IDB

Natural Disasters Financial Risk Management

Technical and Policy Underpinnings for the Use of Disaster-Linked Financial Instruments in Latin America and the Caribbean

Torben Andersen
Mario Marcel
Guillermo Collich
Kurt Focke
Juan José Durante

Natural Disasters Financial Risk Management

Technical and Policy Underpinnings for the Use of Disaster-Linked Financial Instruments in Latin America and the Caribbean

Torben Andersen
Mario Marcel
Guillermo Collich
Kurt Focke
Juan José Durante

IDB

Inter-American Development Bank

2010

Abstract[*]

The Latin American and Caribbean region is highly exposed to natural disasters. The social and economic impact of these events has been historically very significant and it is showing an increasingly growing trend. During the first quarter of 2010, this unfortunate reality was evidenced with the Haiti and Chile earthquakes. Preliminary impact assessments indicate that the powerful January 2010 Port-au-Prince earthquake killed more than 225,000 people and caused damages and losses of about US$8 billion dollars (about 120 percent of last year GDP). This technical note presents the current Inter-American Development Bank Strategic Approach to catastrophe risk financing and discusses the technical and economic underpinnings for the proposed disaster-linked financial instruments. The paper considers the accumulated stock of knowledge about disaster risk management over the past decade and discusses how it is being deployed effectively in the region by the Bank.

JEL Classification: O11, O19, O54, Q54, F35

Keywords: Latin America, Caribbean, Natural disasters, public finances, risk management, insurance.

Content

The Character of Catastrophe Risks

Catastrophes are relatively infrequent events that happen over short periods of time and potentially have significant adverse effects economically and socially.[1] The underlying risk factors can be a result of accidental or willful human actions and various natural phenomena. A natural disaster occurs when an extreme event of nature overwhelms a region and seriously affects social conditions, economic infrastructure, and business activities in the surrounding society. Natural disasters can cause human casualties and economic losses in private assets and public infrastructure. While natural disasters impose hardship on the population, they also represent opportunities to replace existing productive capital with more resistant and efficient economic assets. Hence, risk management policies should ensure that financial resources are available to recover economic activity after major disasters and replace essential physical assets.[2]

The economic losses of natural disasters are both direct and indirect. The direct losses arise from physical destruction of economic assets, including private dwellings, small business properties, and industrial facilities, as well as public infrastructure assets such as roads, bridges, harbors, airports, telecommunication networks, power plants, hospitals, schools, and administration. The indirect losses arise from the disruption of business activities in the wake of natural disasters due to resource shortages, production stops, weakened demand, broken distribution channels, and failing business interactions. In other words, the direct effect refers to destruction of capital stock and the indirect effect to the subsequent reductions on income flow. The replacement value of exposed assets can be determined quite accurately, but it is difficult to predict the exact drop in economic activity, which can be substantial. The effect on economic activity is a significant concern because it affects economic revival and future growth prospects.

The human and economic effects of natural disasters are considerably higher among the poorest segments of the population. Governments and international donors often feel obliged to honor the extraordinary economic claims of these constituents.[3] Under those circumstances, the government acts as unconditional insurer and assumes economic risks often without considering

---

[1] These catastrophic events are often referred to as rapid onset disasters (IDB Natural Disaster Policy, 2004).

[2] Nevertheless, systematic risk management practices continue to be under prioritized even though the emergency response capacity has improved across Latin America (Andersen, 2005; Charveriat, 2000; Freeman and Martin, 2002).

[3] Whereas large business enterprises are typically better prepared for disasters and have coverage with insurance companies, small businesses and households are usually largely unprotected.

how to fund such costs.[4] This can create moral hazards because reliance on public funding reduces the incentives to mitigate exposure and tends to de-emphasize proactive risk management practices (Andersen and Masci, 2001). The exposed countries typically finance the extraordinary costs by diverting investment funds from the public capital budgets assigned for long-term economic development projects (e.g., Benson and Clay, 2000, 2002; Freeman et al., 2003). These unforeseen and unplanned financial needs can put enormous strain on public finances and delay or eliminate essential development efforts. Considering the significant challenges that a natural disaster leaves in its wake, more systematic approaches to risk management need to be developed.

Climate Change and Environmental Degradation

There is evidence to suggest that observable climatic changes are affecting catastrophe risks because of new emerging weather patterns and more extreme occurrences.[5] The environmental context formed by soil conditions and availability of water has a direct effect on food production and is heavily influenced by climatic and weather conditions. Substantial arable land is being lost annually due to soil erosion.[6] There are indications that economic exploitation of natural resources through intensive farming, deforestation, and soil degradation leaves developing economies increasingly vulnerable to natural disasters.

---

[4] Hence, damages to private housing, workmen's compensation, and various relief payments can become a substantial part of the public costs after a disaster (Freeman and Martin, 2002).

[5] Observed long-term changes in climate include widespread changes in precipitation and wind patterns with increased intensity of tropical cyclones and extreme weather situations, including drought, heat waves, and heavy precipitation (IPCC, 2007; Emanuel, 2005; Mills, 2005; Webster et al., 2005). Studies on hurricane activity have analyzed the relation between climate change and frequency and intensity of these events.

[6] The major areas that are degrading are Africa south of the equator, Southeast Asia, southern China, and the Pampas in South America (see Nellemann et al., 2009).

Box 1. The Economic Impact of Natural Disasters

The results of empirical analyses of the economic effects of natural disasters have been somewhat ambiguous. A number of studies found largely positive relationships between disaster events and economic growth enhanced by development assistance and international donations (e.g., Albala-Bertrand, 1993, 2000, 2003; Andersen, 2005), while others reported negative relationships (e.g., Raddatz, 2007; Noy, 2009). However, there is evidence that the economic effect of disasters is negatively correlated with country size (e.g., Andersen and Kalavakonda, 2003; Auffret, 2003; Rasmussen, 2004) and positively correlated with the severity of disaster events (e.g., Cavallo et al., 2009; Hochrainer, 2009). Hence, the adverse economic effects are generally worse for relatively small countries and for relatively large disasters.

In economic analyses based on conventional Cobb-Douglas production functions (e.g., Freeman et al., 2002), a reduction in capital assets caused by a natural disaster will display an adverse effect on production output:

$$GDP = A K^{\alpha} L^{(1-\alpha)}$$

Where: A = multifactor productivity, K = capital stock, L = labor, and α = production elasticity of capital.

However, the model may exaggerate the effects of damage to the capital stock because: (1) the direct losses are overestimated, (2) the least efficient economic assets typically are most vulnerable, (3) previous asset depreciation is not taken into account, (4) the economy may not operate at capacity, and (5) the new assets are more productive than those they replace. This suggests that the potential adverse effects of disaster events can be counteracted by proactive risk management initiatives and *ex ante* financing arrangements that enable the exposed country to quickly re-establish economic activity and subsequently replace the damaged economic infrastructure with more resilient and productive assets. To this end, there is a need to secure funding sources in advance rather than depend on cumbersome and time consuming credit applications.

Ghesquire and Mahul (2007) analyze the social cost of bearing catastrophe risk. They assume N identical members of the economy that may incur a catastrophe loss depicted by draws from a normal distribution (μ, σ). Since this is catastrophe risk, individual loss events are related with the pair wise covariance between loss outcomes expressed in a correlation coefficient (ρ). They show that an economy with many members (large N) will incur social cost per member of bearing catastrophe exposure (sk) approximated as:

$$sk = s \cdot z_{\alpha} \cdot \sigma \cdot \rho$$

Where s = the (marginal) opportunity cost of holding reserves against catastrophe losses
          i.e., the economic returns from a best alternative use of funds
       z_{α} = the standard normal distribution of a loss with probability α
       σ = the variability in individual catastrophe losses indicated by the standard deviation
          (assuming identical normal distribution of outcomes)
       ρ = the correlation between individual pairs of catastrophe losses
       $z_{\alpha} \cdot \sigma \cdot \rho$ = the cash reserve to be held by each member as coverage against losses

This indicates that the need for cash reserves depends on the correlation between individual risk events. In the case of extreme disasters, the risk correlations increase and the need for reserves go up. Small economies populated over a limited geographic area will also display higher correlations between individual risk outcomes. That is, the analysis illustrates the higher adverse effects of extreme events on small countries, as confirmed in an increasing number of empirical studies. It also illustrates that the cost of reserves can increase dramatically in small economies that may obtain high returns from the alternative use of funds in economic development projects.

These circumstances accentuate the need to consider the effects of climate change and environmental degradation when assessing exposure to natural disasters. To mitigate risk, new ways to circumvent the adverse self-reinforcing cycles of economic exploitation, a degrading environment, and vulnerability to natural catastrophes need to be investigated. This requires an integrated approach to risk management that takes into account the impact of different disaster phenomena over larger geographic areas where climatic patterns are better discerned. While some natural phenomena derive from existing threats, other effects from climate change may require further scrutiny. However, many of these effects can be anticipated through more systematic risk assessments. A proactive risk management assessment process must consider the interaction between multiple factors and multiple hazards that could have socio-economic effects across larger exposed regions. This is a necessary precursor to engage in climate adaptation initiatives and requires intra- and inter-organizational collaboration that can be hampered by fragmented institutions and communication barriers (Sperling and Szekely, 2005).

Recent market updates confirm that the severity of economic impact as a result of weather-related disasters continues to increase, though the reported events and associated direct economic losses display considerable variation from year to year. Total reported economic losses as a result of natural disasters worldwide amounted to around US$200 billion in 2008, compared with US$80 billion in 2007 and record losses of US$230 billion in 2005. Despite the variability in annual losses from natural disasters, over time the trend is increasing, especially as a result of windstorm and flooding events. The mounting losses can partially be ascribed to climatic changes that contribute to new weather extremes that, in turn, generate higher losses as the concentration of economic assets increase in exposed areas (Munich Re, 2008). The natural events causing the losses can be ascribed to a large number of tropical cyclones hitting Asia, the Caribbean, and North America, and a major earthquake in China during 2008 (CRED, 2009). The years 2006 and 2007 were marked by typhoon Bilis affecting China and the Philippines, severe flooding in India, an earthquake in Indonesia, major winter storms in Europe, heavy rainfall and flooding in the United Kingdom, and major floods in the Tabasco region of Mexico. The record losses incurred during 2005 were caused by a series of Atlantic hurricanes, including Katrina, Rita, and Wilma, while an earthquake in Kashmir, floods in India, and hurricane Stan in Central America added substantially to the loss figure.

Total insured losses amounted to around US$45 billion during 2008. So, just over 20 percent of the total catastrophe losses were covered by insurance, markedly down from coverage well above 30 percent in previous years (Swiss Re, 2006, 2007, 2008a, 2009a). This reflects that major losses in 2008 occurred in industrialized countries where a large proportion of property is insured smoothing out the economic impact. In contrast, most of the property losses incurred in developing countries that year were not insured, leaving affected households, small businesses, and governments to bear the brunt of the burden.[7]

The Impact of Rapid Onset Natural Catastrophes in Latin America and the Caribbean

Earthquakes, windstorms (hurricanes), and flooding are the most common natural phenomena across the Latin American and Caribbean (LAC) region and represent costly hazards based on reported losses. Many Caribbean countries are exposed to severe windstorm damage as hurricanes pass through this region. Tropical hurricanes also affect Central America and expose countries to windstorms, flooding, and landslides. Large parts of South America are exposed to floods, and Central and South America contain earthquake prone regions.

Recent evidence of the significant economic and social impact of natural disasters in the region includes the significant damage and losses caused by the earthquakes in Haiti and Chile during 2010. A magnitude 7.0 earthquake struck Haiti on January 12, 2010, killing more than 225,000 people. The country suffered extensive damage to its transportation and communication infrastructure, and housing, and most of the public buildings in Port-au-Prince were damaged or destroyed. The preliminary findings of the post-disaster needs assessment conducted by the United Nations and other multilateral institutions estimated damage and losses at about US$8 billion (about 120 percent of 2009 GDP).[8]

According to the International Monetary Fund (IMF) the macroeconomic outlook for Haiti in 2010 is challenging. GDP is projected to fall by 8.5 percent in fiscal 2010, despite a projected

---

[7] Non-life insurance premiums typically range between 0.6 and 1.3 percent of GDP across countries in the LAC region, with an annual growth rate of 3 to 7 percent. This compares to non-life indemnity insurance premiums in the United States of around 3.0 to 3.5 percent of GDP.

[8] A study published by the IDB (Cavallo, Powell, and Becerra, 2010), using simple regression techniques and Haiti's economic and demographic data, made an initial assessment of the monetary damages caused by the earthquake. The base estimate is US$8.1 billion for a death toll of 250,000, but for several reasons this estimate may be low. An estimate of US$13.9 billion for the same death toll is within statistical error.

recovery in the second half of the year led mainly by reconstruction activity. A collapse in revenue is causing a fiscal gap of US$250 million to US$350 million, and the uncertainty regarding the value of collateral and the financial condition of banks' clients has led to a credit crunch.[9]

On February 27, 2010, an 8.8-magnitude earthquake rocked Chile, mostly affecting the second-largest city, Concepción. The Government of Chile reported that the death toll was more than 500 people and that close to one million people were affected. The government estimates that the event caused losses of US$30 billion, equivalent about 17 percent of GDP. There was significant damage to public infrastructure, including Santiago's international airport, the ports of San Antonio and Valparaiso, highways, and housing. In some coastal areas there was also destruction as a result of a tsunami that occurred after the main quake. The National Association of Insurance Companies estimated that the earthquake could have caused US$2.6 billion in insured damage.

The erratic nature of losses ascribed to different natural catastrophes is repeated in the aggregate loss figures for the LAC region. The trend in overall losses from the early 1970s appears to mount along an exponential growth path, with year-to-year variability in total losses increasing at the same time (Figure 1).

Total losses from natural catastrophes in the LAC region over the past decade do not as clearly show exponential growth, but there is a clear increasing trend (Figure 2). On average, natural disasters in the region have affected about four million people, and have caused around 5,000 deaths and average losses of more than US$3 billion yearly.[10] However, the losses associated with earthquakes, hurricanes, droughts, and flooding are growing at four times the rate of GDP growth. This is a major concern that calls for proactive approaches to managing exposure to catastrophes.

---

[9] International Monetary Fund. World Economic Outlook, Haiti. April 2010.
[10] The Centre for Research on the Epidemiology of Disasters (CRED) provides estimates for affected people in approximately 75 percent of the reported incidents in the LAC region and registers loss estimates in around one third of these cases. CRED is a major source of information on direct economic losses from natural catastrophes, collecting data from publicly available sources, including major insurance companies, various multilateral organizations, news media, and other sources.

Figure 1. Losses from Natural Disasters by Kind in the LAC Region (1970-2008)

(US$1,000)
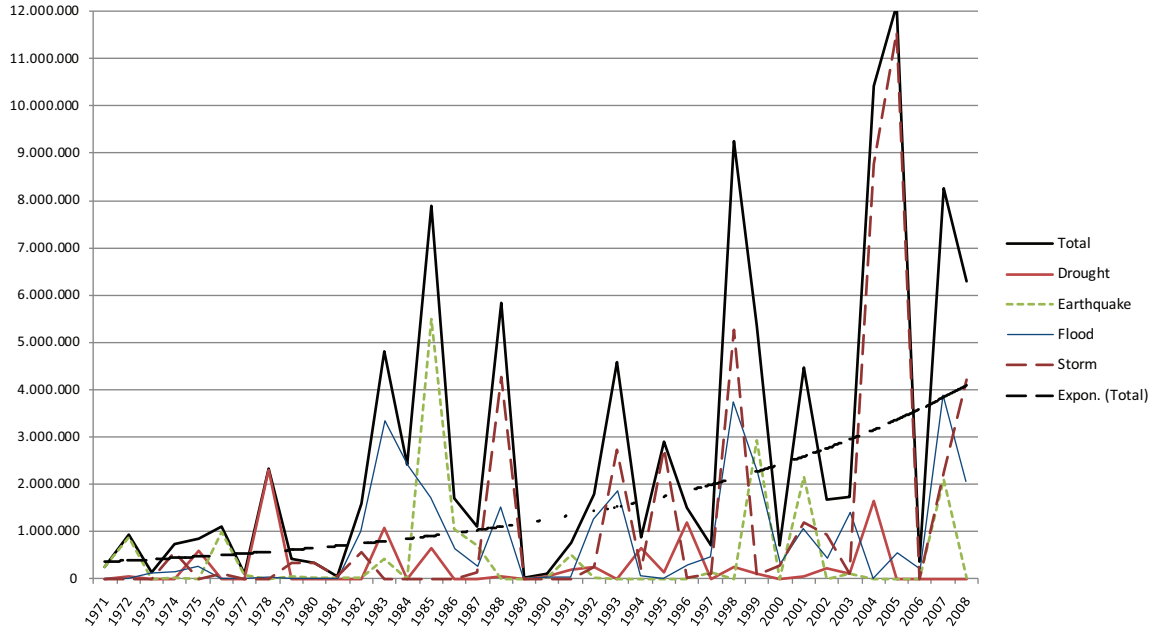
Source: The OFDA/CRED International Disaster Database, Université Catholique de Louvain, Belgium.

Figure 2. Losses from Natural Disasters in the LAC Region (2000-08)
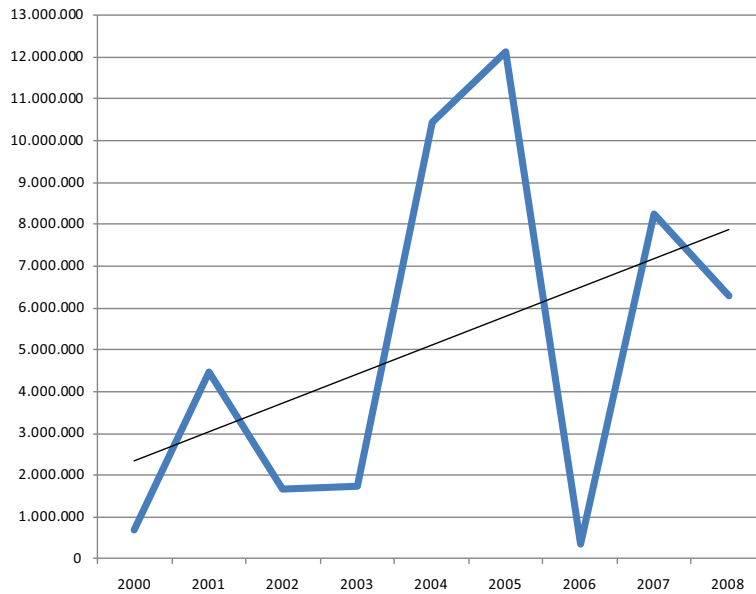
(US$1,000)

Source: The OFDA/CRED International Disaster Database, Université Catholique de Louvain, Belgium.

Risk Diversification Opportunities in the Region

Various LAC subregions are exposed to different natural phenomena and display diverse geographic and climatic conditions. Hence, it is possible to observe some diversity in the loss impact across subregions over time. For example, the Caribbean was hit harder in 2004 and 2008, and Central America was hit particularly hard in 2005 and 2007, whereas South America was affected on and off throughout the period 2000-08 (Figure 3). These uncorrelated loss patterns provide opportunities for risk diversification for insurance agents that operate across the entire region.

Figure 3. Losses from Natural Catastrophes by Subregion (2000-08)

(US$1,000)
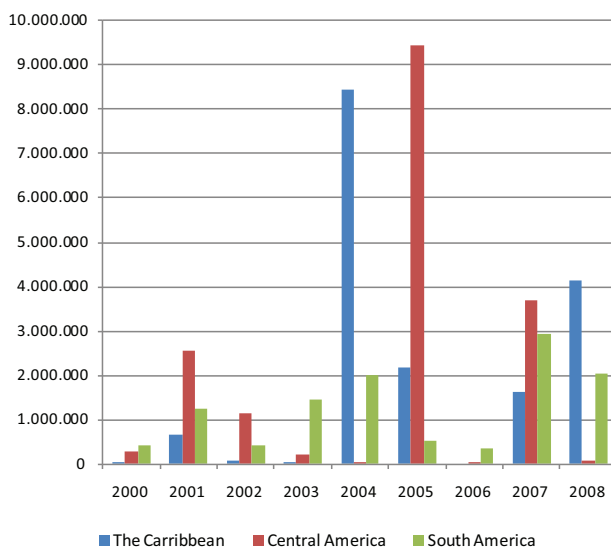
Source: The OFDA/CRED International Disaster Database, Université Catholique de Louvain, Belgium.

Also, different parts of the LAC region are circumscribed by different climatic conditions that cause different natural hazards to hit with different intensities and frequencies, thus distributing the different catastrophes unevenly across subregions (Figure 4). This provides potential for differentiation advantages across exposed countries in those subregions.[11] The

---

[11] These diversification advantages are, for example, motivating the formation of the Caribbean Catastrophe Risk Insurance Initiative (CCRII) where the earthquake and hurricane risks of CARICOM countries are pooled within a single risk transfer vehicle. The recent catastrophic bond transaction by the Mexican Government fund (FONDEN) is another example of how a central vehicle manages the transfer of public sector exposure to diverse perils across a larger geographic region.

potential for diversification advantages requires further analysis of emerging climatic patterns to assess relationships between country exposures over extended time periods.

Figure 4. Losses by Type of Natural Hazard in the LAC Region (2000-08)
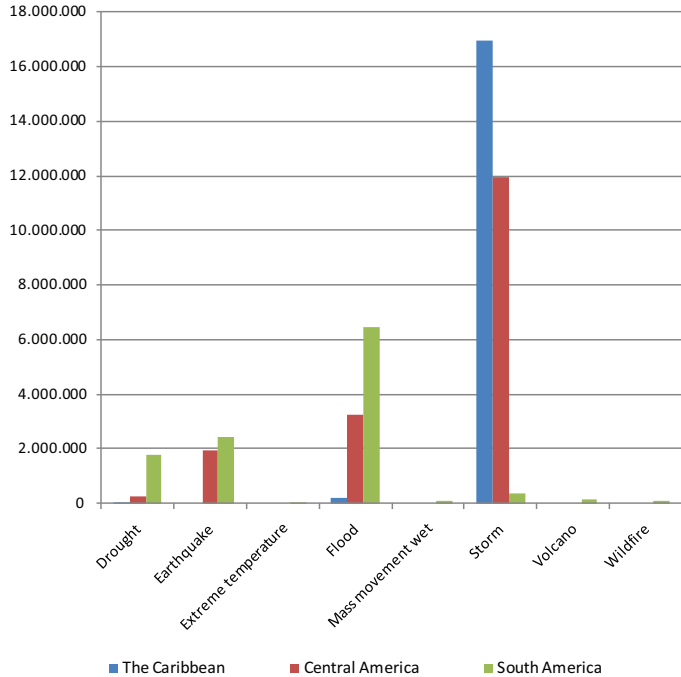
(US$1,000)

Source: The OFDA/CRED International Disaster Database, Université Catholique de Louvain, Belgium.

The Economic Resilience of the LAC Region

Regional Risk-Transfer Markets

The national insurance markets are generally underdeveloped throughout the region, with relatively low market penetration. The risk transfer and financing capacity of the national markets is generally insufficient to deal with mounting exposure to natural catastrophes. This applies to the local insurance industry, but foreign insurance companies with a strong presence in the region are also faced with limitations in institutional structures and technical insurance facilities. Yet, the presence of international financial institutions provides access to the international capital markets and the global reinsurance industry.

On the other hand, the growth in property insurance premiums has generally outperformed GDP growth and thus provides some basis for optimism (Capgemini/EFMA, 2009; Swiss Re, 2008b), and there are signs of promising growth across major national insurance markets despite immediate drawbacks from the global economic crisis. The ongoing development of local financial and insurance markets and supportive institutional frameworks is paramount for the ability to establish local risk-transfer capacities (Keipi et al., 2002; Masci, Tejerina, and Webb, 2007).

Domestic property insurance prices are highly correlated with international property reinsurance rates that, in turn, are affected by developments in global property catastrophe losses. The markets experienced falling rates during the late 1990s but firmed slightly after 2000. The global price level is reflected in the World ROL Index, which captures the development of insurance premiums in the major catastrophe property markets (Figure 5).[12]

Figure 5. World ROL Index (1990–2009)

Index: 1990 = 100
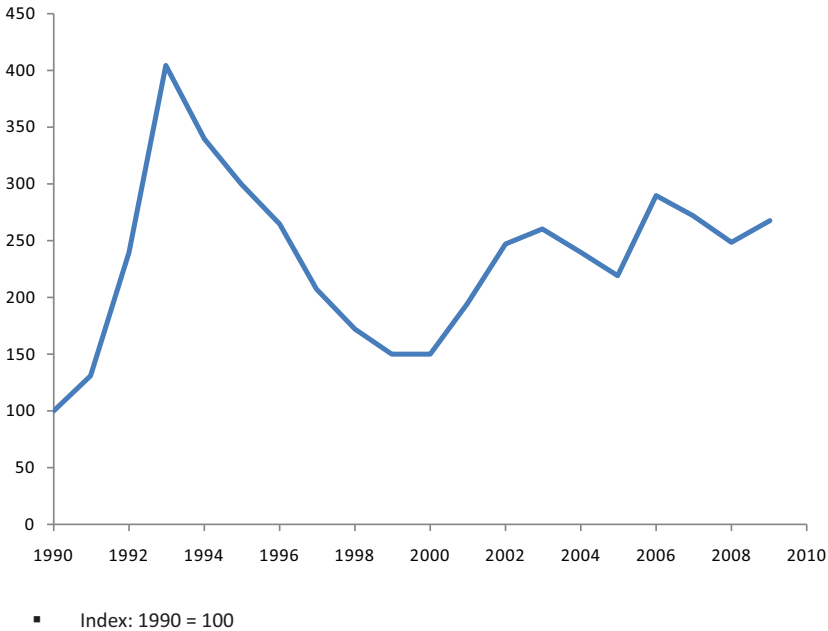
Source: Carpenter (2009).

---

[12] ROL (rate on line) is calculated as the premium paid for reinsurance divided by the amount of risk transferred. The ROL index by Guy Carpenter shows a development trend quite comparable to the global Camares Index calculated by Swiss Re based on its analysis of cat programs in the 13 largest markets.

Rates increased in the wake of Hurricane Andrew, which was a major event with record-breaking property losses in 1992. In the subsequent period, market capacity was gradually restored and led to a general softening of rates. There were other general increases in global rates after 9/11 in 2001 and after catastrophic events in 2005, including Hurricane Katrina. Regional insurance rates are highly correlated among them because of their dependence on the global reinsurance market as the ultimate source of risk diversification. Yet, property reinsurance rates can vary. For example, the 2005–06 rate increase was 76 percent in the United States and 129 percent in Mexico. Barring major unexpected disasters in highly covered areas, or a new economic crisis, the global reinsurance rates are expected to remain fairly stable around current levels (Carpenter, 2009).

Insurance penetration has been increasing across the LAC region in recent years but remains relatively low compared with other regions. In 2008, premiums for property and casualty, and life insurance were around 2.5 percent of GDP in the region, typically ranging between 1 and 4 percent across the majority of the countries. Penetration rates in other regions were 8.5 percent of GDP in North America, 7.5 percent in Europe, 6.0 percent in Asia, and 3.6 percent in Africa. In the LAC region, more than 60 percent of the premiums are for property and casualty insurance, with the remainder spent on life and health insurance. In other words, on average 1.5 percent of GDP was spent on non-life insurance and 1.0 percent on life insurance in 2008 (Swiss Re, 2009b).

There is a significant international presence in the local insurance markets, with a share above 40 percent in property and casualty insurance and even higher in life insurance. This encourages local insurers to develop new products and reduce administration and transaction costs. Yet, administration and marketing costs to net premiums remain relatively high throughout the LAC region because of market structures and business practices that are dominated by conventional distribution channels through brokers, agents, and field representatives.

Global reinsurance rates react to unexpected shocks in the market. Hence, the record losses caused by Hurricane Andrew in 1992 (US$19 billion) led to a major increase in market rates. This event drained insurance reserves and illustrated the limitations of the market when extraordinary events happen. The attack on the World Trade Center in September 2001 was another event that stirred the market (see Figures 5 and 6). This incident was unusual in scope

and pointed toward new unprecedented risk levels that affected market rates. The record year 2005 saw mounting property losses caused by Hurricane Katrina, which pushed rates up somewhat. This illustrates that rates generally increase when events are significant, dramatic, and unexpected. However, the global markets also appear more resilient to major events, possibly as alternative risk-transfer opportunities have emerged through international capital markets.

Figure 6. Total Insured Losses and Major Catastrophe Events (1990–2008)

(US$ million)
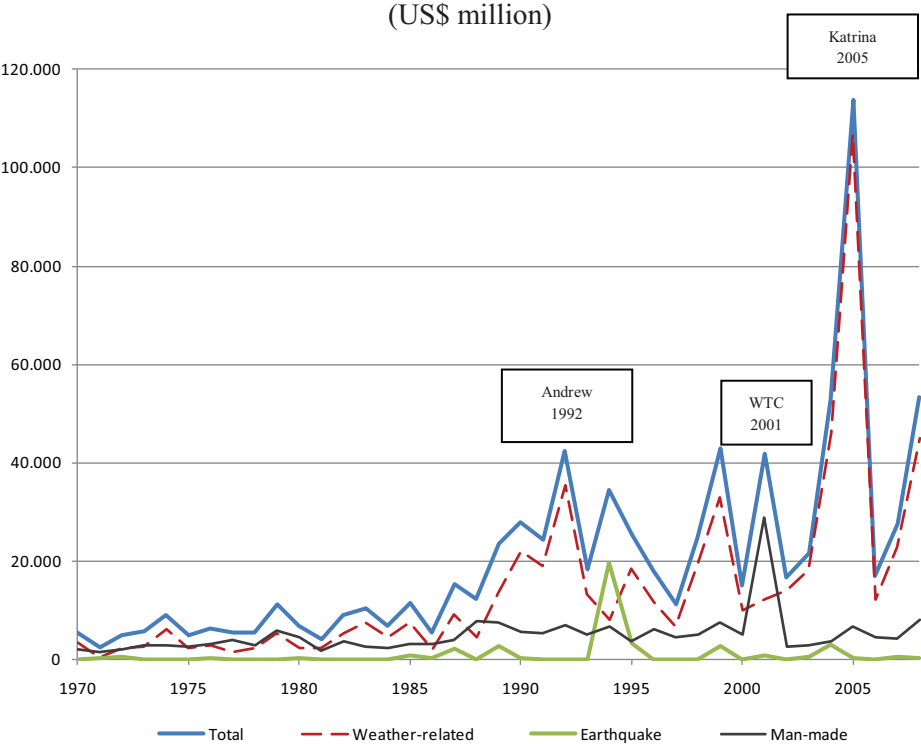
Source: Swiss Re (2009a).

Development Challenges in the Domestic Insurance Markets

The resilience of the global reinsurance market reflects how effectively the market, like any other financial market, thrives on transparency when transferred risks are thoroughly analyzed and understood. When there is uncertainty about underlying exposure, insurance premiums increase and the risk transfer market becomes less efficient. This is a problem, particularly for indemnity insurance, in many developing economies where private property and other economic assets have inconsistent qualities, and where their locations are improperly recorded, if at all. In addition, there is often a lack of data available to describe loss frequencies of different perils

because they are not measured and registered in a systematic manner. This indicates areas where transaction costs can be reduced and opportunities for scale economies gained from specific market improvements.

Expanding knowledge about major perils by measuring their frequencies, patterns, and effects, and establishing public databases can support more thorough risk analyses. Access to high-quality financial data can pave the way for parametric insurance, financial derivatives, and other risk management instruments dealing with local market risks. The efficacy of national risk management systems hinges on reliable public records on exposed economic assets. Transparency about environmental and economic events is instrumental for effective risk management approaches.[13] However, as it is clear in most LAC countries, the local markets may not be sufficiently mature to introduce sophisticated risk-transfer practices in the short term. It seems therefore advisable that as governments tackle and struggle to solve the multiple domestic risk market development issues, in order to increase the transparency they should take actions toward improving the registration of economic assets, valuation systems and procedures, and analysis of catastrophe exposures, and toward creating public databases about major hazard events.[14]

Insurance markets are characterized by standard products distributed through conventional agency channels to larger business enterprises and individual high net worth individuals. Moreover, because of the relative underdevelopment of national insurance markets, a substantial part of the premiums are ceded to the global reinsurance market. Hence, there is a call for improved industry practices, processing efficiencies, and effective IT-enhanced distribution systems. Insufficient technical capabilities and missing information about essential risk factors reduce efficiency and increase uncertainty. Shortage of data on risk phenomena and exposed assets causes adverse selection problems where information asymmetries between insurance buyers and sellers lead to less than optimal market behaviors.

---

[13] A variety of initiatives to develop local market risk instruments, often dealing with agricultural risks, have already been considered in different parts of the LAC region (Arias and Covarrubias, 2006).

[14] As part of the Integrated Disaster Risk Management and Finance Approach Implementation Strategy, the IDB has carried out evaluation of and diagnostics on the public utilities assets registration/valuation systems and procedures in five Central American countries and the Dominican Republic (DR). Moreover, in the DR it is supporting, through technical assistance grants, the implementation of the diagnostic recommendations at the national level.

An effective insurance market also requires reliable counterparts where insurance sellers can be counted on to fulfill their future obligations. To this end there is a need for strong and strongly enforced reporting standards, operational proficiencies, capital reserves, and solvency requirements across the entire financial sector (IMF, 2001). This, in turn, requires updated supervisory agencies, corporate governance practices, and internal control systems.

Institutionalizing Risk Management

The increasing frequency and intensity of natural disasters imposes particular challenges on developing countries. The economic infrastructure is less resilient, building standards are low, and there are few resources available to deal with the aftermath of major disaster events. The consequence of lower insurance penetration is that only a minor part of the direct economic losses caused by catastrophes are covered. In the LAC region, this situation means that typically only 4 to 5 percent of losses are insured, and often less, whereas the insurance percentage typically covers around 40 to 60 percent in developed countries. The low insurance penetration among homeowners and small businesses in the region accentuates a need for government involvement to cover basic economic assets on commercial terms.

Hence, governments should be conscious of all the public and private assets they will be liable for in case of a disaster where government intervention may be needed to cover households and small businesses. Most developed countries have established policy strategies and institutional approaches to address these concerns. National systems dealing with catastrophe exposures are well known among exposed OECD countries, such as the United States, Japan, New Zealand, Taiwan, the United Kingdom, France, Germany, Spain, and others (Andersen, 2005; Freeman and Martin, 2002; OECD, 2008).

Only a minor share of public sector assets are insured across the LAC region and in many instances only rudimentary monitoring and control processes are in place. The Mexican government constitutes a notable exception. The tax-based calamity fund Fondo de Desastres Naturales (FONDEN), established in 1996, supports disaster reconstruction of public assets while federal agencies, state, and municipal governments are required to insure public

buildings.[15] Government involvement should be based on a comprehensive risk management approach in pursuit of an overarching mission coordinated with local public entities and involving the private insurance sector. It could also entail establishment of public insurance pools engaging specialized financial expertise to establish coverage for the otherwise uninsurable households and small businesses. Private property and public institutions assets remain largely uninsured. Hence, it is imperative to consider national natural disaster management systems that can engage in systematic risk assessments and establish coverage using appropriate financing solutions.

Central governments play a fundamental role in post-disaster management initiatives, so there is a need to develop national, integrated, government-induced risk management programs (Freeman and Martin, 2002). Risk management programs enforce a focus on the causes of disaster losses rather than submitting to reactive responses after the disasters have happened. Considering risk financing arrangements in advance can help reduce vulnerability and secure availability of funds for post-disaster recovery (Andersen, 2005).

Managing Exposure to Catastrophes

Imposing Risk Management

The adoption of a structured risk management process by central governments is indispensable to deal effectively with the economic repercussions of exposure to catastrophes. Exposed LAC countries generally need a better understanding of how potential catastrophic events may affect their public finances in the immediate aftermath of a severe or catastrophic event, as well as in the medium and long term. These insights would allow the governments to engage in appropriate preparedness efforts, risk mitigation investments, risk financing arrangements, and subsequent emergency and reconstruction initiatives.[16]

A structured risk management process includes a comprehensive environmental analysis to identify major risk factors and assess the exposure and vulnerability of the population and

---

[15] Whereas the fund has received advance annual budget allocations, this funding was not sufficient to cover all losses that resulted from hurricane Wilma in 2005. Hence, this event has prompted FONDEN to obtain additional coverage through risk-transfer in the international market.

[16] Mexico is one of the few examples of how this can be approached. The Mexican government has a natural disasters prevention fund (FOPREDEN) in support of risk mitigation efforts and a natural disaster fund (FONDEN) for *ex ante* financing arrangements for natural disaster events. Mexico has also established emergency plans to coordinate local and federal activities in case of natural disasters. See for example, Monti (2008).

essential economic assets to these risks, and thereby determine the potential direct and indirect economic losses. This provides a basis to evaluate the net benefits of mitigation investments and the effects of alternative risk-transfer solutions (Figure 7). The structured risk management process incorporates risk preparedness that organizes necessary emergency activities and establishes risk monitoring and early warning systems. The entire risk management process is driven by overarching risk policies that can be audited and scrutinized on an ongoing basis.

Figure 7. The Structured Risk Management Process
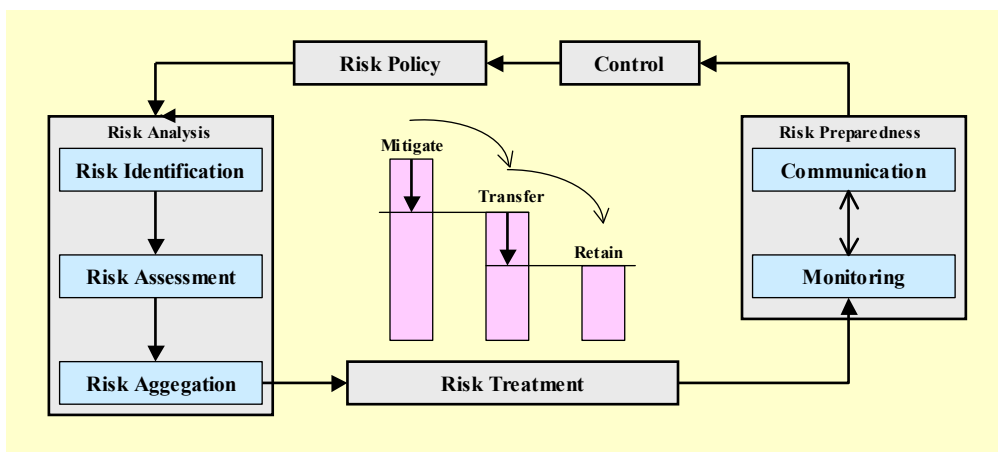
Source: Adapted from Andersen (2007).

Effective risk management ultimately depends on an internalized social culture that promotes risk awareness. That is, societies that ignore potential risks and neglect basic precautions against population and assets concentration in high risk areas and allow technical vulnerabilities to natural disasters to build up are likely to be taken by surprise when extreme events happen, and will be poorly prepared for the negative consequences. A structured risk management process will help circumvent this. Conducting thorough environmental analyses can identify major risk factors that circumscribe a given country or an extended geographic region. The direct economic impact of natural hazards can be determined. In developed countries, this is done by stipulating likely hazard intensities, identifying exposed economic assets, assessing their vulnerability, and determining the cost to replace damaged assets (Freeman, et al. 2003).[17] This exercise can use historical data that show the intensity of past incidents and use this insight to

---

[17] As described hereinafter, the IDB Integrated Disaster Risk Management and Finance Approach (IDRM&FA) introduced a new gradual methodology to deal with this issue in developing countries.

establish probabilities for future occurrences. These calculations can be done by computerized simulation techniques where catastrophe events characterized by relevant occurrence parameters are generated stochastically.[18]

The direct economic exposure to natural disasters can be determined from central data files listing the public infrastructure and from public registers of private dwellings (Andersen, 2005). In many countries of the region, these databases are very weak or nonexistent. The value at risk on these economic assets is found by multiplying the inventory list with cost estimates for each asset class. Given the expected intensity of natural hazards, potential damage inflicted on different types of assets is determined by the hazard intensity and the quality of assets.[19] The intensity of a given hazard combined with the vulnerabilities of exposed assets determines the level of damage inflicted by disaster events. Total direct economic losses are then derived by multiplying the damage ratio with the value at risk across all economic assets for all hazards.[20]

Exposed economic assets fall into different categories, where all public and private assets that may constitute future governmental commitments should be included. Public assets, such as roads, bridges, harbors, airports, telecommunication networks, energy grids, administrative buildings and systems, schools, and hospitals, are essential government concerns. Private assets like small businesses and residential dwellings may also create substantial government obligations after disasters because they are rarely insured (Freeman and Martin, 2002). In contrast, industrial compounds and large business facilities are in many cases covered through self-diversification or policies obtained from international insurance companies.

A main objective of the risk analysis is to understand the underlying risk factors and quantify the economic consequences for the government in case of disaster. The potential losses are often expressed in a few key measures. The average annual loss (AAL) indicates the expected loss per year determined as the sum of all event losses multiplied by the event probabilities. The maximum probable loss (MPL) expresses the loss severity in money terms, or

---

[18] Different parameters characterize catastrophic events. For example, earthquakes can be characterized by location, magnitude, and depth, whereas windstorms can be characterized by central pressure, forward velocity, and direction of landfall.

[19] The quality of economic assets can be classified according to the relative vulnerability of facilities. This if often expressed using a vulnerability ratio that takes various factors into consideration, such as building material, construction type, usage, size, and age.

[20] Technically the calculation can be carried out sequentially where a *hazard module* determines the intensity of hazards, an *exposure module* determines the values at risk, a *vulnerability module* calculates the damage ratios, and a *loss module* derives the direct economic losses from different hazard events.

as a percentage of value at risk, based on the current event expectation where individual event losses can be higher.[21] The calculations are often illustrated in loss exceeding probability curves, where a cumulative distribution indicates the probability that losses will exceed a given amount from a single event. Hence, the loss exceeding probability (LEP) curve shows the probability that losses from a hazard event in a given year will exceed a certain amount. The aggregate exceeding probability (AEP) curve shows the probability that total losses from all events in a given year exceed a certain amount (Figure 8). The occurrence exceeding probability (OEP) shows the annual probability that losses from the single largest event will exceed a certain amount.[22]

Figure 8. The Aggregate Exceeding Probability Curve (AEP)
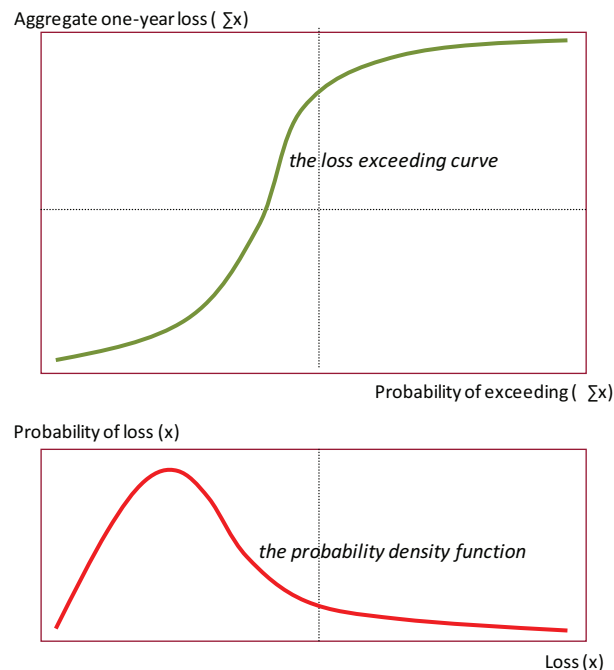
Source: Adapted from Andersen (2007).

---

[21] MPL is not universally defined but is typically derived as the largest likely loss corresponding to, say, a 150-year return period. A 150-year return period event refers to a hazard impact that occurs with an annual likelihood of $1/150 = 0.67$ percent. The definition may also differ among different analysts and for different natural hazards. For example, A.M. Best, a leading insurance rating agency, considers hurricane MPL to be a 100-year return period and earthquake MPL a 250-year return period.

[22] These calculations are often performed in advanced catastrophe simulation models developed by specialized consulting firms. But there are cheaper alternatives to stipulate loss expectancy relationships based on historical loss records maintained by major reinsurance companies, and this can provide sufficient insights to engage in proactive risk management practices and evaluate risk-financing alternatives.

The expected loss profile can be used to discuss the potential for direct economic losses and the effect on government finances under different disaster scenarios. Initially this means assessing whether the loss estimates constitute significant economic exposure in view of available public resources. Say, the calculations indicate 5 percent likelihood that direct losses will exceed the funding capacity of the government over the next year. That may be considered excessive exposure that needs to be mitigated and/or funded in advance. Concerns about the magnitude of exposure depend on the extent to which the losses reduce welfare and impose excessive costs by eliminating promising development investments. So, the government should try to shield existing investment programs with high future returns against the potential adverse effects of a disaster.

It is important to point out that the process of MPL assessment and monitoring is costly and requires solid and sophisticated institutional capabilities. Most of the LAC countries are still far from being able to set up, much less to operate and maintain, the necessary institutional capacity and resources. Confronted with these realities, the Inter-American Development Bank (IDB) is developing assessments and monitoring through a two-pronged, gradual approach. On one hand, the IDB is providing grants to the Central America Probabilistic Risk Assessment Program for technical assistance, which will provide a comprehensive MPL evaluation for the most vulnerable countries in the region. The program was originally designed for Central America, but it has recently been expanded to include a larger number of LAC countries that are more exposed and vulnerable to natural disasters than some of the other countries in the region. Also, the IDB has developed a methodology to estimate the emergency costs of a natural disaster (Collich, et al., 2010) using statistical analysis and projections based on historical data for each country that recorded extraordinary emergency public expenditures related to public disasters. The resulting estimates are instrumental in determining the amount of ex ante funding that the government should expect to have available in case of natural disasters of different magnitudes and the specific kind and amount of financial instruments to be used to provide timely and cost-effective coverage. The IDB has already conducted preliminary studies in the Dominican Republic and five other countries in Central America (Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua).

In addition to the above, the IDB has conducted evaluations of the degree and quality of disaster insurance coverage of the infrastructure assets of major public utilities, with an aim to

improve the effectiveness and efficiency of their coverage. Based of these evaluations and as first step in that direction in the Dominican Republic, the Bank is currently supporting the development of standardized systems and procedures to register, value, and periodically report to the national authorities the residual historical cost, the estimated remaining useful life, and the current reposition cost of the infrastructure assets of all the major public utilities. Once in place, the systems are expected to provide invaluable information to refine decisions about coverage of the assets involved against exposure to natural disasters.

Prevention and Mitigation Investment Issues

The negative self-perpetuating effects of economic exploitation, environmental degradation, and natural disasters call for projects to develop sustainable economic conditions and rebuild natural habitats that can prevent future catastrophes. It is obviously in the long-term interest of exposed countries and their multilateral backers to enhance these efforts. In addition to these initiatives, it is usually possible to reduce the vulnerability of existing economic assets. These risk mitigation considerations can be assessed through simple cost-benefit analyses. For example, imposing stringent building codes can reduce economic vulnerability.[23] This may also require investment in enforcement and adoption of better construction techniques. But there are trade-offs between the need for upfront investment and savings for reconstruction after a disaster. Risk mitigation should be pursued as long as the present value of future benefits can be expected to exceed the upfront expenditure. In this evaluation, potential economic efficiency gains from installing better assets in the reconstruction phase (Figure 9) should also be considered. There is also a subtle relationship between risk mitigation and the possibility for viable risk-transfer arrangements. That is, if the vulnerability to natural catastrophes can be reduced, the cost of risk transfer becomes comparatively cheaper.

---

[23] This can be accomplished through public-private partnerships whereby mortgage loans are granted only if property insurance is in place and/or the house fulfills the building codes and is properly registered with the public authorities. See for example Kunreuther and Michel-Kerjan (2008).

Figure 9. Risk Mitigation: Cost-Benefit Tradeoffs
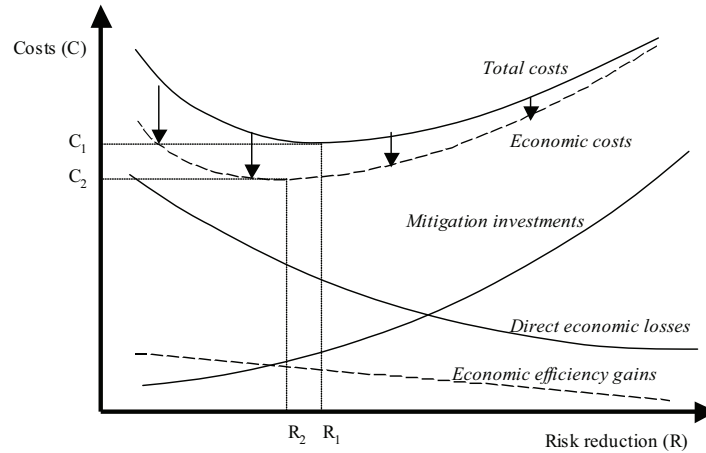
Source: Adapted from Miller and Keipi (2005).

The discussion of risk mitigation and risk financing assumes that major economic assets can be replaced in a timely manner after catastrophic events. This primarily considers the potential impact of direct economic losses with little focus on indirect economic effects that constitute the most important immediate concern after a disaster. That is, if the economy is not quickly reinstated after a disaster, the damage to long-term economic activity could be severe. It is thus important to assess the government's ability to finance essential relief and recovery needs right after a disaster before considering subsequent funding for reconstruction. Under all circumstances, the government must assess the total funding needs and determine how much can be self-financed from cash reserves and how much must be funded through credit facilities and risk-transfer arrangements. Establishing reasonable financing precautions will require ongoing monitoring of credit conditions and insurance rates. The risk financing decision has some underlying tradeoffs because higher coverage typically leads to an exponential increase in the cost of insurance. Hence, ex ante risk financing should only be pursued as long as the cost of obtaining advance funding is lower than the expected cost of post hoc funding after incidents have happened.

Governments have an interest in preparing society for impending catastrophes, reducing the immediate devastation, and preparing for an organized return to normal conditions after a disaster. This requires continuous monitoring of environmental conditions and maintaining early warning systems combined with comprehensive preparedness planning for suitable evacuation

routes, emergency shelters, rescue workers, support services, etcetera. The better a country is prepared for disaster, the lower the human devastation and the higher the likelihood of a speedy economic recovery.

Preparing for the eventualities of extreme environmental events enhances the ability to deal quickly with the onslaught of catastrophes and reduce the associated human devastation. The aftermath of rapid onset events requires focused efforts to clear the environment of debris and restore basic societal functions. This recovery process involves clearing roads, making public areas accessible, and generally reinstating basic public services. Once this has been accomplished, public facilities and basic economic infrastructure can gradually be restored. Depending on the size and forcefulness of events, the initial relief and recovery operations typically last between three and 12 months (Figure 10).[24]

Figure 10. The Timing of Relief, Recovery, Repair, and Reconstruction Costs
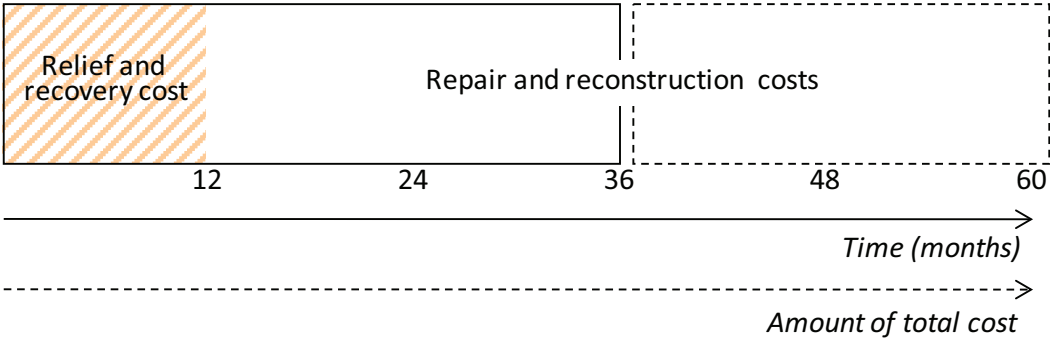
Source: Adapted from Andersen (2007).

The actual repair and reconstruction phase commences once the public space has been cleared and the basic public infrastructure reinstated. Different types of economic assets may be more or less affected by the disaster. When public facilities have only been partially affected, the requirements may be limited to major repairs and reinforcement of existing facilities. In more severe cases, such as where buildings and larger structures have collapsed, there may be a need to rebuild facilities to new improved standards. Again, depending on the severity of the damage, the reconstruction period can last for several years (Figure 10).

---

[24] The expected amount of needed relief and recovery funding can, for example, be assessed on the basis of historical records of public expenditures for these purposes set in relation to the severity of the natural disaster events causing the damage.

The Role of Disaster Financing

The ability to engage in immediate relief and recovery operations and subsequent restoration efforts depends on the availability of government funds to accommodate these activities. A typical response to unexpected financial needs from disasters is to divert funds from the public investment budget, increase tax revenue, and add to the government's debt obligations, including international loans. The practice of diverting funds from long-term investment programs may disrupt economic development and hurt future growth prospects. Hence, there is a need for an orderly approach to finance impending disaster events.

It is important to note that international aid has been more visible and significant. According to an IDB study (Freeman et al., 2003), the amount of aid appears to depend on the nature and extent of the event and there is considerable uncertainty regarding the aid available after a disaster. Based on data regarding historical events from 1960 to 2002 for 16 Latin American countries and limiting the analysis to events that caused economic losses of more than US$50 million, on average international assistance can be expected to cover 8.6 percent of direct disaster losses. Most aid received after a natural catastrophe is in kind and only 5 to 10 percent is in cash.

Making needed funding available on a timely basis requires a systematic risk management approach. There is a need to complete comprehensive analyses of the major catastrophe risks and consider mitigating major exposures to make economic assets less vulnerable to extreme hazard events. This paves the way for determining potential funding requirements in future catastrophe situations and thereby provides the basis to consider implementing suitable risk-transfer and financing arrangements in advance. By engaging in reliable assessments of major economic exposure, the government can face future environmental scenarios with the necessary prerequisite for ongoing considerations about how to handle the residual risks. This implies assessments of expected government cash reserves, fiscal flexibility, credit conditions, and price developments in the global reinsurance market while weighing the costs of ex ante financing arrangements against possible post hoc funding alternatives.

The government can engage in ex ante financing arrangements to protect its long-term investment programs. If, say, the aggregate exceeding probability curve (AEP) indicates a

5 percent likelihood that direct losses may constitute more than 25 percent of the public investment budget, it may be considered an excessive risk that should be reduced. This can, for example, be accomplished by buying an excess-of-loss (EXL) insurance contract that reduces the possible loss to, say, 10 percent of the investment budget. Simulation studies indicate that risk-transfer solutions can stabilize economic growth up to a certain level of coverage (Freeman et al., 2002).[25] However, since premiums for higher disaster risk increase exponentially because of the higher uncertainty, it is not economical to insure the very highest loss levels (Pollner, 2001). That is, governments must consider the viability of ex ante credit facilities and insurance schemes and possibly obtain more modest coverage to safeguard the public funding capacity. The final choice between different risk financing alternatives, such as standby credit facilities, contingent capital, insurance, and cat bonds, must be based on ongoing price comparisons and evaluation of financial market conditions (see for example Andersen, 2005).

A high emphasis on risk prevention and mitigation efforts is instrumental for reducing the economic vulnerability to natural disasters. Risk identification and measurement is essential to assess exposure and develop appropriate risk-transfer and financing solutions for reconstruction. These aspects of risk management are necessary prerequisites for better risk transparency and effective post-disaster funding arrangements. The catastrophe exposure of different economic assets may require different risk-transfer mechanisms. The public economic infrastructure can be dealt with directly by government agencies through financing structures arranged by a central risk management office. Government exposure to private housing and small businesses is probably managed more effectively through government-sponsored vehicles or insurance pools.

Governments often feel obliged to fund disaster losses that have devastated the constituency, including the need to rebuild accommodation for the poorest segments of the population that are typically the hardest hit. To forestall these funding needs, it is imperative to determine the economic assets that can expose the public finances. While these exposures obviously comprise public assets owned directly by the government or quasi-governmental

---

[25] The price of conventional reinsurance is typically indicated by the rate-on-line (ROL) calculated as the premium divided by the cover limit. The ROL is usually higher than the actuarial probability of a full loss within the cover limit because the insurance industry must cover its administrative and financing costs. If these costs seem excessive, it may be viable to engage in self-insurance or pooled solutions based on mutual coverage.

institutions, it may also include some private assets.[26] To the extent the government is tempted to engage in post-disaster property loss coverage to private households, it leads to moral hazard problems because it creates precedence and eliminates the incentives to mitigate risk. This increases the aggregate exposure and postpones improvements in building quality. Offering insurance coverage on commercial terms to the public through a government-sponsored insurance pool can help circumvent some of these inherent problems, but is usually very hard to implement effectively, particularly in developing countries with a very high percentage of their population living in precarious housing.[27]

Adopting a structured risk management process that sets a financial strategy in place before a disaster occurs is the key to securing funding for post-disaster recovery and reconstruction efforts. Quick recovery of normal living and commercial conditions will help minimize the indirect economic effects of disasters. As the restoration of economic assets often adopts state-of-the-art technologies, the replaced assets will be more resilient to natural disasters and will be more efficient in spurring economic growth. Hence, it is in a country's best interests to ensure that this virtuous economic dynamic is set in place by adhering to a systematic risk management process.

Disaster-Linked Risk Financing Instruments and Strategies

Retained Risk Financing Instruments

Other instruments, such as committed credit facilities and contingent capital, secure future funding to finance retained risk rather than transfer risk. These instruments ensure that funds are available on predetermined conditions in case a need arises after a major disaster. Financial institutions, including some multilateral banks, may, for example, offer a committed revolving term facility that provides funding by rolling over short-term credits at a fixed spread over a variable market rate, say, Libor. It can also be arranged as a simple bank loan with a fixed

---

[26] Private housing can constitute a significant share of the economic assets affected by natural disasters where the government feels obliged to provide economic compensation (Freeman et al., 2002).
[27] The Turkish catastrophe insurance pool (TCIP) was the first risk management vehicle established to handle uninsurable catastrophe risks in an emerging economy. The TCIP was established in the wake of major earthquakes in Istanbul in 1999. This required regulatory reforms to mandate insurance for all residential properties and enforce building codes and construction standards. The insurance pool was managed professionally by Milli Re (a national reinsurance company) based on accumulated reserves, reinsurance contracts, and a credit facility provided by the World Bank (Gurenko, 2004). The TCIP is recognized as a significant risk management solution. See for example Monti (2008).

maturity and repayment schedule and a maximum committed drawdown available any one time during the period. These types of committed facilities typically charge a commitment fee to cover the issuer against the implied interest rate, liquidity, and credit risks of making funds available for future draw down.

Contingent capital arrangements such as surplus notes are also offered by some insurance affiliates and guarantee issuance of medium-term debt instruments on predetermined conditions when certain risk-related triggers are activated. The guarantor of the instrument, which effectively is a put option, requires payment of periodic premiums as compensation for the commitment. However, none of these instruments have so far been issued to cover disaster funding in a developing country. It should be noted that payment of premiums and commitment fees only covers the availability of funds on predetermined conditions. All future draws will add to the total debt burden and the loan proceeds must be repaid in full in accordance with the agreed credit terms. This is in contrast to insurance where the premiums are paid against future reimbursements if predefined disaster events occur. Obviously the insurance premiums are determined in a manner that reflects the probability of future losses.

Box 2. Contingent Credit Facility Loans

These credit facilities represent a new type of loan that is a hybrid between committed standby credit facilities and contingent debt instruments. A guaranteed standby facility makes funding available to the holder on agreed terms and can be drawn down by simple request from the borrower. A contingent debt instrument provides funding on predetermined conditions if and when certain events take place and thus constitutes an option. That is, the agreed loan facility is made available for draw down by the borrower when certain events take place, such as a particular (set of) catastrophic event(s) of a given magnitude is registered. All loan facilities can be subject to relevant covenants; for example that the borrower continues to employ systematic risk management practices.

The IDB developed a contingent loan facility in 2009 to cover the immediate funding needs in case of larger natural catastrophes in its member countries. The Contingent Credit Facility (CCF) is intended to support the initial relief and recovery efforts that are essential for a quick economic recovery during the emergency period in the immediate aftermath of severe to catastrophic natural disaster events, when governments typically are short of funds. The CCF uses contingent parametric disbursement loans to provide this support.

Loan resources are made available for disbursement to the borrowing country governments, immediately on verification of occurrence of events of certain pre-agreed type, location, and magnitude (the triggers). Loan proceeds apply to financial needs that exceed the costs associated with frequent and recurring events that should be funded by planned budgetary allocations. Hence, the CCF provides funding targeted beyond current needs from common events with low to medium loss exceeding probability (see figure below).
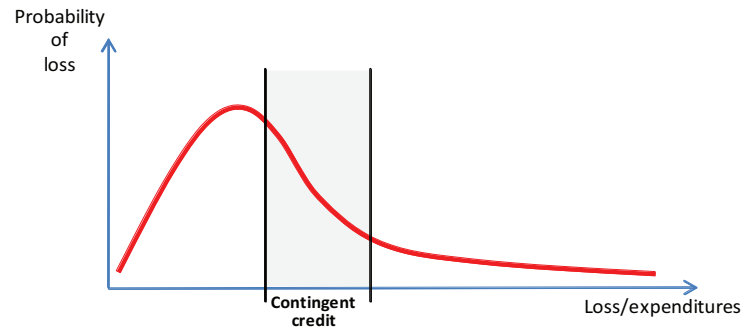
The IDB has introduced parametrically formulated hazard events to effectuate, or trigger, the loan facility. For example, loan proceeds are only made available in the case of hurricane and earthquake events that exceed certain predetermined levels (determined by standardized measures of wind speed, precipitation, and shaking intensity) at exposed locations (areas with a given level of population concentration).

Main Risk Transfer Instruments

When government risk pools and other risk vehicles consider non-budgetary financing strategies, there are a number of alternative instruments to consider. The conventional transfer of catastrophe risk takes place among participants in the global reinsurance market with risk-linked securities taking a strong foothold in the capital market in recent years. All the while, standby loan facilities and committed credit lines from international financial institutions constitute another source of ex ante funding for retained risk, together with contingent capital available in the capital market.

First tier insurance companies provide casualty and property insurance coverage primarily through indemnity-type policies. The insurance contracts may cover various hazards in comprehensive policies, but they may also exclude specific events.[28] Primary insurers that accumulate large exposure to similar risks can cede part of their exposure to global reinsurance companies and the reinsurance companies may, in turn, retrocede exposure to other reinsurance

---

[28] For example, insurance companies that operate in areas with high potential exposure to specific catastrophes, such as hurricanes and flooding, may specifically exclude these events from the comprehensive coverage, and losses caused by war and civil unrest are commonly excluded.

companies, and thereby diversify the risk in the global reinsurance market. Governments and institutions with large aggregate exposure to catastrophe can deal directly with the global reinsurance companies to transfer part of their excess catastrophe risk.

Box 3. Disaster Insurance Facility

In 2008, the IDB recently introduced a disaster insurance facility, the Regional Insurance Facility for Central America, or RIFCA. This facility allows countries in the region to gain direct access to the international reinsurance market through the creation of country-specific risk-transfer solutions geared to deal effectively with the unique circumstances of local exposures. The IDB provides technical advice and funding for development of the facility that may provide multiyear coverage for one or more perils. The facility also opens for collective arrangements across countries with conjoint regional exposures to gain potential diversification advantages. The adherence to a common, but flexible, facility structure will lead to standardization and scale economic advantages over time.

The IDB's global reinsurance partner in RIFCA, Swiss Re, has deep insights about regional hazards and country exposures that, in combination with extensive experience in the international insurance markets, provide the opportunity to arrange economically viable risk-transfer solutions. The IDB acts in an advisory role to the regional governments within the context of their integrative risk management efforts and will arrange funding to cover the facility needs during the take off period.

From an actuarial perspective, disaster risk coverage is special because it represents high levels of uncertainty with extreme loss potential. Furthermore, the individual loss events are not independent of each other, as is the case with most casualty and property risks, but are highly correlated within a given geographic area where an extreme hazard plays out. The direct economic losses from natural disasters typically occur within a short period of time, depicted statistically as event spikes rather than normally distributed loss events. Therefore, catastrophe risks can only achieve diversification by structuring regional non-correlated coverage for each specific peril or by ceding excess exposure to reinsurance companies with a wider global reach or transferring risk to a broader set of financial market participants.

Catastrophe exposure is typically ceded as facultative non-proportional treaties. The facultative insurance treaties cover specific risks, such as windstorms, flooding, and earthquakes, among others. Non-proportional treaties do not divide premiums and losses pro rata but define a deductable or attachment point, up to which the ceding party will assume all losses. The reinsurance company is obliged to cover losses in excess of the deductible up to a certain maximum amount, the exhaustion point. Hence, the insurance coverage applies to a loss range determined within the attachment and exhaustion points, often referred to as a *layer*. Insurance

exposure can be divided into different layers, where each layer has different degrees of coverage and may use a variety of risk financing mechanisms (Figure 11).

Figure 11. Reinsurance Layers and Retention Structures
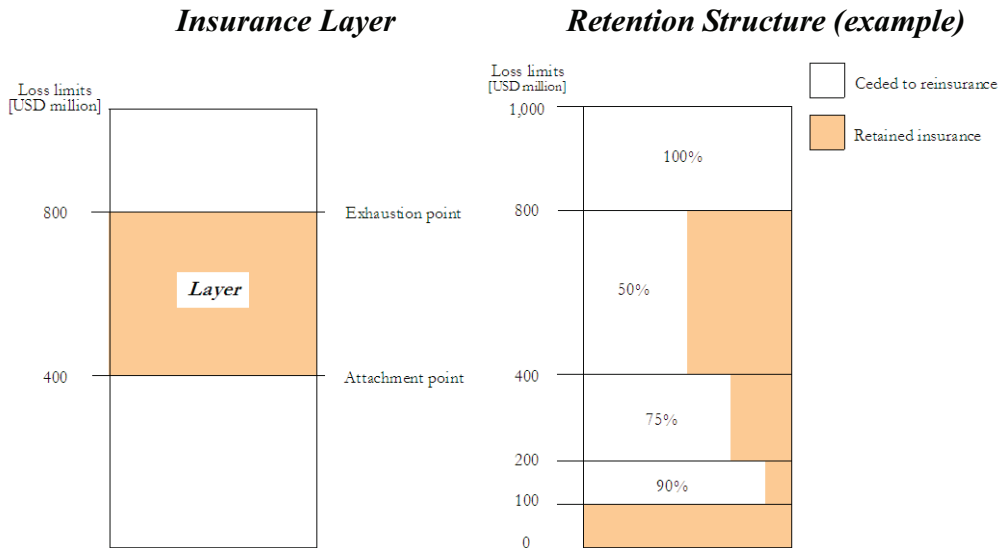
Source: Adapted from Andersen (2005).

In principle, future disaster losses can be infinitely high. That is, everything can be lost and there is really no upper loss limit in the case of a mega-catastrophe, although it might be a highly unlikely event.[29] As loss levels increase, the predictability of their occurrence becomes more uncertain, meaning that when the standard deviation of expected catastrophe losses goes up, there is a push for higher insurance premiums (P_{cat}).

$$\text{Premium } (P_{cat}) = p \bullet \sigma_{cat} / \sigma_{non\text{-}cat} \bullet \text{Cover limit}$$

where p = probability of catastrophic event

σ_{cat} = standard deviation of catastrophe losses

$\sigma_{non\text{-}cat}$ = standard deviation of non-catastrophe losses

Cover limit   = the maximum insured loss

---

[29] For example, if a large meteorite hits an economically dense part of the earth, it could eliminate all economic assets and dramatically change global economic activity, but the likelihood that this will occur is considered very remote.

Current reinsurance premiums are influenced by the most recent event losses. This is partly due to increased uncertainty after a major unexpected catastrophe event and partly because claims after major losses will drain the reserves of the reinsurance industry, which drives a price hike to replenish reserves and reestablish the solvency ratios.

$$P_{cat, t} = p \cdot \sigma_{cat} / \sigma_{non\text{-}cat} \cdot loss_t/loss_{t-1} \cdot \text{Cover limit}$$

$$\text{where } loss_t = \text{loss claims in current period t}$$
$$loss_{t-1} = \text{loss claims in previous period t-1}$$

This is consistent with increases in the rate-on-line following major historical events like Hurricane Andrew in 1992; September 11, 2001; and Hurricane Katrina in 2005 (please refer back to Figures 5 and 6).

A tighter catastrophe reinsurance market in the mid-1990s made financial intermediaries look for alternative risk-transfer opportunities mediated through the capital markets by investment banks to large diversified investors. It was found that institutional investors familiar with the risk market would be willing to incorporate securities linked to disaster risks that are uncorrelated with other commercial exposures and thereby diversify their investment portfolios. That is, large institutions could absorb sizeable catastrophe exposure in their investments and balance their portfolios by including different perils and geographic regions to gain further diversification. The first of these capital market instruments was placed in 1994 when a special purpose vehicle (captive) of Hannover Re issued a catastrophe bond linked to worldwide property catastrophe losses, and the market has evolved since then. These instruments, referred to as cat bonds, typically cover defined catastrophe perils like hurricanes, typhoons, and earthquakes. Payouts from the cat bonds are arranged as loss indemnity, parametric triggers, loss indexes, or modeled losses. Indemnity is less popular among investors because it entails higher moral hazards, while other techniques impose some basis risk on the sponsors. The market has introduced hybrid forms that combine two or more triggers to better manage the basis risk. The market is somewhat split between single and multiple peril transactions. The ceding party may prefer to cover more perils in the same instrument to gain diversification and transaction cost advantages, whereas investors prefer single-peril instruments that increase flexibility when managing their investment portfolios. New issuance activity in the cat bond market expanded

significantly between 2005 and 2007, with total issuance close to US$7 billion in 2007, more than three times the level in 2005 (Figure 12).

Figure 12. Catastrophe Bond Issuance (1970-2008)

(US$ million)
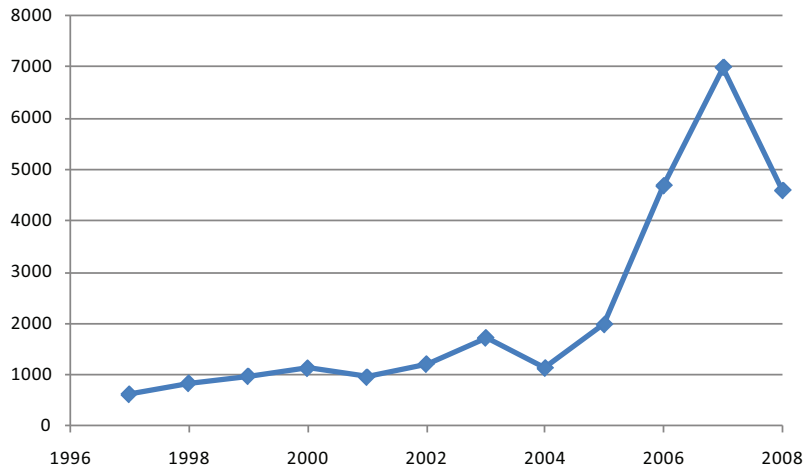
The year 2007 marked a shift toward using capital markets as a source of risk capital in its own right as opposed to an alternative to a pressed reinsurance market. An increasing volume of transactions adopting standardized issuance processes has continued to lower transaction costs. With an impending sub-prime crisis, 2007 was also a resilience test for the cat bond market, which demonstrated some favorable characteristics. When the general trading spreads widened during the second half of the year, the cat bond spreads continued to narrow, thereby validating the claim that cat bond risks are not correlated with commercial risks. As the economic downturn affected financial markets, the level of cat bond issuance dropped somewhat in 2008–09. Total outstanding risk by year-end 2007 was US$13.8 billion, around US$12 billion a year later, and stood at par with the 2007 level by year-end 2009. This reflects a decade of development that has turned the cat bond market into a genuine source of risk capital. Most

transactions continue to be sponsored by participants in the global reinsurance market, with an increasing number of transactions issued by corporate and government entities.[30]

Other techniques used to transfer and securitize catastrophe risk have emerged, including catastrophe risk swaps, so-called sidecars, and industry loss warranties. The risk transfer characteristics of a conventional reinsurance treaty can be replicated in a catastrophe risk swap. The catastrophe risk swap uses standardized swap documentation to formalize the contractual obligations of the reinsurance arrangement, which can provide flexibility and speed. Catastrophe risk swap agreements are relatively simple over-the-counter instruments to transfer catastrophe exposure. Engaging in risk swap agreements requires legal expertise and most likely has an insurance company as a counterpart.[31] In the catastrophe risk swap, the cedant makes fixed payments corresponding to the premiums paid in a reinsurance contract against indemnification if losses materialize. Insurance companies primarily use catastrophe risk swaps to manage and diversify their catastrophe risk exposure.

Sidecars are special purpose vehicles, like cat bonds, formed to create additional retrocession capacity to the reinsurance industry. They are typically structured as class 3 Bermuda reinsurers that enter into quota-share agreements on property and catastrophe exposure. The vehicle is capitalized with funds made available by outside equity and debt investors committing funds for one to two years. The risk of the ceded insurance portfolio is shared between the sponsor and the sidecar in a proportional reinsurance arrangement, which is a quota-share arrangement, where premiums, risks, and losses are split in accordance with a predetermined ratio. Typical transactions represent collateralized quota-share insurance with maturities less than two years. They allow a sponsor to quickly increase its underwriting capacity while investors get access to special insurance lines, natural perils, and geographic regions in

---

[30] The cat bond issued by Mexican FONDEN in 2006 was the first to cover disaster risk in the LAC region. FONDEN, the calamity fund created by the Government of Mexico, sponsored a US$160 million transaction for a vehicle called CAT-Mex Ltd. designed to provide government funding for immediate response requirements in the case of qualifying earthquake events of certain predefined magnitudes in specified regions of Mexico. Given the previous absence of Mexican earthquake risk in the market, the issue was valued by investors as an opportunity to diversify their invested portfolios. It was the first securitization of Mexican earthquake risk and the first government issuer. The Mexican government has followed this initiative with a cat bond issue introduced in October 2009 sponsored by FONDEN. This US$290 million three-year cat bond provides coverage for earthquakes on the Pacific coast (US$140 million), Pacific hurricanes (US$100 million), and Atlantic hurricanes (US$50 million).

[31] There are formal regulatory restrictions imposed on the wider use of catastrophe risk swaps, with the exception of certain offshore markets because the swap agreements are often deemed to constitute insurance contracts that can only be executed by chartered insurance companies.

large cost-effective amounts. Sidecars became popular during 2006 after conditions in the reinsurance market became tighter, but volume decreased again in 2007 as rates softened.

Industry loss warranties (ILWs) typically provide coverage for events after industry-wide losses have exceeded a certain threshold level. There are a variety of ILWs determined by different triggers, perils, and geographic scope. ILWs are usually structured as binary options, or options-on-options, where payoff depends on two triggers, meaning they are hybrids of financial contracts and reinsurance. Transaction cost and pricing risk are relatively low and there is little information asymmetry between cedant and insurer. Recent transactions have provided coverage for second and third event losses, typically with triggers in excess of US$2 billion. The ILW market expanded after significant losses during the 2004 and 2005 windstorm seasons.

ILWs are primarily vehicles to transfer tail risks whereas sidecars give access to lower layer exposures with a focus on specific risks. Most international reinsurance companies are involved in sidecars and ILWs to complement their traditional reinsurance activities. ILWs are relatively easy to structure and may attract different investors that extend the market capacity. The substantial year-on-year changes in outstanding contracts illustrate their role as buffer instruments when the reinsurance capacity is under pressure and as such these instruments may serve to reduce post-event price sensitivity.[32]

Standardized derivative contracts linked to catastrophe risk were introduced on various exchanges during the 1990s. The Bermuda Commodity Exchange offered catastrophe options based on the Guy Carpenter Catastrophe Index (GCCI).[33] The Chicago Board of Trade (CBOT) listed catastrophe futures on quarterly property losses reported by the Insurance Services Office (ISO)[34] and contracts on a catastrophe index from Property Claims Service (PCS).[35] These contracts were based on official indexes for insured losses registered in specific geographic regions. However, the Bermuda Commodities Exchange suspended trading of its catastrophe

---

[32] For more in depth discussions about how these financial instruments are structured see Andersen (2003, 2005, 2007).

[33] The index reflects insured property losses in U.S. regions (Midwest, Northeast, Southeast, Florida, Gulf) caused by hurricanes, windstorms, tornadoes, and other "atmospheric perils."

[34] This index monitors losses from windstorms, hail, floods, earthquakes, and riots paid by 22 insurers registered by the Insurance Service Office.

[35] The PCS index captures catastrophic losses in the Northeast, Southeast, East Coast, Midwest, West, California, Florida, and Texas.

futures and options contracts in 1999. The CBOT experienced declining interest and subsequently closed trading in these futures.[36]

Using contracts based on regional indemnity indexes to hedge catastrophe exposure can be associated with substantial basis risk, which may be a significant barrier to their use. The hedge effectiveness depends on the extent to which the underlying catastrophe loss index co-varies with the catastrophe exposure to be hedged. Covariance might not exist if, for example, the loss index covers insured property losses in a particular region and the portfolio to be hedged is scattered across different geographies. The latter would obviously reduce the viability of trading in the futures contract on the exchange.

Trading in catastrophe futures on indemnified loss indexes has been less than successful, but new weather-related contracts have emerged. These include weather derivatives on the Chicago Mercantile Exchange (CME), such as contracts on the Heating Degree Days (HDD) and the Cooling Degree Days (CDD).[37] These contracts allow energy producers and users to hedge against volumetric risks associated with changes in weather conditions. These contracts are offered for the United States, Canada, Europe, and Australia through the CME's global trading activities. Recently contracts on frost and snowfall have been added to the list. In addition to these contracts, the CME has introduced contracts on accumulated regional hurricane losses during the U.S. hurricane season based on the Carvill Hurricane Index (CHI) describing the severity and loss potential of an Atlantic hurricane. The CHI is determined by the radius to the hurricane-force winds and the maximum sustained wind speed and constitutes a parametric index (see Box 4).[38]

---

[36] Subsequently, the Chicago Board of Trade (CBOT) merged with the Chicago Mercantile Exchange (CME) to form the CME Group in 2007.

[37] The contracts are standardized so the HDD and the CDD indexes reflect the accumulated daily HDDs and CDDs over each calendar month.

[38] For more detailed discussions about use of alternative triggers and various market practices, see Swiss Re (2009c).

Box 4. Triggers in Catastrophe Financing Instruments

Catastrophe financing instruments (e.g., reinsurance contracts, cat bonds, contingent credits, swaps, and futures) can use the development in different hazard effect measures to determine whether the instruments can be exercised (triggered) to effectuate on the contractually agreed terms. It is possible to distinguish between three basic types of triggers:

Indemnity against actual claims: the trigger is determined by actually reported losses and/or registered indemnity claims from affected entities (low basis risk – high moral hazard/adverse selection).

Standard index: the trigger corresponds to the development of an existing index (e.g., property catastrophe indices) that reports ongoing loss developments on a standardized basis over time (high basis risk – limited moral hazard/adverse selection).

Parametric formula: the trigger is composed of objectively measured indicators selected to capture the conditions that are closely associated with direct economic losses from the disaster (moderate basis risk – no moral hazard/adverse selection).

The choice of insurance trigger influences the level of moral hazard, adverse selection, and basis risk ascribed to the risk financing instruments. A moral hazard can arise when the insurance taker knows more about the loss event and can influence the insurer to the taker's advantage. Adverse selection can arise when there is asymmetric information about risks and exposures between insurance taker and insurer. Basis risk occurs when the de facto compensation from the derivative differs from the actual loss.

As moral hazard and adverse selection is lowest in a parametric trigger, which provides the highest level of transparency for the insurers and should lead to better pricing terms. At the same time, a well-constructed parametric formula should impose very little basis risk on the insured party (see figure below).
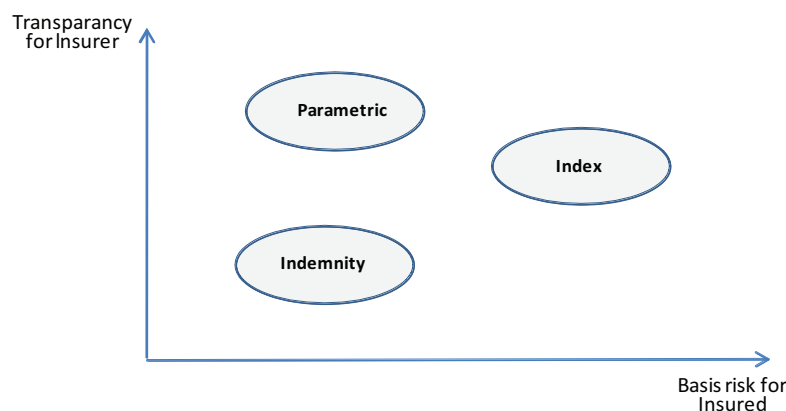
Insurance companies and self-insuring institutions place insurance premiums in liquid financial assets as an invested reserve for future claims against catastrophic events.[39] An

---

[39] One of the of insurance regulators' major concerns is to ensure that commercial insurance providers maintain sufficient reserves that make them able to honor future claims from their customers.

insurance company goes bankrupt if it has insufficient funds to cover payments for insurance claims at any point in time. Therefore, holding a reasonable level of reserves is important. Governments faced with large pools of dependent catastrophe risks are unable to diversify these because the loss obligations are correlated across the exposed regions. In that case, establishing an investment reserve can quickly become insufficient. So, a disaster fund must have access to needed financing if large claims arise.

A government can establish a stand-alone tributary disaster reserve or calamity fund, and obtain the means to support recovery and reconstruction efforts after catastrophes. It can fund such a fund with tax contributions, budgetary revenue allocations, and earmarked taxes or fees for economic restitution. Nonetheless, since the calamity fund is based on the principle of self-insurance, it is often a challenge to gain sufficient provisions for major reconstruction efforts. The government calamity funds often remain undercapitalized and are unable to cover all future obligations.

A more stable financial solution that leaves governments in full control of their own economic assets and manages the implied economic exposure effectively is a national disaster fund that operates as a contingent liabilities financing pool of diverse financial instruments and resources. Comprehensive insurance contracts may provide these pools with some diversification advantages since all economic assets are not equally exposed. The risk pooling provides opportunities to engage in a collective risk financing strategy and establish a national insurance program with special coverage for upper-layer losses. There are clear advantages associated with a national insurance pool, the funding of which may incorporate combinations of alternative risk-transfer and financing solutions.

A natural disaster fund should be able to cover the most immediate funding needs in case of disaster. It may be possible to cover a part of the next higher loss level through increased tax revenue and some budget reallocations. A multilateral institution could make the remaining funding available in the form of a committed credit facility, possibly seconded by local financial institutions to cover costs associated with higher magnitude events. Local insurance companies, including foreign insurance companies in the country, may provide partial coverage through comprehensive mutual contracts for certain types of assets at risk (such as public utilities infrastructure assets), thus removing these risks from the stock of public contingent liabilities and

providing at the same time an excellent vehicle for domestic insurance market development. The higher loss levels that exceed the local market capacity might be ceded to the global reinsurance market. In some cases a government-backed cat bond issue could be a realistic possibility. However, the highest risk layers are often too expensive to cover and exceed what is economically viable to cover on an ex ante basis. Therefore, various multilateral ex post credit arrangements might be needed to cover the highest risk layers, or the government may rely on a combination of various possibilities for ex post financing.

Potential government commitments associated with losses on private assets, particularly houses and small business properties, require more extensive risk management vehicles operating on an arms-length basis. This approach can help establish insurance options to the public managed in accordance with sound commercial and actuarial practices.[40] These government supported insurance pools can provide viable solutions in dealing with these so-called uninsurable risks of natural disasters. This will typically require political initiatives to enforce stringent building codes, but to avoid promoting unmanageable moral hazard issues, it should be voluntary and strive to obtain adherence through direct fiscal incentives, such as tax deductions or tax credits. The purpose of the pool is to make insurance available to legal property owners on economic terms and to enforce building codes. Managing these risk vehicles requires specialized expertise to set up an appropriate risk financing structure and may require government subsidies or multilateral backing as last resort financiers.

These risk pooling vehicles make it possible to transpose moral-hazard-ridden government exposure into an organized ex ante risk market, where private property owners retain a self-interest in the fate of their own assets, but they do not ensure full transfer of covered risk outside the economy, which in case of a catastrophic event could be devastating for domestic finances.

When considering the variety of financial instruments available for risk financing purposes, it is clear that most instruments dealing directly with catastrophe risks are anchored in the international financial markets. Other techniques can be more readily used to handle local

---

[40] The Turkish Catastrophe Insurance Pool (TCIP) was established in 1999 following major earthquakes in Istanbul, Turkey. Although it has major moral hazard issues as a consequence of its mandatory nature, it continues to be an example of this type of vehicle, formed to provide insurance for disaster losses on private property and impose stringent building codes.

risks and could be quite effective in dealing with unique regional exposure. Governments and government-supported insurance pools can gain direct access to sophisticated international financial markets, but should also engage the local financial industry to supply insurance and financial services. This can serve to build institutional strength and technical competencies among local market participants.
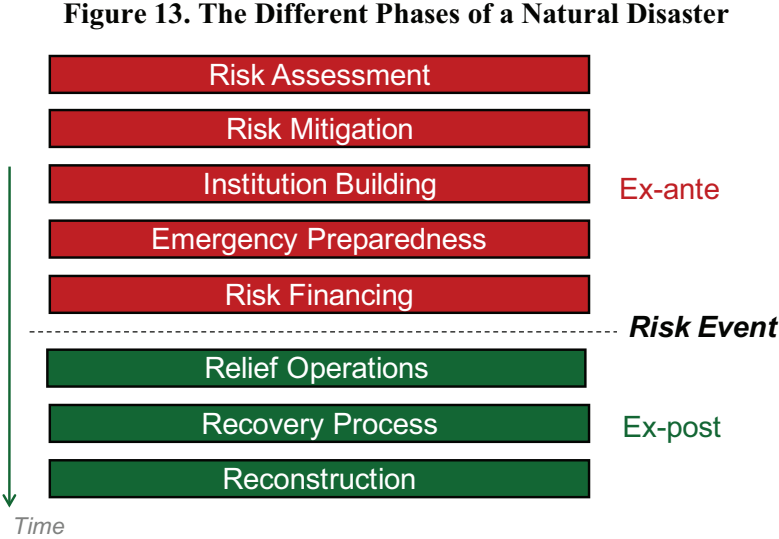
There are many opportunities for public-private collaboration. Local insurance companies can be involved in government projects to create transparent financial markets and develop reliable time-series on risk events in accessible public databases. This can be used to develop new local insurance products and derivatives, allowing local households and businesses to hedge against essential risks. Similar activities can improve data availability on natural phenomena, loss events, property registers, etcetera, all of which will improve the quality of actuarial and credit decisions in the local industry.

Governments can consider collaborative arrangements with established international reinsurance companies as a natural first support toward establishing a structured risk management approach. The major reinsurance companies typically have access to superior data on global catastrophe events and exposed economic assets that can support assessments of the government's direct economic exposure. This constitutes an economical first approach to developing transparent and hands-on risk management practices. The private reinsurance companies can furnish invaluable and timely market data on reinsurance rates and alternative risk-transfer prices. The same institutions will also be invaluable collaborators in thinking through the various alternative financing structures in national insurance pools established to handle government exposure to natural disasters. The multilateral institutions should continue to assume an important role in this process as providers of contingent credit facilities and facilitators of alternative risk-transfer solutions in the capital market.

The Integrated Disaster Risk Management and Finance Approach

The ability to handle exposure to catastrophes effectively can make a significant difference to the potential for economic development. Exposure to natural hazards is related to other country risks, such as political and institutional risks, economic risks, and environmental risks. The capacity to transfer risk within local markets relies on strong institutional structures, which are

seldom present in developing countries, and environmental degradation increases the economic vulnerability to natural hazards. All the while, unexpected catastrophic events and associated funding gaps have adverse economic effects and erode institutional effectiveness. This reality illustrates the need to adopt systematic risk management and establish viable strategies to finance the risk of catastrophes. However, there is a need to create a better balance between instruments for ex post funding and instruments for ex ante financing to make it more opportune to engage effectively in systematic risk management practices. This clearly puts the focus on future product development efforts to establish credit facilities that cater to all the phases of natural disaster management and thereby enhance the considerations for catastrophe funding (Figure 13). The IDB's response to these priorities is the Integrated Disaster Risk Management and Finance Approach (IDRM&FA), which proposes an integrated strategic approach, both institutionally and financially, to all the different phases of the natural disaster management cycle.

Figure 13. The Different Phases of a Natural Disaster

Phase	
Risk Assessment	
Risk Mitigation	
Institution Building	Ex-ante
Emergency Preparedness	
Risk Financing	
- -	**Risk Event**
Relief Operations	
Recovery Process	Ex-post
Reconstruction	

Time

Source: Authors, Andersen (2005), Gurenko and Lester (2004), and Hofman and Brukoff (2006).

The IDB has been quite aware of the adverse effects of natural disasters for more than a decade, as outlined in the Bank's operational policy on natural and unexpected disasters (OP-704) from 1998. These policy guidelines were expressed in the 2000 Action Plan on Natural Disasters, which focused on disaster prevention, mitigation, and response. But the good intentions were not being reflected in public policy practices throughout the region. An evaluation conducted by the Bank's Office of Evaluation and Oversight (OVE) in 2004 found the

IDB's efforts to be mostly reactive, while exposed countries lacked incentives to reduce risk and remained dependent on international donors. In view of these insights, the Bank aimed to become more proactive by adhering to an integrative risk management approach based on analysis, reduction, financing, risk-transfer, preparedness, and post-disaster rehabilitation and reconstruction. To pursue these objectives, in 2005, the Bank established and funded a Natural Disaster Initiative, and within it adopted an Action Plan for improving disaster risk management (GN-2339-1) to advance an integrated risk management approach and introduce new supportive financing instruments.

While the instruments dealing with natural disasters emerged in the context of OP-704 and the Action Plan with a focus on prevention and mitigation,[41] the subsequent policy on disaster risk management (GN-2354-5), approved in 2007, was also advocating financial protection and risk transfer in public governance.[42] The policy promoted a meaningful engagement of civil society toward these ends and recommended that financial products and services be offered through dialogue with member countries. It was conscious of inherent incentive structures that affect both government and private entities. Hence, a Disaster Prevention Sector Facility (DPSF) was introduced to reduce hazard risks through preparedness, mitigation, and risk reduction. A Disaster Prevention Fund and a Multi-donor Disaster Prevention Trust Fund were also established to encourage investments in disaster prevention through eligible donations. Preparedness and prevention investments were similarly supported by sector investment, technical cooperation, and policy-based loans.

The Immediate Response Facility made urgent post-disaster funding available to restore basic services, make preliminary repairs, and prepare reconstruction, while emergency technical cooperation (GN-1862-5/AT-986) provided additional support for humanitarian investment[43]. However, the funding for immediate response, rehabilitation, and post-disaster restoration was mainly derived from restructuring of existing loans, meaning there was a lack of facilities to bridge the integrative risk considerations with committed post-disaster funds.

---

[41] This refers to the Operational Policy on Natural and Unexpected Disasters (OP-704) approved in 1998 and the Action Plan on Natural Disasters (GN-2339) approved in 2000.
[42] Reviewed by the Board of Executive Directors on February 28, 2007.
[43] The Immediate Response Facility was previously the Emergency Reconstruction Facility (ERF).

In response to these shortcomings, and as a logical next step in the previously mentioned Action Plan of the Natural Disasters Initiative, in 2007, the Bank developed an innovative operational strategy, the Natural Disaster Risk Management and Finance Approach (NDRM&FA).[44] The strategy includes an operational proposal for the gradual development of integrated natural disaster risk management and finance strategies in the countries of the region and the development of natural disaster risk financing of country and regional scope.

Implementation of the new approach began early in 2008 in several of the most vulnerable countries of the region, and, at the end of the same year the Bank approved a pilot program for implementing RIFCA (Regional Insurance Facility for Central America) [45]. In 2009, the Bank approved a Contingent Credit Facility for Natural Disaster Emergencies and the first contingent loan under it for the Dominican Republic. Through the facility, the Bank provides ex ante contingent financing for economic relief and interim recovery. Subsequent rehabilitation and reconstruction efforts can be supported by sector investment loans where applicable. In short, the disaster risk policies and the derived institutional practices have evolved gradually over the past decade to promote integrated risk management programs in exposed countries while offering a more complete palette of financing products to serve these programs effectively.

Some of the natural perils reach across several countries in different LAC subregions and may cause related catastrophic events, such as windstorms in the Caribbean, windstorms and flooding in Central America, and floods and drought in South America. Consequently, there can be potential advantages associated with regional insurance pools, or risk management vehicles, to deal with these specific hazards over wider geographic areas.[46] This is so because the uncertainties around the natural perils cause disasters to hit randomly across the exposed subregions and thereby provide the basis for risk diversification among the countries within that subregion. It may also be possible to uncover underlying patterns between different phenomena formed by common climatic drivers, which could provide other diversification opportunities. By managing regional exposures through an insurance pool, the pool can retain part of the diversification advantage. That is, reinsurance treaties and alternative risk-transfer instruments

---

[44] IDB Document GN-2354/7.
[45] Dominican Republic, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.
[46] Accordingly, the Bank received a request from the Council of Secretaries of Finance and Ministers of the Treasury of Central America, Panama and the Dominican Republic (COSEFIM by its Spanish acronym) in October 2007 to assist on financial risk management of disaster exposures.

will be more favorably priced due to the lower risk exposure of the pooled risks.[47] While the Bank is still unable to provide these facilities directly, it can work with international reinsurance companies to facilitate the best possible risk-transfer arrangements. This is exactly what the IDB has been doing recently by offering to design, structure, and partially finance the take-off costs of the new risk-transfer facility (RIFCA) that provides a standardized risk-transfer solution with flexibility to cover single and multiple perils, across countries and regions of exposed countries.

It is apparent that the IDB should continue to promote and facilitate systematic risk management practices in exposed countries throughout the LAC region. This is the key to increase risk awareness and achieve long-term disaster risk management effectiveness. Governments should know their direct economic exposures and understand the underlying causes of the mounting losses from natural disasters, and they should use these insights to engage in meaningful risk reduction and mitigation efforts while preparing for timely responses if disasters strike.

National governments must have actively engaged and coordinated senior policymakers and institutional frameworks to provide the necessary support functions. Committing to proactive risk management practices will enforce ex ante considerations about how to moderate economic exposures, handle impending disasters, and establish financial resources for all phases of the disaster recovery process.

Assessing Disaster Risk Financing Effectiveness

Governments are affected adversely when there is a lack of financing to deal with abrupt catastrophes. There is an immediate need to fund short-term disaster relief operations while tax revenue typically tapers off because of the associated decrease in economic activity. Governments are faced with the longer-term burden of reconstructing public buildings and economic infrastructure and may often feel compelled to cover private sector property losses. This brings public finances under pressure and typically forces the government to divert funds from long-term development investments while adding to the public debt burden. Hence, the effectiveness of ex ante financing arrangements should be seen in the context of quick access to funds on known terms to cover immediate disaster needs and quickly reinstate economic activity.

---

[47] Mexico's cat bond transaction, which covers Pacific earthquakes, Pacific hurricanes, and Atlantic hurricanes, is an example of this.

It may also be advantageous to have financing in place for needed interim reconstruction investments. This allows the government to minimize the adverse effects on economic activity and secure the means to install more resilient and efficient economic assets after a disaster to furnish economic growth.

So, how much funding should be arranged for ex ante and how much ex post? The public finance argument suggests that the government should arrange ex ante availability of funding to shield its long-term development investments from being affected by major events. That is, there should be ex ante funding available up to a certain level. But, it is generally unrealistic to expect coverage beyond aggregate exceeding losses of, say, a 100-year event, because coverage then becomes excessively expensive for most developing countries to bear, particularly if their fiscal situation is weak and their public and external indebtedness high. Conversely, risk financing arrangements serve no economic purpose for natural hazard events that occur with such a high frequency that they must be considered "normal" environmental conditions. Expenditures arising from these events must be funded through regular annual budget allocations as expected government costs of doing business. Hence, the types of risk for which the government should consider ex ante risk financing arrangements relate to events that have a lower frequency of occurrence but not extreme catastrophic events. Hereafter, the question then becomes how the ex ante risk financing structure should be arranged optimally between government-funded calamity funds, contingent credit facilities, and risk-transfer solutions (Figure 14).

**Figure 14. Instruments for Risk Financing Considerations**
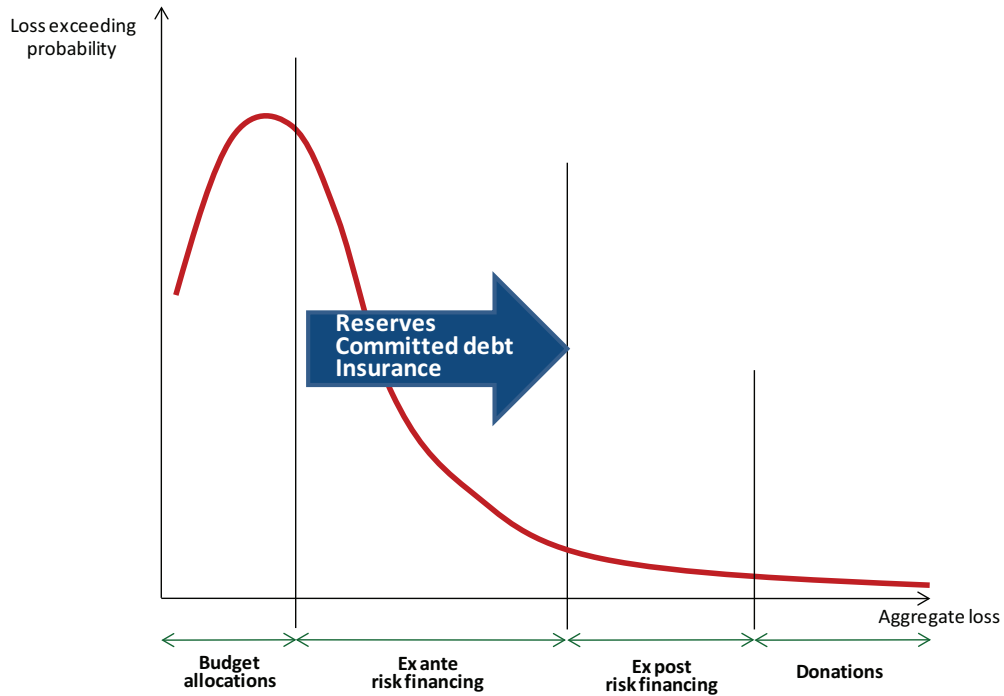
Source: Authors' elaboration.

Given the high opportunity cost of savings, the dimensioning of ex ante financing instruments and strategies should consider the timing of different funding needs, where disaster relief and recovery needs are relatively immediate and short term, whereas reconstruction efforts are longer term and can run several years after the disaster (Figure 15). Moreover, historical data shows that commonly within a year of a severe event, once liquidity pressures have eased, the countries access to financial resources begin to normalize. Consequently, the IDB NDRM&FA proposes to focus on structuring ex ante financial coverage of the extraordinary current public expenditures arising in the immediate aftermath of a severe to catastrophic natural disaster. The main emphasis should be on secure timely funding of immediate liquidity needs to cover relief and temporary rehabilitation expenditures aimed at containing human and material losses that are indispensable for a quick recovery of economic activity. Assuming an upper level of possible ex ante financial coverage, $\bar{U}$, has been determined to manage the government's pooled risks based on analyses of catastrophe exposures, budgetary constraints, and expected financial market

conditions (Figure 15).[48] The next issue to consider is how to arrange the ex ante funding structure, or determine what type of instruments should be adopted and how to weigh and position them within the risk span from 0 to Ū. Three typical instrument types are considered in Figure 15: committed debt (standby credits, contingent loans), risk-transfer instruments (insurance, reinsurance treaties, cat bonds, risk-linked securities), and reserves (disaster and calamity funds). The choice of appropriate funding structure then depends on the comparative financing cost of these alternative financing instruments, as well as each particular country's fiscal and debt sustainability profile.

Figure 15. Cost Dynamic of Risk Financing Alternatives
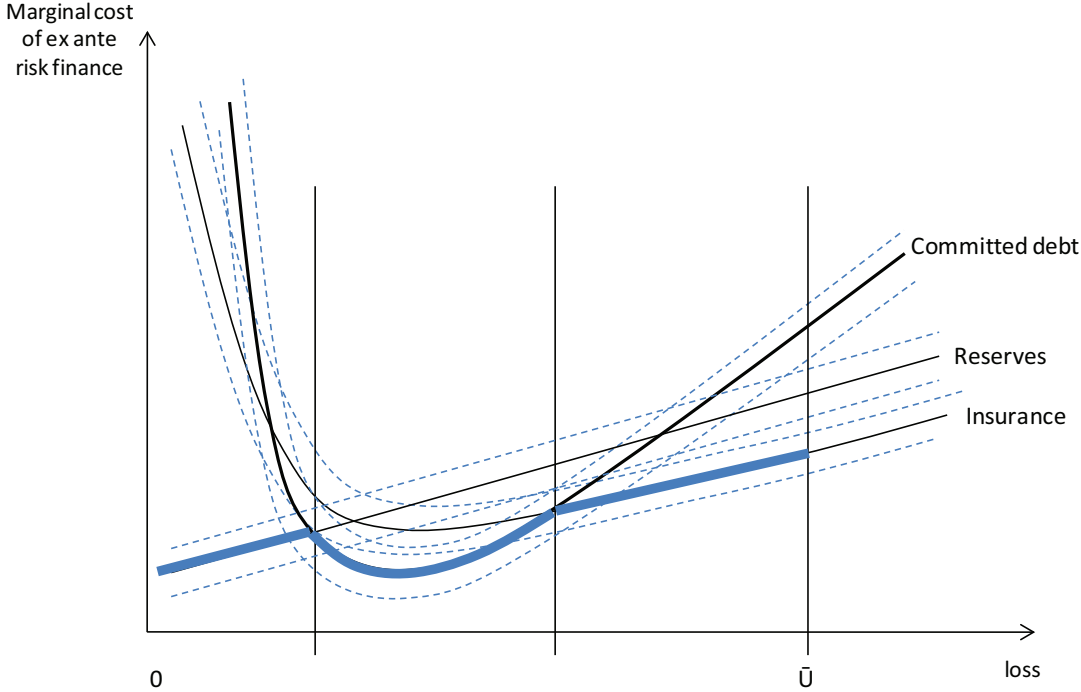
Source: Mahul and Gurenko (2006).

If the social or opportunity cost associated with holding reserves against future catastrophe losses increase gradually with the size of the reserve holding, it may show a gradual increase in cost (Figure 15). If committed debt facilities and insurance contracts have scale

---

[48] In the context of this analysis, Ū indicates the maximum possible level of *ex ante* financing that can be obtained from the public and the financial market, and 0 indicates the loss level beyond "normal" hazard events where *ex ante* financing arrangements become a relevant consideration.

economic effects but also incur increasing bankruptcy risk and uncertainty premiums, respectively, then they will both display u-shaped cost curves. The particular shapes of the two u-curves depend on the relative change in bankruptcy risks and uncertainty-driven insurance premiums as the loss level increases. If the bankruptcy risk increases somewhat faster than the uncertainty premium after a certain level of expected loss, we may see the depicted price curves (Figure 15).[49] In such a price scenario, reserves will be the cheapest way to fund immediate low level losses, then committed debt, and then insurance (indicated by the ideal financing path of the fat line). However, the underlying assumptions about the price dynamic can vary substantially and must, therefore, be assessed critically and reviewed periodically.

The outline of an appropriate financing structure of the proposed general configuration can only be gained through comprehensive analyses to determine an optimal, best, or satisfactory solution. In principle, the government should only buy risk-transfer solutions if the premiums net of the expected losses are lower than the social cost of bearing the catastrophe risk and thereby should only engage in committed debt arrangements if the commitment fee is lower than the social cost.[50] In other words, governments are faced with tradeoffs between securing ex ante financing on predetermined terms that secure future liquidity and shield long-term development investments or engaging in ex post financing that may be available on competitive pricing terms. It has often been suggested that the price efficiency challenge between ex ante and ex post financing alternatives should be determined for each phase of the post-disaster operations: relief, recovery, and reconstruction. Solving this puzzle is not easy and cannot be determined by use of simple optimization algorithms or applying numerical solutions. It is a tradeoff decision that involves pros and cons in the face of great uncertainties about future market conditions and each country's fiscal sustainability profile and individual institutional capabilities.

Based on the marginal costs associated with different ex ante risk financing alternatives within a range of instruments from government reserves and contingent credit facilities to risk-transfer solutions, it is possible to extrapolate an optimal level of ex ante financing. If the marginal cost of ex ante financing is increasing, which is highly plausible, and the incremental benefits from catastrophe financing show diminishing return characteristics, there will be an

---

[49] This may be the case if/when the generic hazard risk is easier to diversify than the country-specific credit risk.
[50] The social cost can be interpreted as an opportunity cost of foregoing sound long-term development investments when financial means are tied up in the reserve fund.

optimum level of ex ante financing (Figure 16). Given that committed debt and insurance solutions rarely fall along a neatly organized increasing cost pattern as suggested (effective availability is one of the most common limitations), the optimal ex ante financing structure will most likely comprise some mixture of debt and risk-transfer instruments well below the maximum level of possible ex ante financing, Ū.

Figure 16. The Optimal Level of Ex Ante Risk Financing
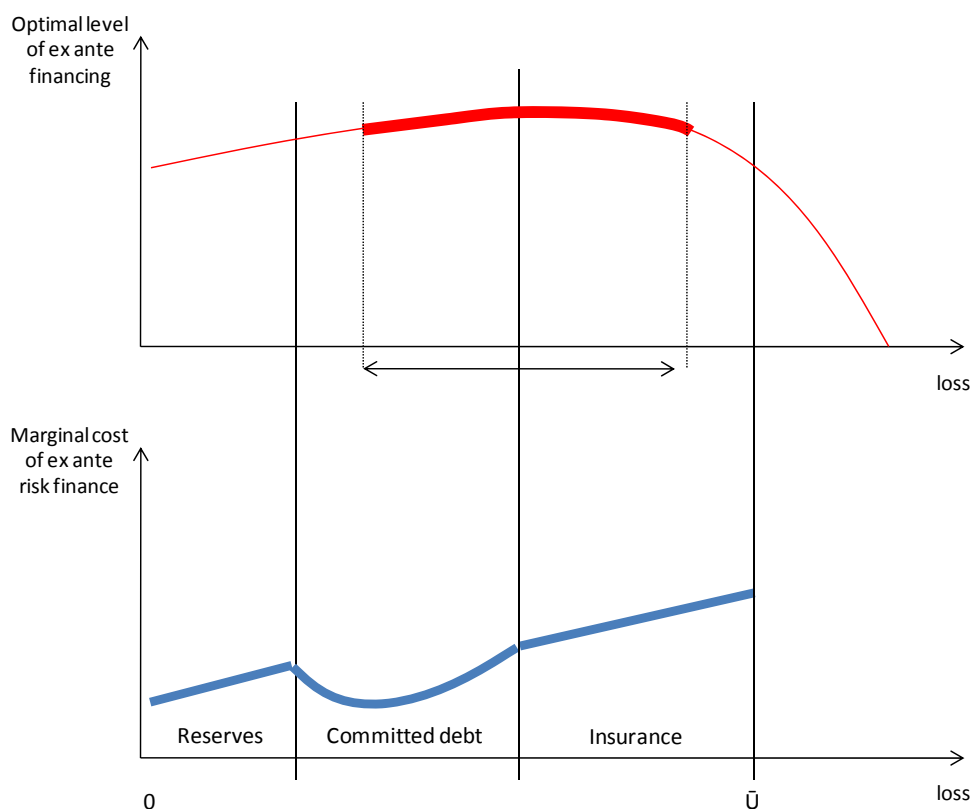
Source: Authors' elaboration.

It should nonetheless be noted that the eventual choice between different types of *ex ante* financing depends on the comparative pricing of alternatives where the cheapest risk financing options should be favored. It should also be noted that different risk layers can be structured and arranged in many ways and can be shared by different types of financing (for an illustrative example, please revert to Figure 14). Determining favorable pricing combinations requires ongoing monitoring of market conditions and active searching for alternative solutions (Box 5).[1]

---

[1] Andersen (2005,) outlines some basic comparative metrics for this purpose.

Box 5. Comparing the Cost of Risk Transfer and Financing Alternatives

Reinsurance

Reinsurance companies consider a pure premium (*PP*) of a size no less than the expected loss (*EL*):

$$PP = EL = p * EPL = p * d * ICL$$

where   *EPL* = expected probable loss estimate
p = probability (frequency) of natural hazard
d = damage ratio = $v * h$
v = vulnerability factor of capital asset
h = hazard intensity factor
ICL = insured capital loss

The total premium (*PT*) charged by reinsurance companies takes operational cost into consideration:

$$PT = PP + exp + u + \pi + R$$

where   *exp* = administrative expenses associated with the insurance business
u = uncertainty factor (risk load) reflecting the unpredictability of disaster events
π = the required rate of return (profit) of investors in the insurance business
R = the reinsurance cost associated with the ceded share of the exposure

Given constant market conditions in perpetuity, the present value of all future reinsurance premiums is:

$$PT/r$$

where r = risk free rate

Credit Facility

The comparable present value of the funding cost associated with a committed credit facility (*CF*) is:

$$CF = [(1-p)(lc\ EPL)] + p \sum ((lr\ (EPL – i/m\ EPL)\ (1+r)-i + (EPL/m)(1+r)-m]/r$$

where   *lr* = interest rate applying to the committed credit facility
lc = commitment fee charged on the committed credit facility
i = the current loan repayment period
m = the final maturity of the committed credit facility

Note: This equation assumes that the loan is repaid in equal installments from year 1 to m and that the final maturity date of the credit facility corresponds to the final repayment date of all needed loans.

Contingent Capital

The comparable present value of the funding cost associated with contingent capital (*CC*) is:

$$CC = [(1-p)OP] + p \sum ((lr\ (EPL – i/m\ EPL)\ (1+r)-i + (EPL/m)(1+r)-m]/r$$

where   *OP* = annual option premium paid for underlying put contract

Note: This equation assumes that funding from the contingent capital contract is the same as the loan structure of the committed credit facility above.

The comparative formulas should be adjusted to reflect changes in the credit facility, for example, inclusion of arrangement fees, different repayment schedules, and bullet payments, among others.

Organizing the Risk Management Offers

Implementation of systematic risk management practices requires a broad set of services ranging from advice about professional risk processes and organization to various analytical risk models and risk financing assessments. Different aspects of risk management need specific attention, including environmental analysis, inventory updates, exposure assessments, mitigation options, financing and risk-transfer alternatives, and preparedness planning. These diverse needs provide opportunities for broad collaboration with international financial institutions and private sector specialists. The IDB should contribute to all these aspects of the risk management process and, as a Bank, should be able to continue offering appropriately tailored catastrophe risk financing solutions to needy member countries.

At the country level, and taking into consideration its fiscal and institutional limitations, the Bank should continue to promote the concept that the various activities required within the integrative risk management approach should be conducted by independent administrative entities dedicated to this work and reporting regularly to the highest levels of government. The reporting should follow the systematic risk management process and perform updated risk assessments, evaluations for risk reduction and mitigation efforts, reviews and revisions of risk financing strategies, and follow ups on general risk preparedness. This type of risk organization would be a natural counterpart for the IDB in discussions about disaster risk concerns as part of regular comprehensive country risk assessments.

Such a government-sponsored risk management organizational structure should operate the complete risk management process through established policies, processes, and practices. An essential part of this effort would include development of data gathering systems to collect reliable information about natural hazards and economic exposures, and thereby reduce the level of uncertainty around disaster outcomes. This is a prerequisite for effective risk assessment and monitoring processes that will favorably influence risk-transfer prices. Implementation of effective risk management requires coordination with third parties, including government agencies, municipalities, regional disaster agencies, and multilateral institutions. The IDB should cater to the operationalization of government risk management offices and engage in the considerations and analysis to supports the countries of insurance pools and related financing and risk-transfer structures that make it possible to deal with disaster exposures on an ex ante basis.

The staffing of government risk management offices with qualified and competent employees to handle the multiple aspects of the risk management process is demanding and may require ongoing training efforts. The IDB could act as a credible source of risk management expertise for this purpose. Being more conscious in the pursuit of a broader risk management agenda may also require the countries to be more explicit about how to identify, engage, and maintain in-house expertise to cover all the relevant aspects of systematic risk management functions. There is a need for specialized expertise that can address all stages of the risk management process. This includes development of information systems, risk modeling, creation of risk-transfer vehicles, evaluation of alternative financing and risk-transfer solutions, while maintaining the existing sector and financial management expertise.

Finally, it should be emphasized once again that moving from a predominantly reactive handling of natural catastrophes toward a proactive risk-management approach requires governance and policy frameworks that provide exposed member countries incentives to implement these strategies. The IDB, through its policies and country operational programs, should continue to put forward consistent incentives to induce supportive behaviors, for example, the offer to grant technical and financial support to develop an IDRM&FA strategy only to those member countries that adhere to sound disaster risk management practices.

Conclusion

The increasing trend in catastrophe events across the LAC region and the associated economic losses and social devastation illustrates more than ever the need for systematic risk management approaches to deal with the situation and break the vicious cycle. This should be complemented by continuous efforts to improve institutional structures and financial market efficiencies to facilitate domestic financing and risk-transfer instruments over time. However, the current capacity of domestic financial markets is insufficient to cope with the need for effective disaster financing solutions. Since its beginnings, the IDB has tried, and should continue trying, to develop public registers on different types of economic infrastructure investments and publicly available data on environmental and financial market events. These efforts, if successful, will be conducive to the eventual development of derivative instruments with direct applications to specific local market exposures. It also requires the Bank to be able to offer a full range of financing solutions to all stages of the disaster management process. This emphasizes the crucial

role of the IDB as provider of risk advisory and financing services to member countries throughout the LAC region to support the development of effective integrative risk management policies.

The IDB should be able to act as an important regional facilitator of effective risk management solutions to its member countries. Successful outcomes from these efforts require that moral hazard issues are eliminated or vastly reduced and that economic incentives of member countries become aligned with the Bank's overarching policy aims. This also requires incentives for sector executives, line managers, and functional specialists to unite around the overarching policy aims and ensure that relevant sector expertise is incorporated in the execution of proactive risk management solutions.

It is of economic interest to avoid moral hazards when private economic losses from natural catastrophes are covered by the public purse. These moral hazards eliminate incentives to mitigate exposures and engage in proactive risk management efforts and quell attempts to introduce domestic insurance coverage. They drive mounting and self-reinforcing problems such as low insurance penetration, poor asset quality, and social destruction in disasters that aggravates economic conditions. The solution is to register what is government property and what are potential public-private losses and set up risk financing vehicles and government pools to manage these economic exposures independently. This way the government knows its potential future obligations and has a chance to finance them appropriately; private assets can be managed separately on professional terms.

The IDB should promote proactive risk management practices among all member countries, including the establishment of national risk management organizations and specialized risk-transfer vehicles. Government risk management functions should be supported in their efforts to recognize and prioritize public risk management responsibilities, including private housing, small business facilities, public sector assets, and essential economic infrastructure, and set up appropriate risk mitigation and financing solutions to deal with them. Introducing proactive risk management practices may require certain behaviors to be considered mandatory for preferential access to Bank products and services. This means, for example, that financing solutions can be priced according to whether a borrower adheres to systematic risk management

approaches, has control over exposed economic assets, and favors mitigation and ex ante risk financing considerations.

The IDB should be in a position to facilitate national risk management systems and regional insurance pools. Existing loans and technical cooperations should be deployed within the confines of the proactive risk management strategy and national programs of the member countries. The Bank's products and services should be geared to support all elements of the risk management process, including prevention, mitigation, risk transfer, risk financing, preparedness, rehabilitation, and reconstruction. The Bank must provide risk financing facilities that can promote ex ante funding of post-disaster reconstruction and related risk-transfer solutions, including contingent credit facilities to governmental risk management vehicles and pools. Engaging in advisory services to create public information systems on major hazards can support efficient regional risk-transfer solutions. While the Bank cannot sell insurance products, it can act in an advisory capacity to establish sound ex ante financing structures for member countries with significant catastrophe exposure. In fact, this is what the Bank has been trying to accomplish through the recent introduction of contingent loan facilities and new disaster insurance facilities in collaboration with an international reinsurance company.

The Bank should continue to promote adoption of systematic risk management among exposed member countries and extend the palette of products and services to support all aspects of this process. This pinpoints a need for further product refinements to enhance effective risk-transfer and ex ante risk financing solutions. The Bank may consider different types of contingent loans that can offer funding under predefined disaster scenarios in the form of standby credit facilities or guaranteed disbursement loans. The current product development initiatives, such as contingent credit and insurance facilities, serve to complement the current assortment of risk financing instruments. The promotion of effective risk management processes depends on the versatility of the financing products and services offered by the Bank as it caters to the development of governmental risk management offices that can deal effectively with mounting exposure to disasters.

Bibliography

Albala-Bertrand, J.M. 1993. *Political Economy of Large Natural Disasters: With Special Reference to Developing Countries*. Clarendon Press: Oxford.

———. 2000. Complex Emergencies versus Natural Disasters: An Analytical Comparison of Causes and Effects. *Oxford Development Studies* 28(2): 187–204.

———. 2003. Urban Disasters and Globalization. In *Building Safer Cities: The Future of Disaster Risk*, Disaster Risk Management Series No. 5, eds. A. Kreimer, M. Arnold, and A. Carlin. The World Bank: Washington, D.C.

Andersen, T.J. 2002. *Innovative Financial Instruments for Natural Disaster Risk Management*. Technical Paper. Inter-American Development Bank: Washington, D.C.

———. 2003. Globalization and Natural Disasters: An Integrative Risk Management Approach. In *Building Safer Cities: The Future of Disaster Risk*, Disaster Risk Management Series No. 5, eds. A. Kreimer, M. Arnold, and A. Carlin. The World Bank: Washington, D.C.

———. 2005. *Applications of Risk Financing Techniques to Manage Economic Exposures to Natural Hazards*. Technical Paper. Inter-American Development Bank: Washington, D.C.

———. 2006a. Catastrophe Risk Analysis and Disaster Financing: A Country Perspective. In *Perspectives on Strategic Risk Management*, ed. Andersen, T.J. (Chapter 9). CBS Press: Copenhagen.

Andersen, T.J. 2006b. *Global Derivatives: A Strategic Risk Management Perspective*. Pearson Education: Harlow, England.

———. 2007. *Developing and Supporting the Use of Disaster-Linked Financial Instruments: The Role of the IDB in Latin America and the Caribbean*. Report to the Working Group on Financing Disaster Risk. Inter-American Development Bank: Washington, D.C.

Andersen, T.J. and V. Kalavakonda. 2003. *The Economic Consequences of Catastrophe Events: An Exploratory Study of Exposed Developing Countries*. Internal Working Paper. The World Bank: Washington, D. C.

Andersen, T.J. and P. Masci. 2001. Economic Exposures to Natural Disasters, Public Policy, and Alternative Risk Management Approaches. *Infrastructure & Financial Markets Review* 7(4): 1–10.

Andersen, T.J. and P. Schrøder. Forthcoming. *Strategic Risk Management Practice: How to Deal Effectively with Major Corporate Exposures*. Cambridge University Press: Cambridge, England.

Alexander, D. 2000. *Confronting Catastrophe: New Perspectives on Natural Disasters*. Oxford University Press: New York.

Arias, D. and K. Covarrubias. 2006. *Agricultural Insurance in Mesoamerica: An Opportunity to Deepen Rural Financial Markets*. Economic and Sector Study. Inter-American Development Bank: Washington, D.C.

Auffret, P. 2003. *High Consumption Volatility: The Impact of Natural Disaster*. Policy Research Paper. The World Bank: Washington, D. C.

Benson, C. and E.J. Clay. 2000. Developing Countries and the Economic Impacts of Natural Disasters. In *Managing Disaster Risk in Emerging Economies*, Disaster Risk Management Series, eds. A. Kreimer and M. Arnold. The World Bank: Washington, D.C.

———. 2002. *Bangladesh: Disasters and Public Finance*. Disaster Risk Management Working Paper Series. The World Bank: Washington, D.C.

Bock, K.J. and M.W. Seitz. 2002. Reinsurance vs. Other Risk-Transfer Instruments: The Reinsurer's Perspective. In *Alternative Risk Strategies*, ed. M. Lane. Risk Books: London.

Bougen, P.D. 2003. Catastrophe Risk. *Economy and Society* 32(2): 275–79.

Canabarro, E., M. Finkemeier, R. Anderson, and F. Bendimerad. 2000. Analyzing Insurance-Linked Securities. *The Journal of Risk Finance* Winter.

Capgemini/European Financial Management and Marketing Association (EFMA). 2009. World Insurance Report 2009. Capgemini/EFMA: Paris.

Carpenter, G. 2009. The World Catastrophe Reinsurance Market 2009. *GC Capital Ideas*. New York.

Cavallo, E., S. Galiani, I. Noy, and J. Pantano. 2009. *Natural Disasters and Economic Growth*. Preliminary Research Paper. Inter-American Development Bank: Washington, D.C.

Cavallo, E., A. Powell, and O. Becerra. 2010. *Estimating the Direct Economic Damage of the Earthquake in Haiti*. Working Paper 163. Inter-American Development Bank: Washington, D.C.

Centre for Research on the Epidemiology of Disasters (CRED). 2009. *Annual Disaster Statistical Review 2008: The Numbers and Trends*. Université Catolique de Louvain: Brussels, Belgium.

Charveriat, C. 2000. *Natural Disaster Risk in Latin America and the Caribbean*. Technical paper. Inter-American Development Bank: Washington, D.C.

Collich, C., Durante, J., Martinez, J., and Vergara. R. 2010. *Gestion financiera de riesgos de desastres para Republica Dominicana*. Technical note. Inter-American Development Bank: Washington, D.C.

Croson, D.C. and H.C. Kuhnreuther. 2000. Customizing Indemnity Contracts and Indexed Cat Bonds for Natural Hazard Risks. *The Journal of Risk Finance* 1(3): 24–42.

Culp, C.L. 2002. *The ART of Risk Management: Alternative Risk Transfer, Capital Structure, and the Convergence between Insurance and Capital Markets*. Wiley: New York, N.Y.

Cummings, J.D., D. Lalonde, and R.D. Phillips. 2002. Managing Risk Using Risk-Linked Catastrophic Loss Securities. In *Alternative Risk Strategies*, ed. M. Lane. Risk Books: London.

Cummins, D. and C.M. Lewis. 2004. Catastrophe Events, Parameter Uncertainty and the Breakdown of Implicit Long-Term Contracting. *Journal of Risk & Uncertainty* 26: 153–78.

Cummins, D.J. 2006. Should Government Provide Insurance for Catastrophes? *Federal Reserve Bank of St. Louis Review* 88(4): 337–79.

Cutler, D.M. and R.J. Zeckhauser. 1999. Reinsurance for Catastrophes and Cataclysms. In *The Financing of Catastrophe Risk*, ed. K.A. Froot. The University of Chicago Press: Chicago.

Doherty, N. and K. Smetters. 2005. Moral Hazard in Reinsurance Markets. *Journal of Risk & Insurance* 72(3): 375–91.

Eisensee, T. and D. Strömberg. 2007. New Droughts, New Floods, and U.S. Disaster Relief. *The Quarterly Journal of Economics* 122(2): 693–728.

Emanuel, K. 2005. Increasing Destructiveness of Tropical Cyclones over the Past 30 Years. *Nature* 436: 686–88.

Freeman, P.K. and L.A. Martin. 2002. *National Systems for Comprehensive Disaster Management: Financing Reconstruction*. The Inter-American Development Bank: Washington, D.C.

Freeman, P.K., L.A. Martin, R. Mechler, and K. Warner. 2002. *Catastrophes and Development: Integrating Natural Catastrophes into Development Planning*. Working Paper Series, Disaster Management Facility. The World Bank: Washington, D.C.

Freeman, P.K., M. Keen, and M. Mani. 2003. *Dealing with Increased Risk of Disasters: Challenges and Options*. IMF Working Paper. International Monetary Fund: Washington, D.C.

Freeman, P.K., L.A. Martin, J. Linneroot-Bayer, R. Mechler, G. Pflug, and K. Warner. 2003. *National Systems for the Comprehensive Management of Disaster Risk: Financial Strategies for Natural Disaster Reconstruction*. The Inter-American Development Bank: Washington, D.C.

Frey, A., M. Kirova, and C. Schmidt. 2009. *The Role of Indices in Transferring Insurance Risks to the Capital Market*. Sigma No. 4. Swiss Re: Zurich, Switzerland.

Ghesquiere, F. and O. Mahul. 2007. *Sovereign Natural Disaster Insurance for Developing Countries: A Paradigm Shift in Catastrophe Risk Financing*. Policy Research Working Paper. The World Bank: Washington, D.C.

Gurenko, E.N. (ed.). 2004. *Catastrophe Risk and Reinsurance: A Country Risk Management Perspective*. Risk Books: London.

Gurenko, E. and R. Lester. 2004. *Rapid Onset Natural Disasters: The Role of Financing in Effective Risk Management*. Policy Research Working Paper. The World Bank: Washington, D.C.

Hochrainer, S. 2009. *Assessing the Macroeconomic Impacts of Natural Disasters: Are There Any?* Policy Research Working Paper. The World Bank: Washington, D.C.

Hofman, D. and P. Brukoff. 2006. *Insuring Public Finances Against Natural Disasters – A Survey of Options and Recent Initiatives*. Working Paper. International Monetary Fund: Washington, D.C.

International Monetary Fund (IMF). 2001. *Experience with the Insurance Core Principles Assessments under the Financial Sector Assessment Program*. Working paper series. August 2001.

Intergovernmental Panel on Climate Change (IPCC). 2007. Summary for Policy Makers. In *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, United Kingdom and New York, USA.

Jaffee, D.M. and T. Russell. 1997. Catastrophe Insurance, Capital Markets, and Uninsurable Risks. *Journal of Risk and Insurance* 64(2): 205–30.

Kaplow, L. 1991. Incentives and Government Relief for Risk. *Journal of Risk and Uncertainty* 4(2): 167–75.

Khater, M. and D. Kuzak. 2002. Natural Catastrophe Loss Modeling. In *Alternative Risk Strategies*, ed. M. Lane. Risk Books: London.

Kelly, M. and A.E. Kleffner. 2003. Optimal Loss Mitigation and Contract Design. *Journal of Risk & Insurance* 70(1): 53–72.

Keipi, K. and J. Tyson. 2002. *Planning and Financial Protection to Survive Disasters*. Inter-American Development Bank: Washington, D.C.

Kleffner, A.E. and M. Kelley. 2001. The Impact of Insurance on the Level of Optimal Loss Mitigation. *Northwest Journal of Business Economics* 4: 29–42.

Kunreuther, H.C. and J. Linnerooth-Bayer. 2003. The Financial Management of Catastrophe Flood Risks in Emerging-Economy Countries. *Risk Analysis* 23(4): 627–39.

Kunreuther, H.C. and E.O. Michel-Kerjan. 2008. Risk Perception and Choice in Homeowners Adoption of Mitigation Measures: The Need for Long-Term Contracts. In *Financial Management of Large-Scale Catastrophes, Policy Issues in Insurance*, No. 12, Chapter 3. OECD: Paris.

Lester, R. and E. Gurenko. 2003. *Financing Rapid Onset Natural Disaster Losses in India: A Risk Management Approach*. Technical Paper. The World Bank: Washington, D.C.

Mahul, O. and E. Gurenko. 2006. *The Macro Financing of Natural Hazards in Developing Countries*. Policy Research Working Paper. The World Bank, Washington, D.C.

Masci, P., L. Tejerina, and I. Webb. 2007. *Insurance Market Development in Latin America and the Caribbean*. Technical Paper. Inter-American Development Bank: Washington, D.C.

Mayer, M.A., D.C. John, and J.J. Carafano. 2009. *Principles for Reform of Catastrophic Natural Disaster Insurance*. Backgrounder No. 2256. The Heritage Foundation: Washington, D.C.

Miller, S. and K. Keipi. 2005. *Strategies and Financial Instruments for Disaster Risk Management in Latin America and the Caribbean*. Inter-American Development Bank: Washington, D.C.

Mills, E. 2005. Insurance in a Climate of Change. *Science* 309(5737): 1040–44.

Monti, A. 2008. Survey of Country Approaches. In *Financial Management of Large-Scale Catastrophes, Policy Issues in Insurance*, No. 12, Chapter 2. OECD: Paris.

Munich Re. 2008. Catastrophe Figures for 2008 Confirm that Climate Agreement Is Urgently Needed. Press release, December 29, 2008.

Nellemann, C., M. MacDevette, T. Manders, B. Eickhout, B. Svihus, A. G. Prins, B. P. Kaltenborn, eds. 2009. *The Environmental Food Crisis: The Environment's Role in Averting Future Food Crisis. A UNEP Rapid Response Assessment*. United Nations Environment Program (UNEP), GRID-Arendal: Norway.

Niehaus, G. 2002. The Allocation of Catastrophe Risk. *Journal of Banking & Finance* 26: 585–96.

Noy, I. 2009. The Macroeconomic Consequences of Disasters. *Journal of Development Economics* 88(2): 221–31.

Nutter, F.W. 2006. Financing Catastrophe Risk with Public and Private (Re)Insurance Resources. In *Seeds of Disaster, Roots of Response: How Private Action Can Reduce Public Vulnerability*, Chapter 21, eds. P.E. Auerswald, L. Branscomb, T.M. LaPorte, and E. Michel-Kerjan. Cambridge University Press: New York.

Organization for Economic Cooperation and Development (OECD). 2008. *Financial Management of Large-Scale Catastrophes, Policy Issues in Insurance*, No. 12. OECD: Paris.

Pollner, J.D. 2000. *The Management of Catastrophe Risks Using Pooled Insurance Structures and Alternative Financing & Risk Transfer Mechanisms: The Insurance Market and the Case of the Caribbean Region*. The World Bank: Washington, D.C.

Pollner, J.D. 2001. *Managing Catastrophic Disaster Risks Using Alternative Risk Financing and Pooled Insurance Structures*. Technical Paper No. 495. The World Bank: Washington, D.C.

Raddatz, C. 2007. Are External Shocks Responsible for the Instability of Output in Low-Income Countries? *Journal of Development Economics* 84: 155–87.

Rasmussen, T. 2004. *Macroeconomic Implications of Natural Disasters in the Caribbean*. Working Paper. International Monetary Fund: Washington, D.C.

Rogers, C. and T. Hori. 2008. *Disaster Risk Management Policy Guidelines*. Inter-American Development Bank: Washington, D.C.

Schwarze, R. and G.G. Wagner. 2006. *The Political Economy of Natural Disaster Insurance: Lessons from the Failure of a Proposed Compulsory Insurance Scheme in Germany*. Discussion Paper. German Institute for Economic Research: Berlin.

Sperling, F. and F. Szekely. 2005. Disaster Risk Management in a Changing Climate. Discussion paper prepared on behalf of the Vulnerability and Adaptation Resource Group (VARG) for the World Conference on Disaster Reduction, 18–22 January, Washington, D.C.

Strömberg, D. 2007. Natural Disasters, Economic Development, and Humanitarian Aid. *Journal of Economic Perspectives* 21(3): 199–222.

Swiss Re. 2006. *Natural Catastrophes and Man-Made Disasters in 2005: High Earthquake Casualties, New Dimensions in Windstorms Losses*. Sigma No. 2/2006. Swiss Re: Zurich, Switzerland.

———. 2007. *Natural Catastrophes and Man-Made Disasters in 2006: Low Insured Losses*. Sigma No. 2/2007. Swiss Re: Zurich, Switzerland.

———. 2008a. *Natural Catastrophes and Man-Made Disasters in 2007: High Losses in Europe*. Sigma No. 2/2008. Swiss Re: Zurich, Switzerland.

———. 2008b. *World Insurance in 2007: Emerging Markets Leading the Way*. Sigma No. 3/2008. Swiss Re: Zurich, Switzerland.

———. 2009a. *Natural Catastrophes and Man-Made Disasters in 2008: North America and Asia Suffer Heavy Losses*. Sigma No. 2/2009. Swiss Re: Zurich, Switzerland.

———. 2009b. *World Insurance in 2008*. Sigma No. 3/2009. Swiss Re: Zurich, Switzerland.

———. 2009c. *The Role of Indices in Transferring Risks to the Capital Markets*. Sigma No. 4/2009. Swiss Re: Zurich, Switzerland.

Webster, P. J., G.J. Holland, J.A. Curry, and H. Chang. 2005. Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment. *Science* 309(5742): 1844–46.

Zanjani, G. 2002. Pricing and Capital Allocation in Catastrophe Insurance. *Journal of Financial Economics* 65(2): 283–305.