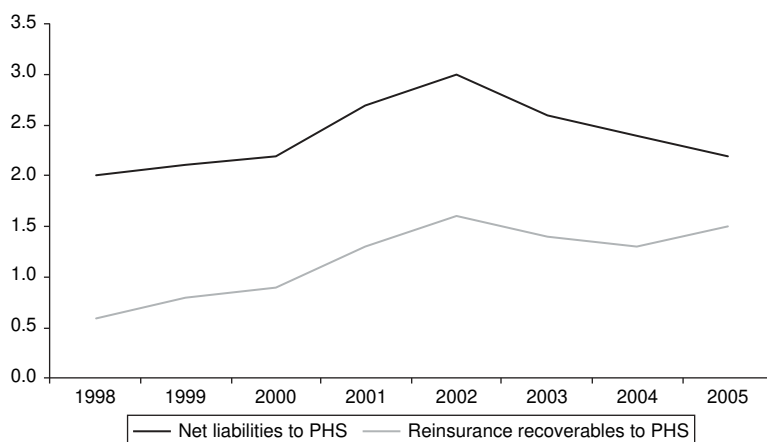
Source: A.M. Best Company (2006a).

Figure A8.6 Global Reinsurance Industry Combined Ratio, 1988–2006

Source: Standard & Poor's and Guy Carpenter (2007).

despite the high hurricane losses and were again profitable in 2006. Because underwriting profits were unusual prior to 2002, the experience since 2002 reveals that the industry has become more proficient at pricing reinsurance and managing exposure to loss.

The Bermuda reinsurance industry bore the brunt of the 2004 and 2005 hurricane losses. Nevertheless, the industry was able to withstand the losses from both disaster years without major disruption. The Best's Bermuda composite combined ratio for 2004 was 94.9 percent, meaning that the firms included in this index actually posted an underwriting profit for 2004. However, the Bermuda composite combined ratio for 2005 was 119.4 percent, implying an underwriting loss of about 20 percent of premiums. The Bermuda composite firms incurred a net operating loss of US$3.3 billion in 2005, following a net operating gain of US$5.5 billion in 2004.

The U.K. and continental European reinsurers also responded well to the 2004–2005 losses. Lloyd's of London and the London market reinsurers had combined ratios below 100 percent in 2004, and the combined ratios for Lloyd's and the London market companies were 112 percent and 119 percent, respectively, in 2005. These combined ratios were far below those experienced by Lloyd's and the London market firms in 2001 (136 percent and 177 percent, respectively). The improved performance for the U.K. firms reflects their improved risk and capital management

techniques, including a risk-adjusted approach to capital. The combined ratios for the continental European reinsurers were mostly in the same range as those of the U.K. reinsurers (see Figure A8.7). Nevertheless, in spite of sustaining approximately US$6 billion in U.S. hurricane losses, the major continental European reinsurers posted operating profits in 2005 (A.M. Best Company 2006a).

In addition to conventional new and seasoned equity, reinsurers also raised capital using innovative vehicles known as *sidecars*. Sidecars date back at least to 2002, but became much more prominent following the 2005 hurricane season (A.M. Best Company 2006a). Sidecars are special-purpose vehicles formed by insurance and reinsurance companies to provide additional capacity to write reinsurance, usually for property catastrophes and marine risks. The capital raised using property catastrophe sidecars following Katrina is shown in Table A8.4. Sidecars are usually off-balance-sheet, formed to write specific types of reinsurance such as property catastrophe quota share or excess of loss from a specified ceding reinsurer. Sidecars generally have limited lifetimes to capitalize on high prices in hard markets and quickly withdraw in soft markets. The sidecars receive premiums for the underwritten reinsurance and are liable to pay claims under the terms of the reinsurance contracts. In addition to providing capacity, sidecars also enable the sponsoring reinsurer to move some of its risks off-balance-sheet, thus improving leverage.

Figure A8.7 Major Reinsurers' Combined Ratios for 2005
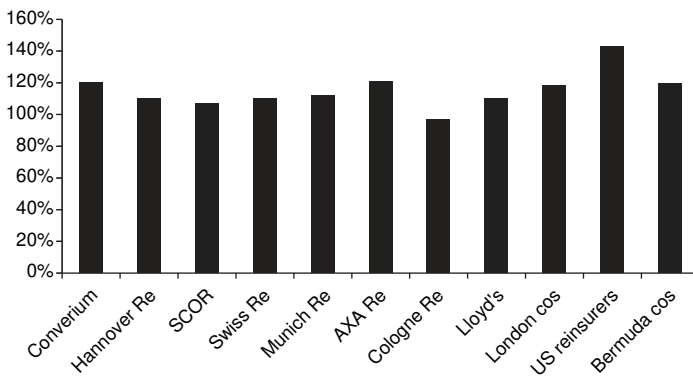
Table A8.4 New Capital in Bermuda: The Classes of 1993, 2001, and 2005

Company/Instrument	Capital ($ M)	Lead Investors
Class of 2005		
Amlin Bermuda Ltd	1,000	Merrill Lynch, Goldman Sachs
Ariel Re	1,000	Blackstone, Texas Pacific, Thomas H. Lee
Arrow Capital Re	500	Goldman Sachs
CIG Re	450	Citadel Investment Group
Flagstone Re	750	West End Capital
Harbor Point	1,500	Stone Point, Chubb
Hiscox Ins. Co.	500	Hiscox Plc
Lancashire	1,000	Capital Z
New Castle Re	500	Citadel Investment
Omega Specialty	170	Omega Underwriting Holdings Plc
Validus	1,000	Aquiline, Merrill Lynch, Goldman Sachs
Total: Class of 2005	8,370	
Sidecars		
Avalon Re	405	Oil Casualty Insurance
Bay Point Re	250	Golden Tree Asset Management
Blue Ocean	300	Montpelier Re and other investors
CastlePoint Re	265	Tower Group
Champlain Ltd	90	Montpelier Re and other investors
Concord Re	375	Lexington (AIG)
Cyrus Re	500	Highfields Management and others
Flatiron Re	600	Goldman subsidiary
Kaith Re	414	Hannover Re
Olympus Re/Helicon	330	
Monte Fort Re	200	Lehman
Panther Re	144	Hiscox
Petrel Re	200	First Reserve Corporation
Rockridge Re	91	West End Capital, Montpelier
Shackleton Re	235	Endurance Specialty Insurance
Sirocco Re	95	Lancashire
Starbound Re	300	Merrill Lynch
Timicuan Re	50	Renaissance Re

(continued)

Table A8.4 New Capital in Bermuda: The Classes of 1993, 2001, and 2005 (*continued*)

Company/Instrument	Capital ($ M)	Lead Investors
Triumphe Re	121	Paris Re
Total: Sidecars	4,965	
Total Sidecars & Reinsurers	13,335	
Class of 2001		
Allied World Assur Co Ltd	1,500	AIG, Chubb, Goldman Sachs
Arch Capital Group Ltd	1,000	Warburg Pincus, Hellman & Friedman
Aspen	200	Aspen Insurance Holdings Ltd
Axis Capital Holdings	1,700	MMC Capital
DaVinci Rein Ltd	400	RenaissanceRe, State Farm
Endurance Specialty Ins Ltd	1,200	Aon, Texas Pacific, Thomas H. Lee
Montpelier Re Hldgs Ltd	900	White Mountains, Cypress, Benfield
Platinum	1,000	Initial Public Offering, St. Paul, Renaissance Re
Olympus Reins Co Ltd	500	Leucadia National, Gilbert Global, Franklin Mutual
Rosemont Re	145	Goshawk Insurance Holdings
Total	8,545	
Class of 1993		
Centre Cat Ltd.	309	Centre Reinsurance Holdings, Morgan Stanley
Global Capital Re	440	Goldman Sachs, Johnson & Higgins, Underwriters Re
IPC (International Property Catastrophe) Re	300	A/G
LaSalle Re	371	Aon, CNA Insurance and Corporate Partners
Mid-Ocean Re	770	Marsh & McLennan, JP Morgan
Partner Re	1,000	Swiss Re, John Head and Partners
Renaissance Re	308	USF&G, Warburg Pincus
Tempest Re	500	General Re
Compass Re	300	SCOR
Starr Excess Liability	500	AIG, General Re, Primerica, Munich Re, Aon
Total	4,798	

Source: A.M Best Company (2006b), Marsh (2006a), Covaleski (1994), Thiele (2006), Benfield (2006d, 2007).

The sidecar structure is diagrammed in Figure A8.8. The sidecar is formed by a ceding reinsurer, and all of its risk-bearing activities are typically confined to this specific reinsurer. The sidecar is usually owned by a holding company, and the holding company raises capital for the sidecar by issuing equity and debt, although sidecars often are exclusively equity financed. If debt is issued, a tiered structure can be used, similar to that of an asset-backed security, to appeal to lenders with differing appetites for risk. Private equity, hedge funds, insurers, and reinsurers provide the capital for the typical sidecar. The capital raised by the sidecar is held in a collateral trust for the benefit of the ceding reinsurer. The cedant then enters into a reinsurance contract with the sidecar, which often represents a quota share agreement. The transaction enables the reinsurer to expand its capacity to write additional reinsurance. Nearly all sidecars to date have been established in Bermuda, due to Bermuda's favorable regulatory and tax systems.

After Katrina, the reinsurance industry raised about US$30 billion in new capital, including both new entrants and existing reinsurers (Benfield 2007a). Conventional equity capital issues totaled about US$9.5 billion for startups and US$12.5 billion in seasoned equity issues. In addition, the

Figure A8.8 Structure of a Typical Sidecar
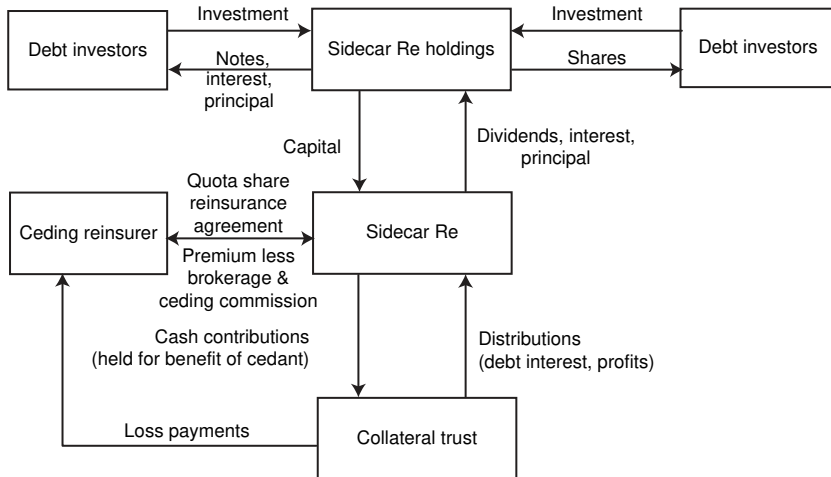
industry raised about US$5 billion in sidecars and another US$5 billion by issuing CAT bonds. The capital raising tended to be centered in Bermuda. To illustrate, the capital raised by new entrants in Bermuda is shown in Table A8.4. The first section of the table shows conventional equity capital issuance by the newly formed Bermuda reinsurers. A total of US$8.37 billion was raised by 11 new entrants. For purposes of comparison, Table A8.4 also shows the new Bermuda companies formed following Hurricane Andrew and the WTC terrorist attack. Startup companies raised US$4.8 billion in new equity following Andrew and US$8.5 billion following WTC. Hence, capital markets respond quickly to new capital needs of reinsurers.

The substantial new equity raised post-Katrina and the development of innovative investment vehicles such as sidecars are signs that the reinsurance market has matured significantly since Hurricane Andrew. The industry is now much more proficient at risk management, and has developed the ability to price contracts more accurately and to raise new capital quickly and efficiently following loss events. The pricing discipline provided by sophisticated equity investors such as hedge funds is likely to dampen the amplitude of underwriting cycles and continue to enhance market stability and capacity.

Although there are many positive signs regarding the financial health of the world's reinsurers, reinsurance prices increased and supply contracted following the 2005 hurricane season, paralleling the market response to earlier catastrophes, such as Andrew and WTC. However, considering the magnitude of the 2005 events, the market response was much less dramatic than in earlier loss episodes. Moreover, because the 2004–2005 hurricanes caused reinsurers to raise their estimates of the frequency and severity of catastrophic losses, price increases were to be expected in 2006.

The overall impact of the 2004 and 2005 hurricanes on the price of reinsurance is illustrated in Figure A8.9, which shows the Guy Carpenter *World Rate on Line Index* for catastrophe reinsurance.[3] The rate on line is a pricing concept defined as the ratio of the premium for a reinsurance contract to the maximum possible payout under the contract.

Figure A8.9 clearly indicates that reinsurance prices are cyclical. That is, they do not fluctuate randomly about a trend line but instead go

Figure A8.9 Catastrophe Reinsurance: World Rate Online Index
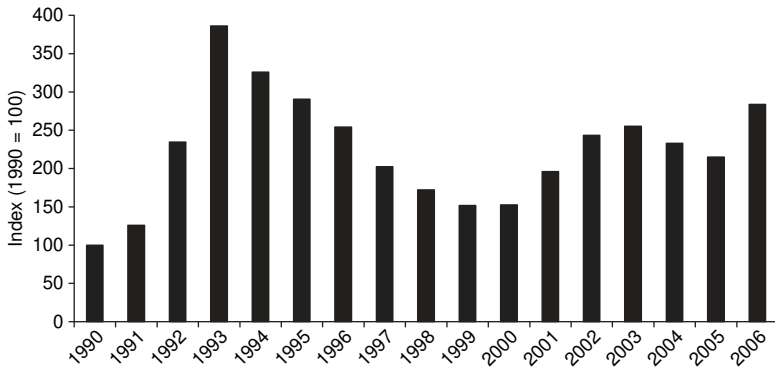
Source: Guy Carpenter and Company (2006).

through periods when prices decline for several years followed by periods
when prices increase. The worst year for the price index was 1993, when
prices spiked as a result of Hurricane Andrew. Prices then declined steadily
until 1999, even though reinsurers incurred heavy losses from the North-
ridge earthquake in 1994. The rate on line index began to increase again
following the WTC terrorist attack of 2001 but did not come close to
duplicating the earlier peak in 1993. In fact, the index declined follow-
ing the 2004 hurricane season, but increased again in 2006 to its highest
level since 1996.

The rate on line index shows the trend in reinsurance pricing but does
not reveal the extent to which price changes are affected by changes in
loss expectations versus changes in loadings (that is, the expense and prof-
it component of the premium). Information on changes in loadings
between 2005 and 2006 is shown in Figure A8.10, which plots the rate
on line against the loss on line for catastrophe reinsurance policies based
on prices in 2005 and 2006. The loss on line is the expected loss on a rein-
surance policy as a percentage of the policy limit.

Figure A8.10 shows that the rate on line increased significantly
between 2005 and 2006 for every level of loss on line. For example, for a
loss on line of 10 percent, the rate on line increased from 17.9 percent to
24.7 percent, an increase of 38 percent. For a 20 percent loss on line, the

Figure A8.10 Reinsurance Pricing
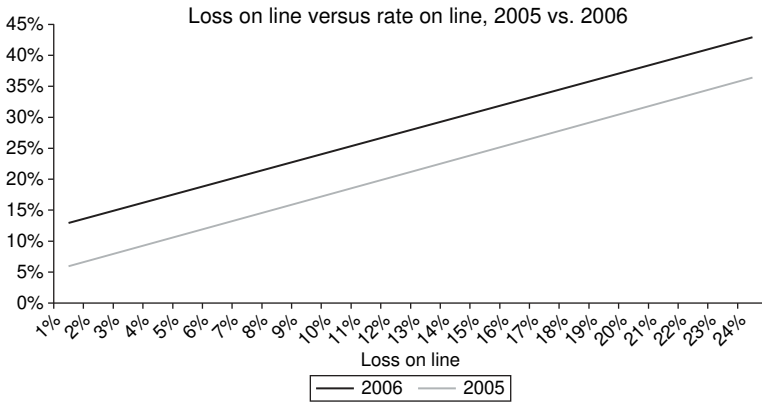
Source: Guy Carpenter (2006).

rate on line increased by 21 percent, from 31.1 percent to 37.7 percent. Thus, reinsurance loadings clearly increased between 2005 and 2006. Such increases are to be expected following events that increase uncertainty about the frequency and severity of loss. The increase also very likely reflected some constraints on capacity due to the 2004–2005 losses that caused price increases through the normal mechanism of supply and demand. As mentioned above, the price increases and accompanying capacity short-ages were especially severe for U.S. coastal properties, although pricing eased somewhat late in 2006 after it became apparent that 2006 would be a favorable loss year.

Conclusion

Reinsurance markets responded efficiently to the catastrophe losses of 2004–2005. Losses were paid with minimal disruption of insurance and reinsurance markets. There were few insurance or reinsurance company insolvencies, and reinsurer combined ratios were moderate in comparison with past loss events such as Hurricane Andrew and the WTC terrorist attacks. Substantial amounts of new capital entered the industry very

quickly following the 2005 hurricane season, paralleling the experience following the WTC attack and revealing that reinsurers have developed a high-speed pipeline into the capital market. Overall, the improved performance of the industry reveals that considerable progress has been made in risk and exposure management, capital allocation, rate of return targeting, and the ability to raise new capital. Although prices increased following the 2005 hurricane season and coverage availability tightened somewhat, this appears to be a normal market response to higher expected loss frequency and severity as well as to increased uncertainty regarding future catastrophe losses.

Notes

1. This review draws upon material published in Cummins (2007).

2. Recoverables represent funds owed by alien reinsurers to U.S. insurers, consisting primarily of loss payments owed under reinsurance contacts. Policy-holders surplus is the property-casualty insurance industry's terminology for equity capital.

3. The *Rate on Line Index* is compiled by Guy Carpenter, the world's largest reinsurance broker, based on prices paid by its clients, which represent most of the world's primary insurers.

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CAT Bonds and Other Risk-Linked Securities: State of the Market and Recent Developments

Introduction

This annex analyzes risk-linked securities as sources of risk capital for the insurance and reinsurance industries. Risk-linked securities are innovative financing devices that enable insurance risk to be sold in capital markets, raising funds that insurers and reinsurers can use to pay claims arising from mega-catastrophes and other loss events. The most prominent type of risk-linked security is the catastrophe risk (CAT) bond, which is a fully collateralized instrument that pays off on the occurrence of a defined catastrophic event. CAT bonds and other risk-linked securities are potentially quite important, because they have the ability to access the capital markets to provide capacity for insurance and reinsurance markets. The CAT bond market has expanded significantly in recent years and now seems to have reached critical mass. Although the CAT bond market is small in comparison with the overall non-life reinsurance market, it is significantly larger than the property catastrophe reinsurance market. Some industry experts observe that nontraditional risk financing instruments, including CAT bonds, industry loss warranties (ILWs), and sidecars, now represent the majority of the property catastrophe retrocession market.

This annex begins by discussing the design of CAT bonds and other risk-linked securities. The discussion then turns to the evolution of the risk-linked securities market and an evaluation of the current state of the market. The scope of the annex is limited primarily to securitization of catastrophic property casualty risks. However, there also are rapidly developing markets in automobile and other types of non-catastrophe insurance securitizations as well as life insurance securitizations, which are discussed in Cowley and Cummins (2005).

The Structure of Risk-Linked Securities

This section considers the structure of CAT bonds and other risk-linked securities that have been used to raise risk capital for property casualty risks. The discussion focuses primarily on CAT bonds. Included in the latter category are some investment structures that are not necessarily securities in the sense of being tradable financial instruments, but are innovative approaches whereby insurers and reinsurers can access capital markets to supplement traditional reinsurance.

Risk-Linked Securities: Early Developments

Following Hurricane Andrew in 1992, efforts began to access securities markets directly as a mechanism for financing future catastrophic events. The first contracts were launched by the Chicago Board of Trade (CBOT), which introduced catastrophe futures in 1992 and later established catastrophe put and call options. The options were based on aggregate catastrophe loss indexes compiled by Property Claims Services (PCS), an insurance industry statistical agent.[1] The contracts were later withdrawn due to lack of trading volume. In 1997, the Bermuda Commodities Exchange (BCE) also attempted to develop a market in catastrophe options, but the contracts were withdrawn within two years as a result of lack of trading.

Insurers had little interest in the CBOT and BCE contracts for various reasons, including the thinness of the market, possible counterparty risk on the occurrence of a major catastrophe, and the potential for

disrupting long-term relationships with reinsurers. Another concern was the possibility of excessive basis risk—the risk that payoffs under the contracts would be insufficiently correlated with insurer losses. A study by Cummins, Lalonde, and Phillips (2004) confirms that basis risk was a legitimate concern.

Interestingly, in 2007 two separate exchanges, the Chicago Mercantile Exchange (CME) and the New York Mercantile Exchange (NYMEX), introduced futures-and-options contracts on U.S. hurricane risk. Both exchanges indicate in their distributional materials on the contracts that their introduction was motivated by the 2005 U.S. hurricane season, which revealed the limitations on the capacity of insurance and reinsurance markets. CME currently lists contracts on hurricanes in six U.S. regions—the Gulf Coast, Florida, Southern Atlantic Coast, Northern Atlantic Coast, Eastern U.S., and Galveston-Mobile. CME contracts settle on the Carvill Hurricane Indexes created by Carvill, a reinsurance intermediary. NYMEX initial listings were a U.S. national contract, a Florida contract, and a Texas-to-Maine contract. The NYMEX contracts will settle on catastrophe loss indexes. The NYMEX indexes are calculated by Gallagher Re based on data provided by Property Claims Services, the same data source used for the earlier CBOT options. Given that both the CME and NYMEX contracts are based on broadly defined geographical areas, they will be subject to significant basis risk. Thus, it remains to be seen whether these contracts will succeed where the similar CBOT contracts failed. However, given the existence of a secondary market as well as dedicated CAT bond mutual funds, it is possible that the CME or NYMEX contracts could be used for hedging purposes by investors with broadly diversified portfolios of CAT bonds.

Another early attempt at securitization involved contingent notes known as "Act of God" bonds. In 1995, Nationwide issued US$400 million in contingent notes through a special trust, Nationwide Contingent Surplus Note (CSN) Trust. Proceeds from the sale of the bonds were invested in 10-year Treasury securities, and investors were provided with a coupon payment equal to 220 basis points over Treasuries. Embedded in these contingent capital notes was a "substitutability" option for Nationwide. Given a prespecified event that depleted Nationwide's equity capital, Nationwide could substitute up to US$400 million of surplus notes for the

Treasuries in the Trust at any time during a 10-year period for any "business reason," with the surplus notes carrying a coupon of 9.22 percent.[2] Although two other insurers issued similar notes, this type of structure did not achieve a significant segregation of Nationwide's liabilities, leaving investors exposed to the general business risk of the insurer and to the risk that Nationwide might default on the notes. In addition, unlike CAT bonds, the withdrawal of funds from the trust would obligate Nationwide to eventually repay the Trust. Consequently, contingent notes are not considered a major solution to the risk financing problem.

Catastrophe Risk (CAT) Bonds

The securitized structure that has achieved the greatest degree of success is the CAT bond—modeled on asset backed security transactions that have been executed for a wide variety of financial assets, including mortgage loans, automobile loans, aircraft leases, and student loans. CAT bonds are part of a broader class of assets known as *event-linked bonds*, which pay off on the occurrence of a specified event. Most event-linked bonds issued to date have been linked to catastrophes such as hurricanes and earthquakes, although bonds also have been issued that respond to mortality events.

The first successful CAT bond was an US$85 million issue by Hannover Re in 1994 (Swiss Re 2001). The first CAT bond issued by a nonfinancial firm, in 1999, covered earthquake losses in the Tokyo region for Oriental Land Company, the owner of Tokyo Disneyland. Although various design features were tested in the early stages of the CAT bond market, CAT bonds have recently become more standardized. The standardization has been driven by the need for bonds to respond to the requirements of the principal stakeholders, including sponsors, investors, rating agencies, and regulators.

CAT bonds often are issued to cover the so-called *high layers* of reinsurance protection, for example, protection against events that have a probability of occurrence of 0.01 or less (that is, a *return period* of at least 100 years). The higher layers of protection often go un-reinsured by ceding companies for two primary reasons: 1) for events of this magnitude, ceding insurers are more concerned about the credit risk of the reinsurer, and 2) high layers tend to have the highest reinsurance margins or pricing spreads above the expected loss (Cummins 2007). Because

CAT bonds are fully collateralized, they eliminate concerns about credit risk, and because catastrophic events have low correlations with investment returns, CAT bonds may provide lower spreads than high-layer reinsurance because they are attractive to investors for diversification.

CAT bonds also can lock in multiyear protection (unlike traditional reinsurance, which usually is for a one year period) and shelter the sponsor from cyclical price fluctuations in the reinsurance market. The multiyear terms (or *tenors*) of most CAT bonds also allow sponsors to spread the fixed costs of issuing the bonds over a multiyear period, reducing costs on an annualized basis.

A typical CAT bond structure is diagrammed in Figure A9.1. The transaction begins with the formation of a single purpose reinsurer (SPR). The SPR issues bonds to investors and invests the proceeds in safe, short-term securities such as government bonds or AAA corporates, which are held in a trust account. Embedded in the bonds is a call option that is triggered by a defined catastrophic event. On the occurrence of the event, proceeds are released from the SPR to help the insurer pay claims. In most CAT bonds, the principal is fully at risk; that is, if the contingent event is sufficiently large, the investors could lose the entire principal in the SPR. In return for the option, the insurer pays a premium to the investors. The fixed returns on the securities held in the trust are usually swapped for floating returns based on LIBOR (London interbank offered rate) or some other widely accepted index. The swap is made to immunize the insurer and the investors from interest rate risk. Consequently, the investors

Figure A9.1 CAT Bond with Single-Purpose Reinsurer
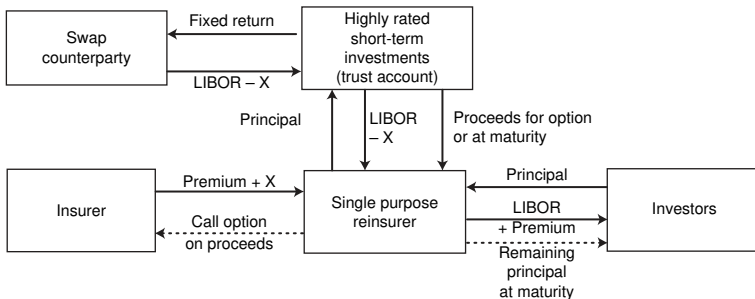
Source: Authors.

receive LIBOR plus the risk premium in return for providing capital to the trust. If no contingent event occurs during the term of the bonds, the principal is returned to the investors upon the expiration of the bonds.

Some CAT bond issues have included *principal protected tranches*, where the return of principal is guaranteed. In this tranche, the triggering event would affect the interest and spread payments and the timing of the repayment of principal. For example, a two-year CAT bond subject to the payment of interest and a spread premium might convert into a ten-year zero-coupon bond that would return only the principal. Principal-protected tranches have become relatively rare, primarily because they do not provide as much risk capital to the sponsor as a principal-at-risk bond.

Insurers prefer to use a SPR to capture the tax and accounting benefits associated with traditional reinsurance.[3] Investors prefer SPRs to isolate the risk of their investment from the general business and insolvency risks of the insurer, thus creating an investment that is a "pure play" in catastrophe risk. In addition, the bonds are fully collateralized, with the collateral held in trust, insulating the investors from credit risk. As a result, the issuer of the securitization can realize lower financing costs through segregation. The transaction also is more transparent than a debt issue by the insurer, because the funds are held in trust and are released according to carefully defined criteria.

The bonds are attractive to investors, because catastrophic events have low correlations with returns from securities markets and hence are valuable for diversification purposes (Litzenberger, Beaglehole, and Reynolds 1996). Although the US$100 billion-plus "Big One" hurricane or earthquake could drive down securities prices, creating systematic risk for CAT securities, systematic risk is considerably lower than for most other types of assets, especially during normal periods.

In the absence of a traded underlying asset, CAT bonds and other insurance-linked securities have been structured to pay off on three types of triggering variables: 1) *indemnity triggers*, where payouts are based on the size of the sponsoring insurer's actual losses, 2) *index triggers*, where payouts are based on an index not directly tied to the sponsoring firm's losses, or 3) *hybrid triggers*, which blend more than one trigger in a single bond.

Three broad types of indexes can be used as CAT bond triggers: industry loss indexes, modeled loss indexes, and parametric indexes. With

industry loss indexes, the payoff on the bond is triggered when estimated industrywide losses from an event exceed a specified threshold. For example, the payoff could be based on estimated catastrophe losses in a specified geographical area provided by Property Claims Services (PCS), the same organization that provided the indexes for the CBOT options. A modeled loss index is calculated using a model provided by one of the major catastrophe modeling firms—Applied Insurance Research Worldwide, EQECAT, or Risk Management Solutions. The index could be generated by running the model on industrywide exposures for a specified geographical area. Alternatively, the model could be run on a representative sample of the sponsoring insurer's own exposures. In each case, an actual event's physical parameters are used in running the simulations. Finally, with a parametric trigger, the bond payoff is triggered by specified physical measures of the catastrophic event, such as the wind speed and location of a hurricane or the magnitude and location of an earthquake.

A number of factors may be considered in the choice of a trigger when designing a CAT bond (Guy Carpenter 2005, Mocklow, DeCaro, and McKenna 2002). The choice of a trigger involves a trade-off between moral hazard (transparency to investors) and basis risk. Indemnity triggers are often favored by insurers and reinsurers, because they minimize basis risk, that is, the risk that the loss payout of the bond will be greater or less than the sponsoring firm's actual losses. However, indemnity triggers require investors to obtain information on the risk exposure of the sponsor's underwriting portfolio, which can be difficult, especially for complex commercial risks. In addition, indemnity triggers put the sponsor at a disadvantage as they require disclosure of confidential information on the sponsor's policy portfolio. Contracts based on indemnity triggers may require more time than non-indemnity triggers to reach final settlement due to the length of the loss adjustment process.

Investors tend to favor index triggers, because they minimize the problem of moral hazard and maximize the transparency of the transaction. Moral hazard can occur if the issuing insurer fails to settle catastrophe losses carefully and appropriately (that is, overpays) because of the correlation of the bond payout with its realized losses. The insurer might also excessively expand its premium writings in geographical areas covered by the bond. Although CAT bonds almost always contain copayment

provisions to control moral hazard, moral hazard remains a residual concern for some investors. Indexes also have the advantage of being measurable more quickly after the event than indemnity triggers, which allows the sponsor to receive payment under the bond more quickly.

The principal disadvantage of index triggers is that they expose the sponsor to a higher degree of basis risk than do indemnity triggers. The degree of basis risk varies depending upon several factors. Parametric triggers tend to have the lowest exposure to moral hazard but may have the highest exposure to basis risk. However, even with a parametric trigger, basis risk often can be reduced substantially by appropriately defining the location where the event severity is measured. Likewise, industry loss indexes based on narrowly defined geographical areas tend to have less basis risk than do those based on wider areas (Cummins, Lalonde, and Phillips 2004). Modeled loss indexes may become the favored mechanism for obtaining the benefits of an index trigger without incurring significant basis risk. However, modeled loss indexes are subject to "model risk," that is, the risk that the model will overestimate or underestimate the losses from an event. This risk is diminishing over time as the modeling firms continue to refine their models.

Sidecars

An innovative financing vehicle with some similarities to both conventional reinsurance and CAT bonds is the *sidecar*. Sidecars date back to at least 2002 but became much more prominent following the 2005 hurricane season (A.M. Best Company 2006a). Sidecars are special-purpose vehicles formed by insurance and reinsurance companies to provide additional capacity to write reinsurance, usually for property catastrophes and marine risks, and typically serve to accept retrocessions exclusively from a single reinsurer. Sidecars are typically off-balance-sheet, formed to write specific types of reinsurance, such as property catastrophe quota share or excess of loss, and generally have limited lifetimes. Reinsurers receive override commissions for premiums ceded to sidecars. Most sidecars are capitalized by private investors such as hedge funds. Sidecars receive premiums for the reinsurance underwritten and are liable to pay claims under the terms of the reinsurance contracts. In addition to providing capacity,

sidecars also enable the sponsoring reinsurer to move some of its risks off-balance-sheet, thus improving leverage. Sidecars can also be formed quickly and with minimal documentation and administrative costs. For further discussion, see Cummins (2007) and Lane (2007).

Catastrophe Equity Puts (Cat-E-Puts)

Another capital market solution to the catastrophic loss financing problem is catastrophe equity puts (Cat-E-Puts). Unlike CAT bonds, Cat-E-Puts are not asset-backed securities, but options. In return for a premium paid to the writer of the option, the insurer obtains the option to issue preferred stock at a pre-agreed price on the occurrence of a contingent event. This enables the insurer to raise equity capital at a favorable price after a catastrophe, when its stock price is likely to be depressed. Cat-E-Puts tend to have lower transaction costs than CAT bonds, because there is no need to set up an SPR. However, because they are not collateralized, these securities expose the insurer to counterparty performance risk. In addition, issuing the preferred stock can dilute the value of the firm's existing shares. Thus, although Cat-E-Puts have been issued, they have not become nearly as important as CAT bonds.

Catastrophe Risk Swaps

Like Cat-E-Puts, catastrophe risk swaps generally are not prefunded, but are based only on an agreement between two counterparties. Catastrophe swaps can be executed between two firms with exposure to different types of catastrophe risk. An example of a catastrophe risk swap is provided in Figure A9.2. In the example, a reinsurer with exposure to California earthquake risk agrees to swap its risk with another reinsurer with exposure to Japanese earthquake risk. Another example is the swap executed by Mitsui Sumitomo Insurance and Swiss Re in 2003, which swapped US$12 billion of Japanese typhoon risk against US$50 million each of North Atlantic hurricane and European windstorm risk. Swaps are facilitated by the Catastrophic Risk Exchange (CATEX), a Web-based exchange where insurers and reinsurers can arrange reinsurance contracts and swap transactions.

Figure A9.2 Catastrophe (Risk) Swap

Reinsurers A and B swap earthquake risk

P_A = contingent payment for Japan earthquake

P_B = contingent payment for California earthquake
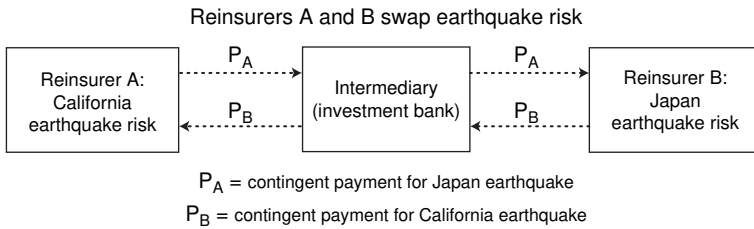
Source: Authors.

The event or events that trigger payment under the swap are carefully defined in the swap agreement. For example, a parametric trigger could be used, such as an earthquake of a specified magnitude in Tokyo for the Japanese side of the swap and a comparable earthquake in San Francisco for the U.S. side. The swap can be designed to ensure that the two sides of the risk achieve *parity*—that the expected losses under the two sides of the swap are equivalent. This obviously requires an extensive modeling exercise, using one of the models developed internally or by catastrophe modeling firms. With parity, there is no exchange of money at the inception of the contract, only on the occurrence of one of the triggering events. The swap also defines a specified amount of money (such as US$200 million) to be paid if an event occurs. Some contracts have sliding-scale payoff functions, which specify full payout for the severest events and partial payout for smaller events. Swaps can be annual or can span several years. Swaps also can be executed to fund multiple risks simultaneously, such as swapping North Atlantic hurricane risk for Japanese typhoon risk in the same contract as the earthquake swap.

Swaps may be attractive substitutes for reinsurance, CAT bonds, and other risk financing devices. They are advantageous because the reinsurer simultaneously lays off some of its core risk and obtains a new source of diversification (Takeda 2002) by exchanging uncorrelated risks with the counterparty. Thus, swaps may enable reinsurers to operate with less equity capital. Swaps also have low transaction costs and reduce current expenses, because no money changes hands until the occurrence of a triggering event. The potential disadvantages of swaps are that modeling the risks to achieve parity can be challenging and not necessarily completely

accurate. Swaps also may create more exposure to basis risk than some other types of contracts and also create exposure to counterparty non-performance risk. The possibility of nonperformance risk provides another potential role for an investment bank or specialized reinsurer to execute hedges to enhance the credit quality of the swap. However, such hedging would add to the transactions costs of the deal.

Industry Loss Warranties

As explained below, a possible impediment to the growth of the CAT securitization market has to do with whether the securities are treated as reinsurance by regulators, and hence given favorable regulatory accounting treatment. It seems clear that properly structured *indemnity* CAT securities (those that pay off based on the losses of the issuing insurer) will be treated as reinsurance. However, U.S. regulators are still deliberating about the regulatory treatment of index-linked risk financing securities. Nevertheless, regulation does not seem to have impeded the strong growth of the CAT bond market during the past several years, because sponsors and their bankers have found various ways to finesse potential regulatory problems. For example, even if the SPV is an offshore vehicle, the trust holding the assets can be onshore, mitigating regulatory concerns regarding credit risk of offshore entities.

Dual-trigger contracts known as *industry loss warranties* (ILWs) also overcome regulatory objections to non-indemnity bonds (McDonnell 2002). ILWs are dual-trigger reinsurance contracts that have a *retention trigger* based on the incurred losses of the insurer buying the contract, and also a *warranty trigger* based on an industrywide loss index. That is, the contracts pay off on the dual event that a specified industrywide loss index exceeds a particular threshold at the same time that the issuing insurer's losses from the event equal or exceed a specified amount. Both triggers have to be hit for the buyer of the contract to receive a payoff. The issuing insurer thus is covered in states of the world when its own losses are high and the reinsurance market is likely to enter a hard market phase. ILWs cover events from specified catastrophe perils in a defined geographical region. For example, an ILW might cover losses from hurricanes in the southeastern United States. The term of the contract is

typically one year. ILWs may have *binary triggers*, where the full amount of the contract pays off once the two triggers are satisfied, or *pro rata triggers*, where the payoff depends upon how much the loss exceeds the warranty.

The principal advantages of ILWs are that they are treated as reinsurance for regulatory purposes, and that they can be used to plug gaps in reinsurance programs. They also represent an efficient use of funds in that they pay off in states of the world where both the insurer's losses and industrywide losses are high. The principal disadvantage is that ILWs are supplied primarily by reinsurers and hence do not access the capacity of the broader capital markets. However, ILWs can be packaged and securitized to broaden the capital base.

The Risk-Linked Securities Market

This section reviews the recent history and current status of the risk-linked securities market. The focus is primarily on CAT bonds, the most commonly used securitized structure in financing catastrophic risk.

The CAT Bond Market: Size and Bond Characteristics

Although the CAT bond market seemed to get off to a slow start in the late 1990s, the market has matured and is now a steady source of capacity for both primary insurers and reinsurers. The market is growing steadily and set new records for market issuance volume in 2005, 2006, and 2007. CAT bonds make sound economic sense as a mechanism for funding mega-catastrophes. Catastrophes such as Hurricane Katrina and the fabled and yet to be realized US$100 billion-plus "Big One" in California, Tokyo, or Florida are large relative to the resources of the insurance and reinsurance industries but are small relative to the size of capital markets. A US$100 billion loss would represent less than 0.5 percent of the value of U.S. securities markets and could easily be absorbed through securitized transactions. Securities markets also are more efficient than insurance markets in reducing information asymmetries and facilitating price discovery. Thus, the CAT bond market will likely continue to grow, and CAT bonds will probably eventually be issued in the public securities markets, rather than being confined primarily to private placements.

The new issue volume in the CAT bond market from 1997 through July 2007 is shown in Figure A9.3. The data in the figure apply only to non-life CAT bonds. Recently, event-linked bonds have also been issued to cover third-party commercial liability, automobile quota share, and indemnity-based trade credit reinsurance. There is also a growing market in various types of life insurance securitizations.

Figure A9.3 shows that the market has grown from less than US$1 billion per year in 1997 to more than US$2 billion per year in the first half of 2005, and then accelerated to nearly US$5 billion in 2006 and nearly US$6 billion in the first seven months of 2007. The number of transactions has also been increasing, to 24 in the first seven months of 2007. A substantial number of the issuers in 2005–2007 were first-time sponsors of CAT bonds, although established players such as Swiss Re continue to play a major role (Guy Carpenter 2007). Figure A9.4 shows that the amount of risk capital outstanding in CAT bond markets has also grown steadily. Risk capital outstanding represents the face value of all bonds still in effect in each year shown in the figure. Nearly US$9 billion of risk capital was outstanding by the end of 2006, and nearly US$14 billion by mid-2007 (Swiss Re 2007a).

The characteristics of CAT bonds continue to evolve, but the overall trend is toward a higher degree of standardization. The issue volume by trigger type between 2000 and 2006 is shown in Figure A9.5. For the

Figure A9.3 Non-Life CAT Bonds: New Issues
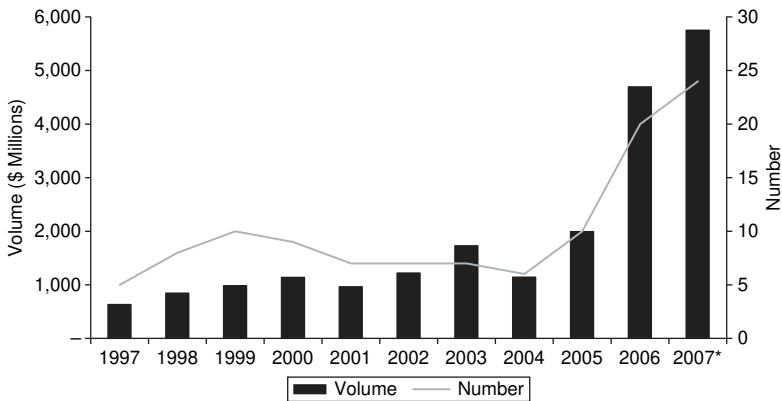
Source: Guy Carpenter (2007), Swiss Re (2007).
*Through July 31, 2007.

Figure A9.4 CAT Bonds: Risk Capital Outstanding
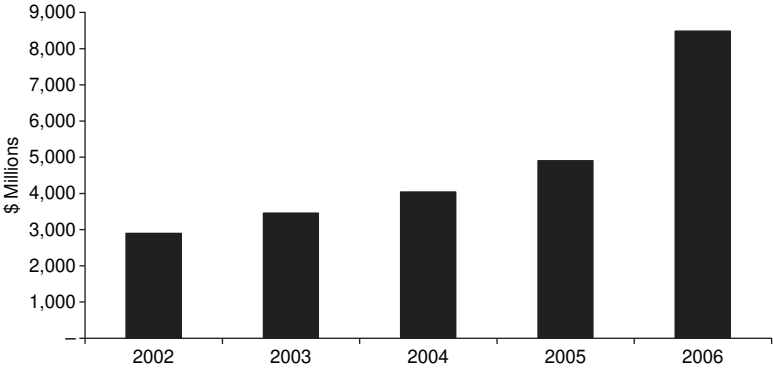
Figure A9.5 CAT Bond Issues by Trigger Type
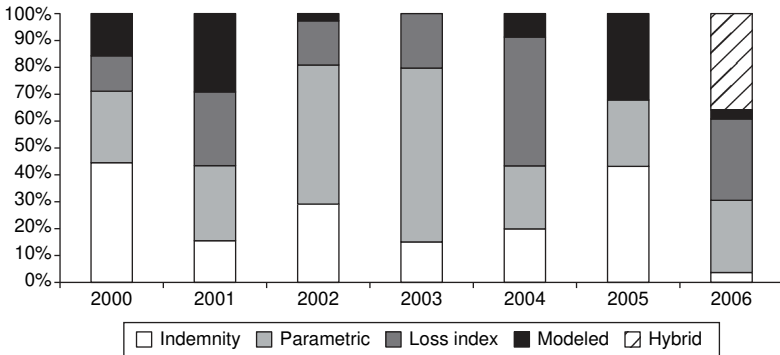
period as a whole, index or hybrid bonds accounted for 80 percent of total issue volume. The leading type of index by issue volume is the parametric index, accounting for 34 percent of total issuance. Indemnity bonds made a comeback in 2005, but fell off again in 2006.

The trends in bond tenor are shown in Figure A9.6. Even though some 10-year bonds were issued during the 1990s, the market seems to have converged on shorter-term issues, with 3-year bonds constituting the majority of issues in 2005 and 2006. Maturities greater than one year tend to be favored, because they provide a steady source of risk capital that is insulated from year-to-year swings in reinsurance prices, and because they permit issuers to amortize costs of issuance over a longer period, reducing

Figure A9.6 CAT Bond Transactions by Bond Tenor
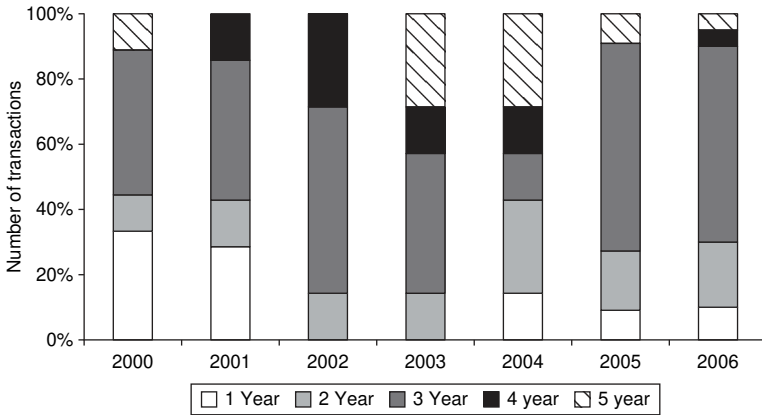
Source: Guy Carpenter (2006a, 2007).

per period transactions costs. Bonds longer than five years are not favored by the market, because market participants would like to re-price the risk periodically to reflect new information on the frequency and severity of catastrophes and to recognize changes in the underwriting risk profile of the sponsor.

For the period as a whole, insurers accounted for 47.9 percent of bonds by issue volume, reinsurers accounted for 47.5 percent, and corporate or government issues accounted for 4.7 percent. In 2006, the first government-issued disaster relief bond placement was executed to provide funds to the government of Mexico to defray costs of disaster recovery. The bond transferred US$160 million of Mexican earthquake risk to the capital markets through a special-purpose vehicle (CAT-Mex Ltd.). The deal was part of an overall US$450 million transaction, involving both conventional reinsurance and securitization. The transaction was executed by Swiss Re and Deutsche Bank Securities. Because Mexican earthquake risk has very low or zero correlation with the risks covered by other newly issued and outstanding CAT bonds, the Mexican bond is very valuable to CAT bond investors for diversification purposes. Accordingly, the premium on the Mexican bonds is quite low, about 2.3 percent over LIBOR for the class A bonds issued by CAT-Mex. This compares very favorably with the premiums on prior earthquake bonds issued in the United States and Japan (Cardenas 2006).

Obtaining a financial rating is a critical step in issuing a CAT bond, because buyers use ratings to compare yields on CAT bonds with other corporate securities. Consequently, almost all bonds are issued with financial ratings. The ratings by bond issue volume from 2000 through 2006 are shown in Figure A9.7. The vast majority of CAT bonds issued in 2005 and 2006 have been below investment grade (ratings below BBB), that is, 93.0 percent of the 2005 issuance volume and 94.5 percent of the 2006 volume were rated BB or B. In 2007, there has been a resurgence in investment grade bonds (Swiss Re 2007a), although the majority of CAT bonds are below investment grade in 2007 as well. Although bond ratings lower than investment grade are generally bad news for insurers, reinsurers, and other corporate bond issuers, they are not necessarily adverse in the CAT bond market. Because CAT bonds are fully collateralized, CAT bond ratings tend to be determined by the probability that the bond principal will be hit by a triggering event. Thus, the bond ratings merely indicate the layer of catastrophic risk coverage provided by the bonds.

In the past, the CAT bond market has been criticized for lack of investor interest. However, that assessment is now outdated—recent data suggest broad market interest in CAT bonds among institutional investors. Figure A9.8 shows the percentage of new issue volume by

Figure A9.7 CAT Bond Issue Volume by Financial Rating
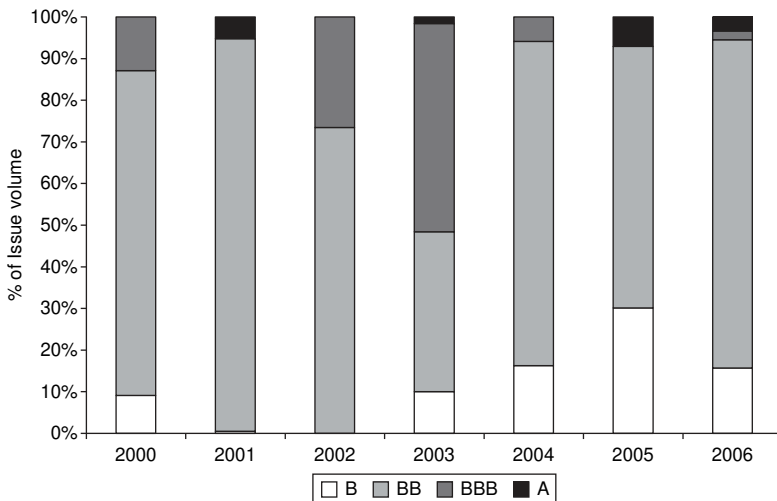
Source: Guy Carpenter (2006a, 2007).

Figure A9.8 CAT Bonds: New Issue Volume Purchased by Investor Type
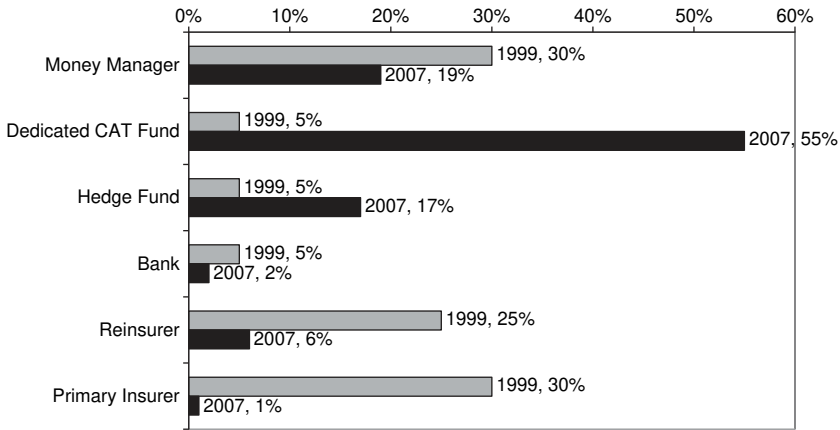
Source:Swiss Re (2007).

investor type in 1999 and 2007. In 1999, insurers and reinsurers were very prominent on both the supply and demand sides of the market and were among the leading investors in the bonds, accounting for 55 percent of the market. If insurers and reinsurers are on both sides of the market, the market cannot be said to have attracted very much new capital into the financing of catastrophic risk. However, by 2007, insurers and reinsurers accounted for only 7 percent of demand, suggesting that substantial external capital has been attracted to the market. Dedicated CAT funds accounted for 55 percent of the market in 2007, and money managers and hedge funds accounted for 36 percent. The declining spreads and increasingly broad market interest in the bonds suggest that the bonds are attractive to investors and are playing an increasingly important role relative to conventional reinsurance.

In addition to CAT bonds, a significant amount of new capital was raised through sidecars in 2005 and 2006. The new capital raised through Bermuda sidecars in 2006 is shown in Table A9.1. Eleven sidecar transactions took place in 2006, totaling US$2.9 billion in risk capital. In 2005, there were eight transactions, which raised a total of US$2.5 billion. There was some indication that sidecars were competing with CAT bonds for risk capital of interested investors in 2005, leading to rising prices and tightening capacity in the CAT bond market (Guy Carpenter 2006a). However, the CAT bond market clearly rebounded in 2006 and 2007.

Table A9.1 New Capital Raised Through Sidecars in 2006 ($ Millions)

Vehicle Name	Sponsor	Equity	Debt	Total
Bay Point Re	Harborpoint	125	125	250
Concord Re	Lexington Insurance	375	375	750
Helicon Re	White Mountains	145	185	330
Monte Forte Re	Flagstone Re	60		60
Panther Re	Hiscox	144	216	360
Petrel Re	Validus Re	200		200
Sirocco Re	Lancashire Re	95		95
Starbound Re	Rennaissance Re	127	184	311
Stoneheath Re	XL Re	300		300
Timicuan Re	Rennaissance Re	50	20	70
Triomphe Re	Paris Re	121	64	185
TOTAL		1,742	1,169	2,911

Source: MMC Securities (2007).

The first publicly acknowledged total loss of principal for a CAT bond took place in 2005, although there apparently have been earlier wipeouts that were not publicly announced (Lane and Beckwith 2006). Kamp Re, a US$190 million bond issued in July 2005 under the sponsorship of Zurich Financial, apparently paid out its entire principal to the sponsor as a result of Hurricane Katrina claims (Guy Carpenter 2006a). Kamp Re had an indemnity trigger, and the short-term impact of the wipeout was to increase investor wariness of indemnity-based transactions. Indemnity transactions rebounded in 2007, however, due to a surge of primary insurer CAT bond issues (Swiss Re 2007a).

The longer-term impact of the Kamp Re wipeout on the CAT bond market is likely to be favorable. The smooth settlement of the Kamp Re bond established an important precedent, showing that CAT bonds function as designed, with minimal confusion and controversy between the sponsor and investors. Thus, the wipeout served to "reduce the overall uncertainty associated with this marketplace and therefore increase both investor and sponsor demand for these instruments" (Guy Carpenter 2006a, p. 4).

CAT Bond Prices

CAT bonds are priced at spreads over LIBOR, meaning that investors receive floating interest plus a spread or premium over the floating rate.

In the past, CAT bonds have been somewhat notorious for having high spreads, and much has been written trying to explain the magnitude of the spreads (for example, Froot 2001). However, there are now significant indications that the spreads are not as high as they might seem relative to the cost of reinsurance, showing CAT bonds to be more competitive with conventional reinsurance than earlier analyses may have suggested.

Because CAT bonds are not publicly traded, it is difficult to obtain data on CAT bond yields. However, there is an active, though nonpublic, secondary market that provides some guidance on yields. The secondary market yields on CAT bonds are shown quarterly from the third quarter of 2001 through the first quarter of 2007 in Figure A9.9. The numbers in the figure reflect investment yields over LIBOR. The figure shows the absolute yields and also an estimate of the expected loss. The data are from Lane and Beckwith (2005, 2006, 2007a). Figure A9.9 shows the expected loss, the premium, and the bond spread (ratio of premium to expected loss), based on averages of secondary market transactions.

Prior to Katrina, there was a somewhat steady decline in yields and a slight increase in the expected loss, implying a general decline in the cost of financing through CAT bonds. The ratio of the premium to expected loss was about 6.0 in early 2001, and prior research covering periods before 2001 showed median ratios of yields to expected loss of about 6.5

Figure A9.9 CAT Bond Premiums and Expected Loss
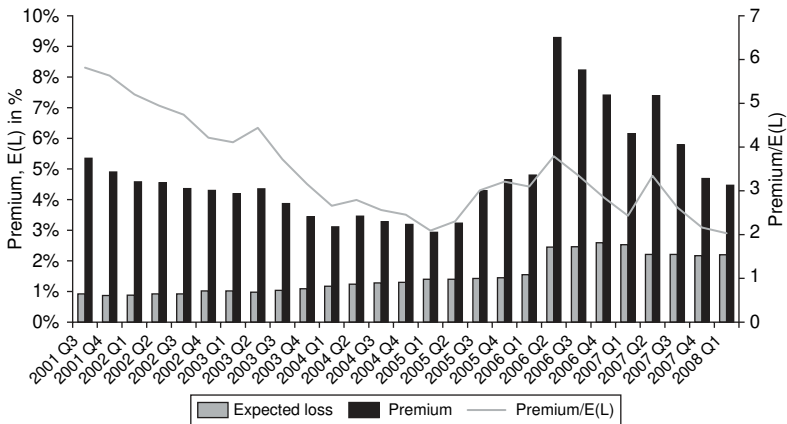
Source: Lane Financial LLC (2007).

for CAT bonds (Cummins, Lalonde, and Phillips 2004). However, the ratio of premium to expected loss began somewhat steady decline in 2001 and stood at 2.1 in the first quarter of 2005. Not surprisingly, yields and spreads increased following Katrina as the market tightened and investors had opportunities to place capital in other catastrophic risk vehicles, such as sidecars. The spread peaked at 3.7 in the second quarter of 2006 but declined again to 2.3 by the first quarter of 2007. Thus, the CAT bond market was able to withstand the post-Katrina competition for capital without returning to the high relative spreads of earlier periods. Consequently, it seems that the earlier critique of CAT bonds (that is, excessive spreads) no longer applies. This is the expected result in a market where there is growing investor interest and expertise as well as increasing volume, which adds to market liquidity.

Comparison of CAT bond and catastrophe reinsurance pricing is difficult because of the general lack of systematic data on reinsurance prices. However, unpublished data from Guy Carpenter on the relationship between the rate on line and the loss on line for catastrophe reinsurance provides a general indication of the comparative prices of CAT bonds and reinsurance. The rate on line (ROL) is defined as the reinsurance premium divided by the policy limit, and the loss on line (LOL) is the expected loss on the contract divided by the policy limit. The ratio of the ROL to the LOL is somewhat analogous to the ratio of the yield to expected loss on CAT bonds shown in Figure A9.9. The Guy Carpenter ROL and LOL data are based on average figures for Guy Carpenter clients buying reinsurance in 2005 and 2006 and are given separately for national primary insurers and regional primary insurers.

Like the CAT bond yield-to-expected-loss ratios, the ratios of rates on line to expected loss on line for Guy Carpenter clients are significantly higher in 2006 than in 2005, reflecting the effects of Hurricanes Katrina, Rita, and Wilma. In addition, the ROL-to-LOL ratios are significantly larger for national insurers than for regional insurers. Finally, the ratios are lower for contracts with higher expected losses on line, reflecting the fact that policies with low expected LOL are covering the more risky upper tails of the loss distribution.

The ratios of ROL to LOL for national insurers in 2005 and 2006 are shown in Figure A9.10. The figure focuses on national insurers, because

Figure A9.10 Catastrophe Reinsurance Ratios of Rate on Line to Loss on Line
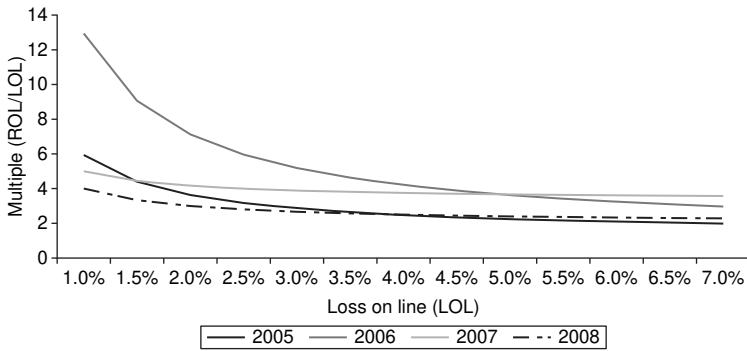
the issuers of CAT bonds tend to be large national and international firms. Thus, the most relevant comparison of CAT bond premiums is with reinsurance prices for national insurers.

As shown in Figure A9.9, CAT bonds on average tend to have expected losses of between 1 percent and 3 percent of principal, and thus are most comparable to catastrophe reinsurance contracts with relatively low LOLs. As shown in Figure A9.10, the ROL-to-LOL ratios for LOLs of 1 percent, 2 percent, and 3 percent were 12.9, 7.1, and 5.2, respectively, for national companies in 2006, and 5.9, 3.6, and 2.9 for national companies in 2005. These ratios compare with bond premium-to-expected-loss ratios of about 3.3 in 2006 and 2.7 in 2005, based on averages of the four quarterly numbers for these years from Figure A9.9. Even with the more normal pricing of 2005, CAT bonds clearly are "in the ballpark" with regard to pricing for national companies and also seem attractive relative to reinsurance in 2006. Hence, CAT bonds do not appear to be expensive relative to catastrophe reinsurance. Moreover, investment banks have succeeded in reducing transaction costs and speeding the time to market as they have gained experience with insurance-linked securitizations, also making the bonds more attractive to insurers and reinsurers.

For regional companies, at the 1 percent, 2 percent, and 3 percent LOL levels, the ROL-to-LOL ratios were 2.9, 2.5, and 2.3, respectively, in 2006, and 2.4, 2.0, and 1.9, respectively, in 2005. Thus, CAT bond prices look less attractive relative to reinsurance for regional companies. However, because regional firms have not been active in

the CAT bond market, it is not clear what the bond premiums would be for these firms.

Another relevant comparison is that of CAT bond yields relative to yields on comparably rated corporate bonds. This comparison has been performed in MMC Securities (2007). The results show that BB CAT bond yields were comparable to yields on BB corporate bond yields from 2001 up until the time of Hurricane Katrina in 2005. Yields on CAT bonds exceeded yields on BB corporates during most of the period from September 2005 through February 2007, although the gap had narrowed considerably by the end of the period. At the peak, yields on CAT bonds were 2–3 percent higher than the yields on BB corporates. Nevertheless, considering the magnitude of reinsurance prices in 2006 and the uncertainty created by Katrina and other recent catastrophes, the CAT bond market seems to have weathered the storms in very good shape.

Conclusion

The CAT bond market is thriving and seems to have reached "critical mass." The market achieved record bond issuance in 2005, 2006, and 2007. Bond premiums have declined significantly since 2001, and the bonds now seem to be priced competitively with catastrophe reinsurance. Even following Hurricane Katrina, bond premiums were roughly comparable to yields on similarly rated corporate bonds. The amount of risk capital raised through CAT bonds has been growing, and the bonds now account for a significant share of the property-catastrophe reinsurance market. The bonds have an especially important role to play for high coverage layers and in the retrocession market. Thus, the future looks bright for the CAT bond market, and CAT bonds, sidecars, and other innovative capital market solutions will play an increasingly important role in providing risk finance for large loss events. Event-linked bonds are also being used increasingly by primary insurers for lower layers of coverage. However, it remains to be seen whether CAT futures and options will play an important role in catastrophe risk management in the years to come. Basis risk and counterparty credit risk are the primary impediments to the success of these contracts.

Notes

1. Contracts were available based on a national index, five regional indexes, and three state indexes, for California, Florida, and Texas. For further discussion, see Cummins (2005).

2. Surplus notes are debt securities, issued by mutual insurance companies, that regulators treat as equity capital for statutory accounting purposes. The issuance of such notes requires regulatory approval.

3. Harrington and Niehaus (2003) argue that one important advantage of CAT bonds as a financing mechanism is that corporate tax costs are lower than for financing through equity, and that the bonds pose less risk in regard to potential future degradations of insurer financial ratings and capital structure than does financing through subordinated debt.

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Catastrophe Reinsurance Pricing

Introduction

Reinsurance pricing uses the standard actuarial pricing formula for non-life insurance:

$$P = \frac{PV[E(L)]}{(1-e)(1-\pi)} \tag{1}$$

where P = the premium,

    L = the loss random variable,

    e = the expense ratio,

    π = the reinsurer's target economic return, expressed as a percent of the premium,

    PV= the present value operator, and

    E = the expected value operator.

In practice, the formula is likely to be more complicated because of other types of expense loadings such as ceding commissions, paid to the primary insurer, and brokerage fees (see Patrik, 2001). However, this formula expresses the essentials of the pricing process.

To set prices, the actuary must determine the expected loss, the timing of the loss payout pattern, the discount rate for the present value process, the expense ratio, and the target economic return (often called the risk load or profit load). These quantities determine the actuarial price or "technical price" of the contract (Patrik, 2001, p. 358). However, the

price actually charged will depend upon the operation of the reinsurance market and thus will be affected by competition among reinsurers as well as negotiations between the reinsurer, reinsurance brokers, and the primary (ceding) insurer. Another way of looking at the process is to recognize that π, and therefore the price of reinsurance, will be determined by the operation of the reinsurance market.

This annex provides more details on the pricing of reinsurance, focusing on high-risk policies such as property catastrophe excess of loss, where the reinsurer is likely to be insuring a high layer of coverage. High layers of excess reinsurance are expressed as $c million excess of $d million, where d is the attachment point of the reinsurance (the loss amount where the reinsurer first begins to become liable to pay losses), and c is the coverage amount (the maximum amount the reinsurer will have to pay). Hence, the reinsurer's payment can be expressed in terms of a call option spread:

$$\tag{2}$$

Thus, for excess-of-loss reinsurance, the problem is to find the expected value of the call spread as well as the appropriate risk loading. Determining these quantities requires determining the probability distribution of the loss random variable, x.

This annex is organized as follows: the next section provides insights into the pricing process with a simple mean-variance model. Although insurance claim distributions tend to be highly skewed, especially for catastrophe coverages, the mega-variance model permits the pricing problem to be analyzed in a relatively simple manner that incorporates intuition into the process that determines reinsurance prices. The section following offers a more realistic model of the insurance claim process, based on actuarial risk theory. Finally, the last section provides an analysis of the determination of the profit loading, based on recent advances in modern financial theory.

The Mean-Variance Model

In the mean-variance model, we consider an insurer on N risks, where the losses from the ith risk over a specified planning horizon are expressed by the random variable x_i, where the x_i are not necessarily identical or independent. The total losses of the insurer are then equal to   .

The insurer will charge each risk a premium equal to the expected value of loss, $E(x_i)$, plus a risk loading π. The risk loading is assumed to be set so that the insurer can attain a specified target solvency level, that is,

$$(3)$$

where ε is called the *ruin probability* or *insolvency probability*.

Assuming that N is large, we can use the central limit theorem to establish the insurer's total risk premium that will be needed to achieve the target ruin probability.[1] The central limit theorem states that as $N \to \infty$, the distribution of the following ratio (the random variable z) approaches a standard normal distribution:

$$(4)$$

In the general case of correlated risks, the Var(x) can be written as follows:

$$(5)$$

where σ_{ij} = the covariance of random variables x_i and x_j = Cov(x_i, x_j). Then, using the central limit theorem, the total risk charge needed to achieve a ruin probability no greater than ε is given by

where z_ε = the value of the standard

normal variate z, so that $\Pr[z \, '' \, z_\varepsilon] = 1 - \varepsilon$. If the risks are independent, the covariances will be zero and the risk charge will be based only on the square root of the sum of the variances. However, if the risks are positively correlated, which tends to be the case in practice, especially for catastrophe risk exposure, the risk charge could be significantly larger.

Further insight into the risk charge and therefore into reinsurance pricing can be obtained by making some simplifying assumptions. For

example, assume that the risks are identical so that $Var(x_i) = Var(x_j) = \sigma^2$ for all i and j and that $Cov(x_i, x_j) = \rho\sigma^2$, where ρ is the correlation coefficient between risks i and j, for all i and j. Then the risk charge becomes Therefore the risk charge per policy would be given by:

$$\tag{6}$$

and the premium per policy would be:

$$\tag{7}$$

where $\mu = E(x_i)$, which is the same for all i under the assumption that the risks are identical. Notice that if risks are independent, so that $\rho = 0$, the risk charge $\pi \rightarrow 0$ and $N \rightarrow \infty$. However, if the risks are correlated, then the risk charge approaches   as $N \rightarrow \infty$, the limiting result of expected value pricing in large pools fails to operate. The magnitude of the premium will thus depend upon the loss mean and variance (μ and σ), the target ruin probability (ε), and the correlation among risks (ρ).

It is useful to provide a numerical example based on a loss distribution used in Patrik (2001) to illustrate reinsurance pricing. Patrik (2001, p. 425) specifies an excess-of-loss reinsurance policy with attachment point 5,000,000 and coverage of 5,000,000, that is, the policy is for 5 million excess of 5 million. The underlying loss random variable is assumed to be gamma distributed with expected value 5,729,860 and standard deviation 1,981,724. For the reinsurance layer, 5 million excess of 5 million, the expected loss is 1,192,118, and the standard deviation is 1,443,791. Assume that the reinsurer has set a target ruin probability of 0.001, meaning that it can survive an event expected to occur once in 1,000 years (that is, a "return period" of 1,000 years). For this return period, $z_\varepsilon = 3.09$, so the limiting risk charge becomes $\pi = 3.09*(1,982,724)*\rho^5$.

The risk charge for the hypothetical reinsurance policy for various values of ρ and various return periods is provided in Table A10.1. The total premium for the policy would be equal to the expected loss, US$1,192,118 plus the risk charges shown in the table and plus the insurer's administrative expenses. Table A10.1 shows that the risk charges can be substantial,

Table A10.1 Risk Charge and Premium for Hypothetical Reinsurance Policy

Ruin Probability	Return Period	Values of the correlation coefficient				
		0	0.05	0.1	0.15	0.2
Panel A: Risk Charge						
0.01	100	-	751,042	1,062,133	1,300,842	1,502,083
0.005	200	-	831,585	1,176,038	1,440,347	1,663,169
0.002	500	-	929,190	1,314,073	1,609,404	1,858,380
0.001	1000	-	997,655	1,410,898	1,727,990	1,995,310
0.0005	2000	-	1,062,319	1,502,345	1,839,990	2,124,637
0.0002	5000	-	1,142,886	1,616,285	1,979,537	2,285,772
0.0001	10000	-	1,200,653	1,697,980	2,079,592	2,401,306
Panel B: Premium (Net of Expenses)						
0.01	100	1,192,118	1,943,160	2,254,252	2,492,961	2,694,202
0.005	200	1,192,118	2,023,703	2,368,157	2,632,465	2,855,288
0.002	500	1,192,118	2,121,308	2,506,192	2,801,523	3,050,498
0.001	1000	1,192,118	2,189,774	2,603,016	2,920,108	3,187,429
0.0005	2000	1,192,118	2,254,437	2,694,464	3,032,108	3,316,756
0.0002	5000	1,192,118	2,335,004	2,808,403	3,171,655	3,477,890
0.0001	10000	1,192,118	2,392,771	2,890,098	3,271,710	3,593,424

Source: Authors.

even for relatively low values of the firm-wide correlation coefficient. For example, for a return period of 100 years, which would be considered much too risky by real-world reinsurers, and a correlation coefficient of 0.05, the risk charge would be US$751,042, or 63 percent of the expected loss. For a more realistic return period such as 500 or 1,000 years and for higher values of the correlation coefficient, the premiums would be substantially larger; for example, the risk charge for a return period of 1,000 years with correlation coefficient of 0.1 would be US$1,410,898, or 118 percent of the expected loss. Moreover, because real-world insurance loss distributions tend to be positively skewed, basing the risk charge only on the variance would understate the ruin probability, so that an even larger risk charge would be needed if skewness were taken into account.

A More Realistic Actuarial Model

A more realistic approach, which does take into account the skewness of insurance loss distributions, is to model total claims using models from

actuarial risk theory. Such models are explained in detail in Klugman, Panjer, and Willmot (2004). The basics of the model will be discussed here.

Actuarial risk theory is concerned with modeling the total claims process of an insurer or the total claims from individual insurance policies or blocks of policies. In the present context, it is helpful to conceptualize the problem in terms of pricing an individual excess-of-loss reinsurance policy, an approach which places no limitations on the generality of the results.

The model of the total claims payment as a result of providing coverage during some standardized period of time, such as one year, envisions

the total payment as arising from a random sum: where N =

the loss *frequency,* that is, the number of losses that occur during the specified time period; x_i = the loss *severity* for loss i, that is, the severity of the ith claim; and x = total losses. In insurance pricing, the underlying loss random variable is often subject to deductibles and policy limits. For example, in excess-of-loss reinsurance pricing, the reinsurer's payment y_i (per claim) y (overall), depending upon the terms of the coverage document, are usually subject to a lower strike price or *attachment point* and also a maximum coverage limit or upper strike price, such that

$$\tag{8}$$

Similar inequalities would apply to y if the reinsurance contract applies to aggregate claims rather than individual claims. Excess-of-loss reinsurance policies that apply separately to individual claims are called *per risk excess* policies, whereas policies that apply to the sum of all claims from a given loss event are called *per occurrence excess* policies. Policies that apply to all losses arising during a specified time period are known as *aggregate excess* or *stop-loss* reinsurance policies.

The frequency random variable N is modeled according to a discrete probability distribution such as the Poisson, negative binomial, Poisson inverse Gaussian, and so on. The severity random variable generally follows a continuous probability distribution such as the lognormal, gamma, Pareto, inverse Gaussian, Burr 12, or generalized beta of type 1 or 2 (GB1 or GB2). Choosing the correct probability distributions for frequency and

severity is extremely important in order to obtain accurate estimates of the risk premiums and other important quantities such as the probable maximum loss, which is the maximum loss that will occur with a specified small probability such as 0.01. Choosing the wrong distribution for either frequency or severity can provide seriously erroneous estimates of the probability in the tail or the loss distribution, leading to overpricing or underpricing. Commonly used distributions, such as the gamma and log-normal, have proven to be too light-tailed for many insurance applications.

Based on the random sum model of total claims payments, we can specify the probability distribution of x as follows:

$$\tag{9}$$

where $p(N)$ = the probability of N claims from the frequency distribution,

= the claim severity distribution, and

= the distribution of total claims.

Most modeling is conducted under the assumption that claim severities are independent and identically distributed. In addition, frequency and severity are assumed to be uncorrelated. These assumptions are usually necessary to obtain analytical results, although they can be relaxed when using simulation to obtain numerical results.

With independent and identically distributed severity, it can be shown that the moment generating function of   is equal to:

$$\tag{10}$$

where $M_N(t)$ = the moment generating function of the frequency distribution and $M_{xi}(t)$ = the moment generating function of the severity distribution. Defining C(t) as the log of the moment generating function, we can write:

$$\tag{11}$$

Differentiating the log-moment generating function and evaluating at $t = 0$ enables us to derive the first three cumulants of the distribution $f_X(x)$ as function of the moments of the frequency and severity distributions. The first three cumulants are, respectively, the mean, variance, and third moment about the mean and thus enable us to establish the expected value

of loss as well as variance loadings and the skewness of the total claims distribution. The relevant quantities are:

$$\tag{12}$$

$$\tag{13}$$

$$\tag{14}$$

where μ_N = the mean of the frequency distribution,

  = the mean of the severity distribution, and

  = the kth moment about the mean of random variable Y where
  Y = N = frequency and Y = x_i = severity.

Reinsurer's Target Economic Return

The analysis now turns to the reinsurer's target economic return (RTER), or risk loading. Because the techniques used to model the loss process itself are well known and are now supplemented by the models promulgated by catastrophe modeling firms, obtaining estimates of the loss-probability curve and its moments and percentiles has become conceptually straightforward, although some of the mathematical details are challenging. Much more difficult is the estimation of the RTER, which is denoted here as π. Actuaries have developed formulas for the risk loading, which are usually functions of the variance or standard deviation of loss. However, ultimately, the price of reinsurance will be set through the operation of the reinsurance market, where the major players are the leading global reinsurers, smaller reinsurers that participate in syndicates established by the leading players, the reinsurance brokers, and the primary or ceding companies who are buying the reinsurance.

Even though the reinsurance market is highly concentrated, especially among the top writers (Cummins and Weiss, 2004, Cummins, 2007), it remains a very competitive market. Nevertheless, it is far from the textbook example of a perfectly competitive, informationally efficient, frictionless market, accounting for the price and availability cycles that are widely observed. Informational asymmetries exist between reinsurers,

ceding companies, and brokers about the nature and quality of the exposures being reinsured, as well as the quality of the ceding insurer's underwriting and claims management. Such informational asymmetries lead to classic adverse selection problems in the reinsurance market of the type first identified by Rothschild and Stiglitz (1976). For example, when insurers cannot perfectly identify policyholder risk types, they may make policy offers with relatively low coverage amounts and high prices to head off adverse selection by policyholders with adverse loss portfolios.

Capital market imperfections also plague reinsurance markets—again, usually driven by inaccurate information. Thus, capital may not flow freely into and out of the industry because of investor uncertainty about the quality of underwriting and the extent of exposure to various types of losses (Winter 1994). Capital flows may be particularly impeded following large loss events due to uncertainty about loss exposures, the adequacy of loss reserves, and the parameters of loss distributions. Capital providers also may charge a higher cost of capital, especially during periods when reinsurers are experiencing heavy losses, because of these informational problems. As capital shortages develop, prices rise as buyers bid for scarce coverage, and coverage shortages can develop.

Fortunately, there is evidence that capital has begun to flow much more promptly into the industry following recent disasters such as the 2004 and 2005 U.S. hurricane seasons, both to capitalize new and existing reinsurers and to create innovative financing vehicles such as sidecars. It appears that the reinsurance industry has developed a "high-speed pipeline" into capital markets (Cummins 2007). However, it is clear that significant market imperfections remain, as evidenced by the increase in reinsurance risk loadings following Hurricane Katrina (Cummins 2007).

Because the RTER, or risk premium, is set through the operation of the reinsurance market, it is necessary to go beyond actuarial science to obtain an understanding of reinsurance pricing. Specifically, the field of capital budgeting from modern financial theory offers significant insights into the pricing of intermediated risks such as reinsurance.

In standard capital budgeting, each project has a unique value determined by its cash flows and discount rate, which do not depend upon the identity or characteristics of the investor. In addition, the discount rate is determined by an asset pricing model, such as the capital asset pricing

model (CAPM) or the Fama-French three-factor model. Discount rates from these models consist of the sum of the risk-free rate of interest plus a risk premium. For example, the CAPM cost of capital (discount rate) formula is:

$$(15)$$

where r_i = the cost of capital for firm i,

r_m = the return on the market portfolio of securities,

r_f = the risk-free rate of interest, and

β_i = firm i's *beta coefficient* = $\text{Cov}(r_i, r_m)/\text{Var}(r_m)$.

It is characteristic of standard asset pricing models that they price only systematic risk factors, that is, risk factors that cannot be diversified away by holding a diversified portfolio of assets. Although research has shown that there is a small systematic risk component in some types of insurance, most insurance risk is nonsystematic, that is, not correlated with market factors. Accordingly, the standard costs of capital models do not provide much guidance concerning the pricing of reinsurance.

However, there is increasing recognition among finance scholars that the standard asset pricing models do not necessarily apply to some types of intermediated risk projects, such as those undertaken by banks, insurance companies, and other financial institutions. Froot and Stein (1998) develop a model of capital budgeting and capital structure for financial institutions, where the valuation of intermediated risks incorporates pricing factors that are not reflected in standard perfect markets financial pricing models. They posit that financial institutions invest in liquid assets, which are perfectly hedgeable in financial markets, but also invest in illiquid assets, which are not frictionlessly hedgeable, because they are information-intensive and have unique features. Examples of nonhedgeable assets in banking include bank loans to small businesses and the credit-risk component of foreign exchange swaps. Examples in the insurance industry include most types of property-liability insurance policies, including commercial liability insurance and catastrophe reinsurance.

The other key features of the Froot-Stein model are that financial institutions face frictional costs of holding capital and increasing costs of raising new funds, where the latter element derives from earlier research by Froot, Scharfstein, and Stein (1993). Because holding capital is costly (due

to factors such as corporate taxation, regulatory costs, agency costs, and informational asymmetries), financial institutions optimally do not hold sufficient capital to completely shelter their operations from random outcomes that deplete capital, and thus are exposed to the risk of financial distress and of potentially having to raise expensive external capital. In the Froot-Stein model, costly capital and convex costs of raising new funds give financial institutions a legitimate concern with risk management.

Under the conditions of their model, Froot and Stein (1998) demonstrate that the cost of capital for illiquid, nonhedgeable assets incorporates the standard market systematic risk term, familiar from asset pricing theory, as well as a term reflecting the covariability of the unsystematic risk of a nonhedgeable asset with the other illiquid assets in the firm's portfolio. Hence, nonhedgeable unsystematic risk is priced in their model, because it may force the firm to raise costly external capital or forego positive net present value projects. The market price of the nonsystematic risk factor depends upon the firm's capitalization. Hence, price is a function of both unsystematic risk and the firm's capital structure, implying that hurdle rates, and thus the prices of nonhedgeable assets, may vary across institutions, in contrast to conventional capital budgeting.

Froot (2007) generalizes the Froot-Stein model to incorporate customer aversion to the institution's insolvency risk and negatively asymmetric return distributions, which are characteristic of insurers because of their positively skewed loss distributions. The former generalization has the effect of increasing the price of the nonsystematic risk covariability factor, and the latter feature adds a third pricing factor. Froot (2007) derives the following cost-of-capital formula for a new project (for example, a reinsurer issuing a new or renewal policy):

$$(16)$$

where μ_N = cost of capital for new project "N",
   = the random capital market component of the return on the new project,
   = the random insurance market component of the return on the new project,
   = the random insurance market component of the insurer's existing insurance portfolio,

w = internal funds (for example, equity capital),

M = return on the market portfolio of securities, and

χ, F, G,   = risk premiums.

Thus, the cost of capital is determined using a three-factor model. The first factor is the standard market systematic risk term familiar from the CAPM. The second is the quantity of firm-wide risk introduced by the new project, multiplied by the price of firm-wide risk. This factor is the same as the second factor in the Froot-Stein (1998) model. However, its price is higher than in Froot-Stein (1998), because Froot (2007) introduces the assumption that insurance buyers are averse to insolvency risk. The third factor represents the asymmetry of firm-wide payoffs, triggered by the positive asymmetry of insurance loss distributions. It is the product of the asymmetry risk term,   and the price of asymmetry risk,   .

The Froot (2007) model is especially important for pricing risky policies such as excess-of-loss reinsurance. Such policies place considerable non-systematic risk on the reinsurer, which needs to be priced for the reinsurer to avoid losing money on the transaction due to a decline in its market value. Most insurance risks are also highly skewed, justifying the use of the skewness factor. Unfortunately, however, although the model is theoretically sound, not much progress has been made in measuring the nonsystematic risk covariances or the risk premiums, due to the firm-specific nature of the internal data that would be required. Nevertheless, the model is valuable in conceptualizing the risk premium component of the price of reinsurance, and it shows that the risk premium may be substantially larger than conventional estimates of the cost of capital based on the CAPM or the Fama-French three-factor model.

The theory of capital allocation for financial institutions is also applicable for the pricing of intermediated risks as demonstrated by Myers and Read (2001) and Zanjani (2002). Like Froot (2007), the capital allocation literature posits that solvency risk matters to customers of financial institutions, because the performance of financial contracts depends upon the solvency of the firm. Because banking and insurance relationships often involve risk transfer and risk management, customers of these institutions are more concerned about solvency risk than are investors or customers of nonfinancial firms. Hence, the demand for intermediated products is

sensitive to insolvency risk, and riskier institutions will receive lower market prices for their products.

Capital allocation theories also recognize that risky activities contribute more to insolvency risk than do lower-risk activities. This provides the motivation for the allocation of capital by line of business, with the amount of capital allocated by line reflecting the marginal stress placed by each line on the overall insolvency risk of the firm. Thus, other things being equal, lines of business that have a larger marginal effect on insolvency risk consume more capital and should have higher prices than less risky lines. As in Froot and Stein (1998), these models imply that prices reflect the covariability of risks with the firm's existing portfolio, not just covariation with the overall securities markets, as in conventional capital budgeting (Zanjani 2002), but the mechanism, in the most general sense, incorporates covariability nonlinearly through the allocation of capital by line of business.

Myers and Read (2001) developed a marginal capital allocation model that uniquely assigns 100 percent of the intermediary's capital. They hypothesize an N line firm and calculate marginal capital allocations by taking the derivative of the firm's overall insolvency put value with respect to the loss liabilities of each of the N lines. The methodology is not dependent upon any particular distributional assumptions with respect to the firm's asset or liability returns. However, they illustrate the model under the assumptions that assets and liabilities are jointly normal and lognormal, respectively. The latter assumption involves modeling the firm as a Black-Scholes exchange option.

Because all lines of insurance have equal priority in bankruptcy, Myers and Read argue that capital should be allocated so that the marginal contribution of each line of business to the insolvency put value is equal (Myers and Read 2001, pp. 549, 559). This ensures that there is no cross-subsidization across lines of insurance and is consistent with equal priority rules in bankruptcy (Phillips, Cummins, Allen 1998). We adopt the approach of equating the marginal default valued among lines in the empirical part of this paper, because this reflects insurance bankruptcy law and thus is likely to be reflected in the market prices of insurance.

Although Myers and Read do not explicitly consider the issue of hurdle rates, a logical implication of their paper is that the price of a given

line of insurance should be directly related to the amount of capital allocated to the line at the margin. The covariability of the line's return distribution with the return distributions for the firm's other business lines and its asset portfolio is embedded in the capital allocation through its effect on the firm's overall insolvency put value. However, the covariability presumably could be reflected in the price through the hurdle rate as well, through a pricing model such as Froot-Stein (1998) or Froot (2007).

It is useful to briefly sketch the Myers-Read model using the lognormality assumption. The two stated variables in the model are the market value of the firm's assets, V, and the riskless present value of its loss liabilities, L. The firm's *overall capital*, called surplus in the insurance industry, is then defined as C = V − L. Define the firm's default value (insolvency put option) as $D(V, L, \tau, r_f, \sigma)$, where $D(\bullet)$ = the insolvency put = PV{E[Max (0, L − V)]}, τ = time to expiration of the option, r_f = the risk-free rate of interest,   = the firm's overall volatility parameter,   = the volatility of the firm's losses,   = the volatility of the firm's assets, and σ_{LV} = the covariance of the natural logs of losses and asset values (log losses and log assets).

Myers and Read decompose loss liabilities by line, such that L =

where L_i = present value of liabilities for line i and M = the total number of lines of business. In our analysis, we also decompose assets into the primary categories discussed above, such that V =   , where V_i = amount of assets of type i and N = the number of asset categories. Also define x_i = L_i/L and y_i = V_i/V. Then the components of the volatility parameter σ are defined as:

$$\tag{17}$$

$$\tag{18}$$

$$\tag{19}$$

where   = the correlation coefficient of the logs of loss series *i* and *j*,
              = the correlation coefficient of the logs of asset classes i and j,

      = the correlation coefficient of the logs of asset class i and
liability class j,

= the standard deviation of the log of asset class i, and

= the standard deviation of the log of liability class j.

The Myers-Read capital allocations are derived by taking the derivatives of the insolvency put value D with respect to the loss liabilities in each line, that is, $d_i = \partial D/\partial L_i$. In this paper, we assume that the operation of the competitive insurance market results in the equalization across lines of the marginal default values within each insurer. In this case, Myers-Read shows that the firm's capital, C, is allocated across lines of business so that the allocated capital per dollar of liabilities in line i is:

$$(20)$$

where c_i = allocated capital per dollar of liabilities for line $i = C_i/L_i$,

    c = the overall capital-to-liability ratio of the firm = C/L,

    σ = firm's overall volatility parameter,

    d = the firm's insolvency put per dollar of total liabilities = D/L,

    $\partial d/\partial c$ = the partial derivative of d with respect to c (the option delta),

    $\partial d/\partial \sigma$ = the partial derivative of d with respect to the volatility parameter σ (the option vega),

    = the covariance between the log of losses in line i and losses of the liability portfolio,

    = the covariance between the log of losses in line i and the log of assets.

Thus, because $\partial d/\partial c < 0$ and $\partial d/\partial \sigma > 0$, line i's capital allocation is directly proportional to its covariability with the loss portfolio (   ) and inversely proportional to its covariability with the asset portfolio (   ). Lines that contribute more (less) to the covariability of the loss portfolio increase the firm's overall risk level and therefore require more (less) capital. However, because the firm's overall volatility parameter is inversely related to the covariability between assets and liabilities, lines with higher covariability with assets require less capital. Intuitively, positive correlation between assets and liabilities creates a natural hedge that reduces the risk of the firm.

Although Myers-Read applies the model to lines of business (for example, automobile, commercial liability, and so on), the model applies equally well to individual policies. In fact, it probably is more appropriate for individual policies than for entire lines of business, given its derivation using calculus, which envisions very small changes in the insurer's loss liabilities at the margin. Thus, to apply the model to reinsurance pricing, we would need to know the reinsurer's overall capital-to-liability ratio, the overall volatility parameter, delta and vega, and the relevant covariances such as   , the covariance of the specific policy being analyzed with the firm's overall liability portfolio. Thus, just as in the simple mean-variance model, pricing will be affected by the correlation between each additional policy and the reinsurer's existing portfolio.

Numerical Illustration

This illustration uses the actuarial pricing formula and the limiting mean-variance premium formula with correlated risks. Premiums are calculated using three versions of the pricing formula for a range of risk premiums. The most basic pricing formula simply adopts equation (1), which is repeated here for convenience:

$$\text{(21)}$$

This version incorporates a risk premium but does not include an adjustment for the presence of correlated risks. The second version assumes that buyers are charged a premium that reflects correlation among risks, where there is a risk charge designed so the insurer can attain a target insolvency probability. The limiting version of the mean-variance pricing formula for correlated risks yields the following premium formula:

$$\text{(22)}$$

The third formula assumes that the insurer does not necessarily need to obtain the entire amount   from the present generation of policyholders, but rather can raise equity capital to fund this fluctuation

charge. In that case, the policyholders will pay the cost of capital. Assuming that the cost of capital equals π, the third formula becomes:

(23)

To parameterize the example, it is assumed that the expense ratio is e = 0.20. This is a conservative assumption in the sense that actual expense ratios are likely to be higher, given that the usual brokerage commission is 10 percent. A 20 percent expense ratio thus leaves the reinsurer with only 10 percent of the premium to cover its expenses. For the expected loss, we use the Patrick (2001) example of excess-of-loss reinsurance considered earlier, that is, $E(L) = 1,192,118$. It is assumed that there is no discounting, so the present value operator = 1. The standard deviation is also from the Patrick example, $\sigma = 1,443,791$, and the ruin probability is set at 0.001 so $z_\varepsilon = 3.09$. The correlation coefficient ρ is assumed to be 0.1.

Using the three pricing formulas, equations (21), (22), and (23), premiums are calculated for a range of values of the risk premium π. Because highly predictable, low-risk lines of insurance such as private passenger automobile are often given costs of capital in the range of 10–12 percent, the illustration begins with a minimum value of $\pi = 0.10$. The analysis by Cummins and Phillips (2005) of the cost of capital of the U.S. property-liability insurance industry tends to show costs of capital in the range of 15–20 percent. Because the analysis considers the entire industry, this cost of capital would be appropriate for lines of business of average risk. Relatively risky lines, such as property catastrophe reinsurance, should have a higher cost of capital. Moreover, Cummins and Phillips use the Fama-French three-factor model in estimating the cost of capital, and hence their costs of capital do not include a component for nonsystematic covariance risk or skewness risk, as in Froot (2007). Accordingly, for excess-of-loss reinsurance, costs of capital well in excess of the 15–20 percent range can be anticipated, and thus the premium calculations include costs of capital of up to 0.5, or 50 percent.

The premium estimates are shown in Table A10.2. We focus on the relationship of the illustrated premiums to the expected value of loss under the policies, that is, the *pricing multiple*. For pricing formula (21) with no adjustment for covariance, the pricing multiple ranges from 1.39 to 2.50. Using formula (22), the pricing multiples are significantly higher,

Table A10.2 Hypothetical Reinsurance Premiums

Risk Premium	No Covariance		With covariance loading: ρ = .1, Ruin = .001			
			With Cov Charge		With Cov Cost of	
	Premium	Premium/E(L)	Premium	Premium/E(L)	Premium	Premium/E(L)
0.10	1,655,720	1.39	3,615,300	3.03	1,851,678	1.55
0.11	1,674,324	1.40	3,655,921	3.07	1,892,299	1.59
0.12	1,693,350	1.42	3,697,466	3.10	1,933,844	1.62
0.13	1,712,814	1.44	3,739,965	3.14	1,976,343	1.66
0.14	1,732,730	1.45	3,783,453	3.17	2,019,831	1.69
0.15	1,753,115	1.47	3,827,965	3.21	2,064,343	1.73
0.16	1,773,986	1.49	3,873,536	3.25	2,109,914	1.77
0.17	1,795,359	1.51	3,920,205	3.29	2,156,583	1.81
0.18	1,817,254	1.52	3,968,012	3.33	2,204,390	1.85
0.19	1,839,689	1.54	4,017,000	3.37	2,253,378	1.89
0.20	1,862,685	1.56	4,067,212	3.41	2,303,590	1.93
0.21	1,886,263	1.58	4,118,696	3.45	2,355,074	1.98
0.22	1,910,446	1.60	4,171,500	3.50	2,407,878	2.02
0.23	1,935,257	1.62	4,225,675	3.54	2,462,053	2.07
0.24	1,960,721	1.64	4,281,276	3.59	2,517,654	2.11
0.25	1,986,864	1.67	4,338,360	3.64	2,574,738	2.16
0.26	2,013,713	1.69	4,396,986	3.69	2,633,364	2.21
0.27	2,041,299	1.71	4,457,219	3.74	2,693,597	2.26
0.28	2,069,650	1.74	4,519,125	3.79	2,755,503	2.31
0.29	2,098,800	1.76	4,582,774	3.84	2,819,153	2.36
0.30	2,128,783	1.79	4,648,243	3.90	2,884,621	2.42
0.31	2,159,635	1.81	4,715,609	3.96	2,951,987	2.48
0.32	2,191,394	1.84	4,784,956	4.01	3,021,334	2.53
0.33	2,224,101	1.87	4,856,373	4.07	3,092,751	2.59
0.34	2,257,800	1.89	4,929,954	4.14	3,166,332	2.66
0.35	2,292,535	1.92	5,005,800	4.20	3,242,178	2.72
0.36	2,328,356	1.95	5,084,015	4.26	3,320,393	2.79
0.37	2,365,314	1.98	5,164,714	4.33	3,401,092	2.85
0.38	2,403,464	2.02	5,248,016	4.40	3,484,394	2.92
0.39	2,442,865	2.05	5,334,049	4.47	3,570,427	3.00
0.40	2,483,580	2.08	5,422,950	4.55	3,659,328	3.07
0.41	2,525,674	2.12	5,514,864	4.63	3,751,242	3.15
0.42	2,569,221	2.16	5,609,948	4.71	3,846,326	3.23
0.43	2,614,295	2.19	5,708,368	4.79	3,944,746	3.31
0.44	2,660,978	2.23	5,810,303	4.87	4,046,681	3.39
0.45	2,709,360	2.27	5,915,945	4.96	4,152,323	3.48
0.46	2,759,533	2.31	6,025,500	5.05	4,261,878	3.58
0.47	2,811,600	2.36	6,139,188	5.15	4,375,567	3.67
0.48	2,865,669	2.40	6,257,250	5.25	4,493,628	3.77
0.49	2,921,859	2.45	6,379,941	5.35	4,616,319	3.87
0.50	2,980,296	2.50	6,507,540	5.46	4,743,918	3.98

Note: Reinsurance expense ratio = 0.2, covariance loading = 1,410,898.

ranging from 3.03 to 5.46. Formula (23) provides an intermediate case, where the multiples range from 1.55 to 3.98. To put these results in perspective, it is important to note that we have chosen moderate values for the ruin probability and the correlation coefficient. With a smaller ruin probability or a higher correlation coefficient, the pricing multiples would be considerably higher, even for relatively moderate costs of capital, such as 20 percent. Hence, it is not difficult to generate pricing multiples similar to those observed in real world reinsurance and CAT bond markets.

Note

1. In practice, the approach to normality is too slow to permit the use of the central limit theorem to accurately estimate the risk charge, because insurance claim distributions are highly skewed and usually have very heavy tails, that is, relatively high probabilities of large losses.

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Boxes, figures, notes, and tables are indicated by b, f, n, and t respectively.

Tribute to GFDRR Partners

Since its establishment in September 2006, the Global Facility for Disaster Reduction and Recovery (GFDRR) has evolved into a partnership among Australia, Canada, Denmark, the European Commission, Finland, France, Germany, Italy, Japan, Luxembourg, Norway, Spain, Sweden, Switzerland, the United Kingdom, the UN International Strategy for Disaster Reduction, the USAID Office of Foreign Disaster Assistance, and the World Bank.