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Sovereign Natural Disaster Insurance for Developing Countries:

A Paradigm Shift in Catastrophe Risk Financing

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Abstract

Economic theory suggests that countries should ignore uncertainty for public investment and behave as if indifferent to risk because they can pool risks to a much greater extent than private investors can. This paper discusses the general economic theory in the case of developing countries. The analysis identifies several cases where the government's risk-neutral assumption does not hold, thus making rational the use of ex ante risk financing instruments, including sovereign insurance.

The paper discusses the optimal level of sovereign insurance. It argues that, because sovereign insurance is usually more expensive than post-disaster financing, it should mainly cover immediate needs, while long-term expenditures should be financed through post-disaster financing (including ex post borrowing and tax increases). In other words, sovereign insurance should not aim at financing the long-term resource gap, but only the short-term liquidity need.

This paper—a joint-product of the Hazard Risk Management Unit, Latin America and Caribbean Region, and the Financial Markets for Social Safety Net Department, Financial and Private Sector Development Vice Presidency—is part of a larger effort in the department to support clients in the management of disaster risks. Policy Research Working Papers are also posted on the Web at <http://econ.worldbank.org>. The authors may be contacted at omahul@worldbank.org.

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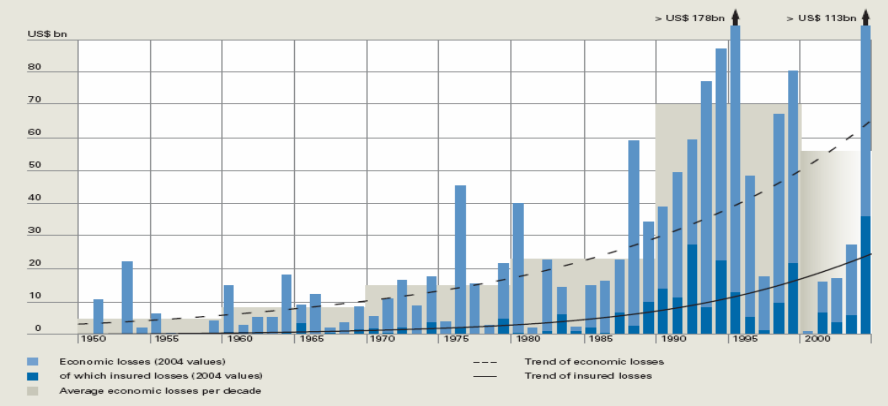
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1. Introduction

There is growing evidence that the frequency and severity of natural disasters is on the rise (see Figure 1). Due to a variety of reasons, ranging from the growing concentration of population and assets in risky areas to increases in climate variability, the fiscal and economic exposure of developing countries is becoming larger by the year. Catastrophic events loom large in numerous countries, and in the absence of active risk management, bear a serious risk to long-term development efforts. While most emphasis has been on the need for risk mitigation, a growing literature analyzes government capacity to react in the aftermath of a major disaster and in particular, government capacity to finance relief and reconstruction needs after disasters (see, for example, Freeman, Keen and Mani 2003; Hoffman and Brukoff 2006; Rasmussen 2004; Mahul and Gurenko 2006).

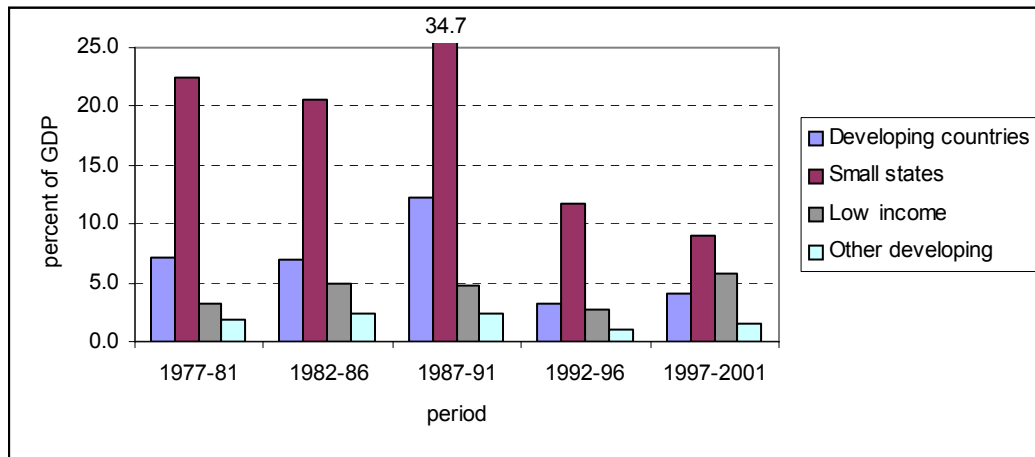
Figure 1. Economic Losses and Insured Losses due to Natural Disasters



Source: Munich Re, 2005.

As a result of the increased concentration of the world's population in vulnerable urban areas, substandard construction practices and low insurance penetration, the fiscal and economic risk exposure of developing countries to catastrophic events looms large. As illustrated in Figure 2, average damages from large disasters faced by developing countries represent 7.1% of GDP over the period 1977-2001, with a peak at 12.3% of GDP in 1987-1991. Such an exposure to natural disasters affects more specifically small states, where these average damages are 9% over 1997-2001 and reach 34.7% over 1987-1991.

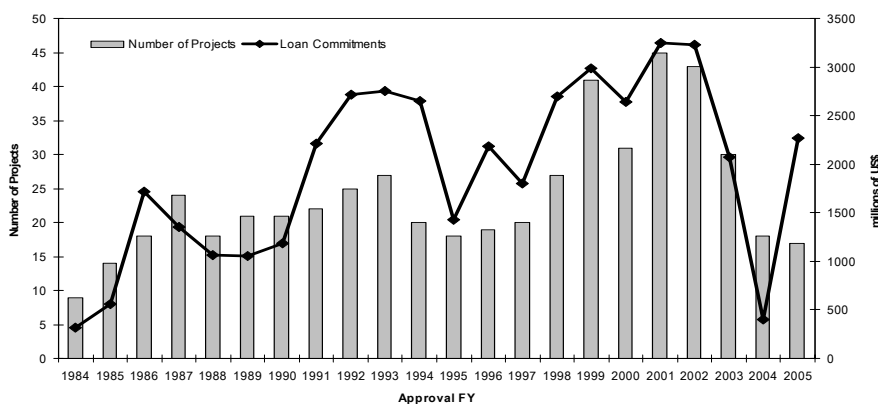
Figure 2. Average Damages from Large Disasters



Source: IMF 2003.

Indeed, a quick analysis of recent catastrophes shows that funding for relief and reconstruction in developing countries generally comes from very different sources than is the case in industrialized countries. In more advanced economies, losses from natural disasters are typically funded through a combination of private risk financing arrangements and an efficient public revenue system relying on wide and deep taxation catchments. In middle and low-income countries, which have relatively low tax ratios and ongoing fiscal pressures, funding sources for post disaster reconstruction tend to be more varied, with strong reliance on ex-post borrowing and assistance from international donors. Assistance from multilateral financial agencies plays a particularly important role in middle-income countries, while support from bilateral donors is generally dominant in low-income countries. The World Bank alone has disbursed more than US\$40 billion in emergency loans related to natural disasters, as shown in Figure 3. Much of this assistance is recent: about 43 percent of all disaster-related loans have yet to close.

Figure 3. World Bank Emergency Lending Related to Natural Disasters



Sources: World Bank 2005

The economic theory suggests that countries should ignore uncertainty for public investment and behave as if indifferent to risk because they can pool risks to a much greater extent than private investors. In particular Arrow and Lind (1970) demonstrate that when the risks are publicly borne, the social cost of risk-bearing is insignificant and, therefore, the government should ignore uncertainty in evaluating public investment because it can distribute the risk associated with any investment among a large number of

people. However, a key assumption underlying this result is that returns from a given public investment are independent of other components of national income. In the context of the financing of natural disasters, this theory suggests that governments should act as risk neutral towards natural disasters and thus they should not invest in any risk financing strategies that are more expensive than the expected losses caused by a natural disaster. This theory is in fact implemented by a number of large developed countries that rely on post disaster financing (including budget reallocation and tax increases) to finance catastrophic losses.

The paper revisits this theory for developing countries. It identifies several cases where the assumption of the government's policy of risk neutrality does not hold, thus making rational the use of ex ante risk financing instruments. First, the small size of some states, like small state islands, prevents them from efficiently pooling natural disasters, as the passage of a hurricane for example is a systemic risk that affects the entire economy of the country. Second, the high level of indebtedness of some countries does not allow them to access capital markets in the aftermath of a disaster, thus preventing them from transferring some of the risks to the future generations (inter-temporal diversification). Third, post-disaster risk financing instruments may not provide quick liquidity after a disaster, creating a liquidity crunch. Under these cases, a cost-effective risk financing (or sovereign insurance in a broad sense) strategy for governments would be to secure funds ex ante, through reserve funds, insurance or contingent debt (except when the level of debt is already very high).

The next question addressed in this paper is how much sovereign insurance governments should buy. The concept of dynamic liquidity gap is first introduced. It is defined as the potential lack of funds for the financing of government deficit losses at different periods after the occurrence of a natural disaster (e.g., short term, medium term and long term). It presents a matrix of fiscal vulnerability that should help governments analyze potential liquidity gaps and devise optimal insurance strategies. This concept differs from the standard concept of resource gap, usually defined as the long term gap between financial needs and post-disaster financing instruments. The paper shows that, because sovereign insurance is usually more expensive than post-disaster financing, it should mainly cover immediate needs, while long term expenditures should be financed through post-disaster financing (including ex post borrowing and tax increases). In other words, sovereign insurance should not finance the long term resource gap, but only the short term liquidity gap.

Finally, the paper illustrates this discussion in the light of the newly established Caribbean Catastrophe Risk Insurance Facility. It shows why catastrophe insurance is a cost-effective risk financing solution for the small state islands in the Caribbean basin to secure liquidity in the aftermath of a disaster.

The paper is organized as follows. Section 2 revisits the Arrow-Lind public investment theorem in the context of the financing of natural disasters. Section 3 introduces the concept of dynamic liquidity gap and presents a matrix of fiscal vulnerability. Section 4 illustrates these concepts in the light of the Caribbean catastrophe risk insurance initiative. Section 5 concludes.

2. The Arrow-Lind Public Investment Theorem and the Social Cost of Natural Disasters

Arrow-Lind Public Investment Theorem

In a seminal article about the evaluation of public investments Kenneth Arrow and Robert Lind (1970) have shown that, as the net returns to an investment of given size are shared by increasingly many individuals, the risk premium for the representative agent vanishes and the aggregate of these premiums for all individuals also approaches zero. This means that the social cost of risk-bearing is insignificant and, consequently, the government should ignore uncertainty in evaluating public investments. Under

this result known as the Arrow-Lind Public Investment Theorem, the government should apply the policy of risk neutrality in the evaluation of public investment and evaluate projects on the basis of expected net benefit alone.

This theorem has been challenged by several economists. Fisher (1973) shows that the policy of risk neutrality should be modified, where these investments produce certain side effects, such as external costs in the form of environmental damages that represent a non-negligible fraction of the real income of the affected individuals. Foldes and Rees (1977) show that the Arrow-Lind theorem does not hold if the public investment is correlated with national income. This is the case for example if the project income is not free from taxation and/or some of it is retained to finance public expenditure. Gardner (1979) stresses that the size of the government risk becoming small relative to the economy plays the decisive role in the Arrow-Lind Theorem. Magill (1984) revisits the Arrow-Lind theorem when agents in the economy are not affected equally by the introduction of a public project, that is, when some agent may be favorably affected while others may be adversely affected.

The Arrow-Lind theorem is discussed in an economic world a la Lucas (1978) with a risk-averse representative agent (with an infinite time horizon). The national economic growth is depicted by an exogenous vector of random variables (c_0, c_1, c_2, \dots) where c_t is the level of consumption per capita at time t . The probability distribution of the vector of consumption is assumed to be known at $t=0$. This distribution represents the macroeconomic risk over time. In the expected utility framework, the inter-temporal welfare of the representative agent is determined by the net present value of his utility:

$$V_0 = \sum_{t=0} e^{-\delta t} Eu(c_t)$$

where $u(\cdot)$ is the representative agent's Von Neumann-Morgenstern utility function, increasing and concave, and δ is his discount factor.

Consider the public investment defined by a vector of cash-flow (X_0, X_1, X_2, \dots) , where X_t is the net benefit at time t generated by the investment. The probability distribution of the cash flows and its correlation with the macroeconomic risk are assumed known.

The costs and benefits of this public investment are equally shared among all taxpayers. Let ε be the fraction of net cash flows allocated to each taxpayer. If the project is undertaken, the welfare of representative agent will be

$$V_1 = \sum_{t=0} e^{-\delta t} Eu(c_t + \varepsilon X_t).$$

This project is socially efficient if the welfare of the representative agent increases, i.e., V_1 is higher than V_0 . Assuming a very large number of taxpayers, this implies,

$$\left. \frac{\partial}{\partial \varepsilon} \sum_{t=0} e^{-\delta t} Eu(c_t + \varepsilon X_t) \right|_{\varepsilon=0} > 0$$

which is equivalent to

$$\sum_{t=0} e^{-\delta t} E[X_t u'(c_t)] > 0.$$

This can be rewritten as

$$NPV = X_0 + e^{-r_t t} B_t > 0,$$

$$\text{with } r_t = \delta - \frac{1}{t} \ln \frac{Eu'(c_t)}{u'(c_0)} \text{ and } B_t = \frac{E[X_t u'(c_t)]}{Eu'(c_t)}.$$

It is noteworthy that the social discount rate r_t is independent of the public project but it depends on the maturity of the project and the macroeconomic risk. B_t is the risk-adjusted expected social net benefit, i.e., the expected cash-flow adjusted by the macroeconomic risk. It is also of interest to note that the social discount rate r_t as described above is a standard result in modern finance theory (see, for example, Cochrane 2001; Cox, Ross and Ingersoll 1985). It is easy to show that in the particular case where the agent's preferences are represented by a power function, i.e., his preferences satisfy constant relative risk aversion (with the index of constant relative risk aversion equals γ), and the logarithm of consumption follows a Brownian motion with tendency μ and volatility σ , the social discount rate becomes

$$r_t = \delta + \gamma\mu - 0.5\gamma^2\sigma^2.$$

The social discount rate can be decomposed as follows: the pure discount rate δ , a (positive) wealth effect and a (negative) precautionary effect. The wealth effect, $\gamma\mu$ increases with μ , i.e., the representative agent expects an increase in future consumption and thus reduces the net present value of future earnings. The precautionary effect, $0.5\gamma^2\sigma^2$, increases with the volatility σ , i.e., an increase in the uncertainty of future growth reduces the social discount rate.

The risk-adjusted expected social net benefit can be rewritten as

$$B_t = \frac{E[X_t u'(c_t)]}{Eu'(c_t)} = EX_t - \text{cov}\left(X_t, \frac{u'(c_t)}{-Eu'(c_t)}\right).$$

Using a first-degree approximation of $u'(c_t)$, one can show that the above equation can be rewritten as

$$B_t = \frac{E[X_t u'(c_t)]}{Eu'(c_t)} = EX_t - \gamma \text{cov}\left(X_t, \frac{c_t}{Ec_t}\right),$$

where γ is the index of representative agent's index of constant relative risk-aversion.

The term $\gamma \text{cov}\left(X_t, \frac{c_t}{Ec_t}\right)$ can be interpreted as the social cost of risk bearing. Should the public investment be uncorrelated with the national income, this term vanishes. This means that the project should be evaluated on its expected value. The government should thus apply the policy of risk neutrality

in the evaluation of public investment. This leads to the Arrow-Lind Public Investment Theorem. If the public project is positively (negatively) correlated with the national income, then the social cost of risk bearing is positive (negative) and, consequently, the risk-adjusted expected social net benefit of the project is lower than the expected social net benefit.

The social cost of catastrophic risk bearing

The question of risk neutrality, and thus the social cost of risk bearing, is reconsidered in the context of the financing of catastrophic risks. How should the government value the economic impact of natural disasters? Should the government invest in ex ante risk financing? The Arrow-Lind Theorem says that governments should *not* invest in ex ante risk financing, like insurance (as long as the insurance premium is higher than the expected indemnity payouts) because of the policy of risk neutrality in the evaluation of public investment (e.g., purchasing insurance).

These questions are examined with a simple but robust model of risk-sharing under uncertainty. The proposed model makes explicit the correlation among individual risks (leading to the macro-economic risk) and assumes that the government's risk aversion is mainly caused by its aversion towards short term liquidity crunch.

Consider an economy consisting of identical N agents/taxpayers, i.e., they have the same preferences, where each agent faces a random loss \tilde{x}_i due to the occurrence of a natural disaster. The series of individual random individual losses is denoted $(\tilde{x}_1, \tilde{x}_2, \dots, \tilde{x}_N)$ and, for the sake of simplicity, is generated from a probability distribution with mean $\mu > 0$ and variance $\sigma^2 > 0$. It is important to notice that the individual random losses \tilde{x}_i are *not* assumed to be statistically independent. In particular, this means that each individual risk can be correlated with the other individual risks, which can be viewed as the macro-economic risk.

The law of large numbers states that the sample mean $\tilde{X} = \frac{1}{N} \sum_{i=1}^N \tilde{x}_i$ tends to the population mean μ as the size of the sample increases:

$$\lim_{N \rightarrow \infty} \Pr \left[\left| \tilde{X} - \mu \right| < \varepsilon \right] = 1, \text{ for } \varepsilon > 0,$$

The central limit theorem can be used to specify the amount of reserves the government needs to set aside to finance emergency needs in the aftermath of a disaster (e.g., relief operations, early recovery operations). We assume that the government holds reserves to achieve a specified *probability of liquidity crisis* α . The amount of risk capital per taxpayer to cover any deviations from the expected loss (population mean) is thus calibrated to satisfy the liquidity constraint:

$$\Pr \left[\tilde{X} - \mu \leq k_N \right] = 1 - \alpha,$$

Assuming that the correlation between any pair of individual losses is ρ and, for the sake of simplicity, the individual losses are identically normally distributed,² one can easily show that the amount of risk capital per taxpayer is

$$k_N = z_\alpha \frac{\sqrt{N\sigma + N(N-1)\sigma^2\rho}}{N},$$

where z_α is the value from the standard normal distribution such that $\Pr[\tilde{z} < z_\alpha] = 1 - \alpha$. It is interesting to note that k_N increases as the variability of individual losses and/or the correlation among losses increases. It is noteworthy that, as the size of the population N becomes large, the amount of reserves per taxpayer satisfies $\lim_{N \rightarrow \infty} k_N = z_\alpha \sigma \rho$.

The social cost of catastrophic risk bearing is defined as the cost of holding these reserves (per taxpayer), beyond the annual expected loss μ . Denoting s the (marginal) opportunity cost of holding catastrophic reserves, the social cost of catastrophic risk bearing is

$$sk = sz_\alpha \sigma \rho.$$

The above equation allows for a discussion on the key drivers of the social cost of catastrophic risk bearing. First, it is equal to zero if individual losses are not correlated, $\rho = 0$, that is, there is no macroeconomic risk. This leads to the Arrow-Lind theorem. On the contrary, the higher the correlation among individual losses, the higher the social cost of catastrophic risk bearing. This illustrates that small states exposed to natural disasters that can affect the entire country, like small Caribbean islands exposed to hurricanes, face a high social cost of catastrophic risk-bearing. For example, hurricane Ivan in 2004 hit the island of Grenada and caused losses equal to 200% of GDP. On the contrary, if natural disasters affect a small fraction of the economy and thus the size of the event is small relative to the economy, as it is the case for large economies, the correlation coefficient ρ is negligible and thus the social cost of catastrophic risk bearing becomes negligible, leading large countries to apply the policy of risk neutrality in the financing of natural disasters.

A second key variable in the social cost of catastrophic risk bearing is the (marginal) opportunity cost of reserves. Should a country be able to reallocate his budget immediately after a disaster to finance its liquidity needs, then the opportunity cost of holding catastrophic reserves is negligible and thus the social cost of catastrophic risk bearing is negligible. Again, most developing countries, and particularly small countries, do not have this flexibility in their budget, making the opportunity cost of reserve high, and thus the social cost of catastrophic risk bearing is high.

Finally, governments may want to reduce the social cost of catastrophic risk bearing by increasing the probability of liquidity crisis α . Governments would be ill-advised to do so because this may generate huge economic and human losses in case the government is not able to face basic emergency needs in the aftermath of a disaster.

As discussed later in this paper, very few financial instruments allow for quick disbursements in the aftermath of a disaster. Insurance is one of them. The demand for catastrophic risk insurance is thus

² It can be shown that the results still hold if individual losses are not normally distributed, but they can be decomposed into a systemic risk and an idiosyncratic component, where idiosyncratic risks are independent and identically distributed.

driven by the social cost of catastrophic risk bearing. It is cost-effective for the government to purchase insurance if and only if the cost of insurance, defined as the commercial premium net of the expected payout μ , is lower than the social cost of catastrophic risk bearing $sk = sz_{\alpha}\sigma\rho$.³

3. Liquidity Gap vs Resource Gap

In order to help countries reduce their reliance on external assistance, the World Bank has been promoting a country risk management framework which is partly based on corporate risk management principles but also factors in key economic and social metrics such as government fiscal profiles, the living conditions of the poor, and investment in risk mitigation (Gurenko and Lester 2004). This risk management approach relies on the identification of potential resource gaps between potential losses and the capacity of a country to finance relief and reconstruction needs in time of a crisis. This approach is based on a static framework for the financing of catastrophe risks – it focuses on the total losses caused by a potential event and determines how to fund these losses.

Unfortunately, this approach fails short of providing a practical framework for action and may lead to sub-optimal use of risk financing instruments. While losses resulting from a major disaster can occur in a very short time, the resulting financing needs can spread over a much larger period. Although losses are immediate, relief and reconstruction operation can spread over several years. An analysis of the resource needed after a disaster that integrates this time variable should allow for the development of more efficient risk financing strategy for countries exposed to natural disasters.

This section presents a catastrophe risk financing framework for countries (and sub-national entities like municipalities) exposed to adverse natural events that integrates the dynamic aspect of risk financing needs and resources. It defines the concept of *dynamic liquidity gap* as the potential lack of funds for financing public expenditures at different periods after the occurrence of a natural disaster (e.g., short term, medium term, long term). It examines how liquidity gaps can be financed using a combination of ex-ante risk financing instrument (including reserves, budget reallocations, contingent debts, insurance) and ex post vehicles (including borrowing, donor assistance, tax increases, etc.). It presents a matrix of fiscal vulnerability that should help governments analyze potential liquidity gaps and devise optimal risk financing strategies.

The budgetary impact of natural disasters

In addition to the enormous human toll, natural disasters generally create enormous strain to the budget of an affected country. The budgetary implications can be derived from the financing needs faced by a government during the three main phases of recovery operation post disaster.

Relief operations include emergency assistance provided to the affected population to ensure basic needs, such as the need for shelters, food and medical attention. Such costs can be difficult to estimate ex-ante, as they depend on the specific characteristics of the catastrophic event (location, intensity, period of the year (winter or summer), period of the day (day or night), etc.), but are relatively small compared to the subsequent recovery and reconstruction operations. These expenditures can be estimated based on scenario analysis as recently done by the Directorate for Prevention and Emergency Response in Bogotá DC, Colombia (Ghesquiere, Jamin and Mahul, 2006). While relief costs are limited, they need to be financed in a matter of hours after a disaster event. The capacity of governments to mobilize resources for relief operation at short notice should be a key component of its risk financing strategy.

³ Mahul and Gurenko (2006) provide a formal analysis of the design of an optimal ex ante risk financing strategy.

Early recovery operations following the initial relief efforts are crucial to limit secondary losses and ensure that reconstruction can start at earliest. They include, among other things, the emergency restoration of lifeline infrastructure (e.g., water, electricity and key transportation lines), the removal of debris and the financing of basic safety nets. It is also during this phase that engineering firms can be mobilized to start the design of infrastructure works that will have to take place during the reconstruction phase. Several techniques exist to estimate the likely cost of recovery operations. Catastrophic risk models can simulate the impact of natural disasters, such as earthquake, on the infrastructure and thus provide rough estimates of the lifeline infrastructure that is likely to be damaged in case of a major disasters. Such models can also be used to assess the number of people that are likely to result homeless and the number of building that will have to be rebuilt.

Reconstruction operations generally center on the rehabilitation or replacement of assets damaged by a disaster. These include public building and infrastructure which are the direct responsibility of the state. At the same time, it is important to note that national or municipal authorities generally have to face obligations that go beyond their own assets. In most cases, government will have to subsidize the reconstruction of private assets and in particular housing for low-income families who could not otherwise afford to rebuild their homes. Here again, catastrophe risk modeling techniques can be used to estimate the potential damage to the infrastructure and public and private dwellings. They can provide, for each group of assets, risk metrics such as the probable maximum loss for given return period, which can help the authorities assess the budgetary needs caused by potential catastrophic events. The use of scenario analysis coupled with risk models can also help authorities better understand their potential needs over time.

Table 1 provides an illustration of the difference in timing of financing needs resulting from relief, recovery and reconstruction operations.

Table 1. Estimated Timing of Budgetary Outflow caused by a Catastrophic Event

	Short term (1-3 months)	Medium term (3 to 9 months)	Long term (over 9 months)
Relief Operations			
Emergency assistance	██████████		
Recovery Operations			
Removal of debris	██████████	██████████	
Temporary safety net		██████████	
Rehabilitation of lifeline utilities		██████████	
Reconstruction			
Rehabilitation of strategic infra.		██████████	██████████
Housing		██████████	██████████
Utilities		██████████	██████████
Education		██████████	██████████
Administrative buildings		██████████	██████████
Transport		██████████	██████████

In all three phases, the capacity to provide relief, carry out recovery works and complete reconstruction operations will also depend on the absorption capacity of the affected economy. In the cases of major disaster, all the damaged assets cannot be rebuilt at once and the government will have to establish a pecking order allowing for key assets to be rebuilt/rehabilitated first (e.g., hospitals), while other can be restored at a later stage (e.g., schools, administrative buildings). These choices made by the authorities will influence the timing of financing required for reconstruction operations.

Finally, when analyzing budget requirement, it is important to consider local budget appropriation and execution regulations. While some countries have developed emergency legislations that allow for the emergency procurement before a financing source has been identified, most countries have maintained more conservative legislations. In some countries for example, tender for emergency work cannot start until full budget appropriation has been approved by parliament. An optimal risk financing strategy will have to ensure that funds are available at the appropriate time in a post disaster situation, but should also aim at amending outdated legislation that may prove a burden in the aftermath of a major event.

Financing post disaster operations

In the larger industrial countries, losses from natural disasters are typically funded through a combination of private risk financing arrangements and an efficient public revenue system relying on wide and deep taxation catchments. In the case of developing countries, which have relatively low tax ratios and ongoing fiscal pressures, funding sources for post disaster reconstruction tend to be more varied, with a strong emphasis on assistance from international donors. Multilaterally sourced infrastructure loans and relief aid from donors are among the most common sources of such disaster funding.

A variety of instrument can be considered in the establishment of a risk financing strategy. These can be classified as ex-ante risk financing instruments such as the building of financial reserves, contingent debt agreements, insurance (and alternative risk transfer solutions), and post-disaster risk financing instruments including tax increases, reallocating funds from other budget items, access to domestic and international credit, borrowing from multilateral finance institutions, etc. Many developing countries also rely on the assistance from international aid. While donors have been generous in a number of cases, assistance has been highly dependent on the visibility of a given event in the international press, making it a fairly unreliable instrument for risk management.

Table 2 provides a classification of risk financing instruments based on the availability of funds in the short-term, medium-term and long-term period following a catastrophe. The timing on the availability of fund is based on the experience of recent operations (e.g., Turkey, Mexico, Mongolia, and Colombia) and can vary depending on the economic and financial characteristics of a country. In particular, the borrowing capacity of the country will depend on its level of indebtedness and its access to insurance is usually limited by the size of its domestic insurance market. The capacity of a country to finance post disaster operations at any given time will very much dependent upon the source of financing available. A government that would rely solely on ex-post credit and tax increase would face serious challenges in the financing of its relief and emergency recovery operations. Conversely, a government relying solely on reserves and insurance may be very well positioned to finance post disaster operations but this strategy may be more costly than is strictly necessary.

Table 2. Availability of Financial Instruments Over Time

	Short term (1-3 months)	Medium term (3 to 9 months)	Long term (over 9 months)
Ex-post financing			
Budget contingencies	█	█	
Donor assistance (relief)		█	
Budget reallocation	█	█	
Domestic credit		█	█
External credit		█	█
Donor assistance (reconstr.)			█
Tax increase			█
Ex-ante financing			
Reserve fund	█	█	█
Contingent debt	█	█	█
Parametric insurance	█	█	█
Traditional insurance	█	█	█

The government pays for reconstruction using different domestic sources, such as reorienting the national budget, raising taxes, new domestic credit, and the accumulation of financial reserves (Caballero 2003). However, pursuing a post-disaster financing strategy has high opportunity costs. Budget allocations are diverted from priority development projects in order to face emergency and recovery needs. Raising new domestic debt in an expensive post-event capital market may significantly affect the country's debt service, and raising taxes may discourage new private investments that are central to restart the economy. The government may not wish to retain all possible losses given the cost of risk transfer, but rather those which are below a tolerable fiscal cost threshold. This threshold should be determined with a view to avoiding disruption in the projected fiscal and macroeconomic performance and should also take into account post funding sources provided by international donors.

An important consideration when building up the response capacity of the state is the benefit of stabilizing budget appropriations for the state. Too often, important development programs are interrupted because of small disaster event that require immediate attention. The use of budget contingencies and reserves should allow for limited disruption in the budget of long term development programs. The use of contingent budget lines and the building of small is usually appropriate to cover events with return period of 1 to 7 years. The use of contingent credit lines may be appropriate for events with longer return period.

The transfer of catastrophic risk constitutes a key financial strategy in the economic management of disaster prone countries. The access to a new generation of sovereign insurance (or macro-insurance) instruments to guard against the impact of natural disasters may enhance the risk financing strategy of developing countries (Caballero 2003). These macro insurance instruments should be contingent on observable variables that are independent of the country's actions, voiding moral hazard problems, such as weather indices (e.g., rainfall, temperature, earthquake magnitude, wind speed).

Catastrophe (cat) bonds are an example of insurance-linked securities (ILSs) that transfer catastrophic risk to the capital markets via the issue of a bond where repayment of principal is contingent upon occurrence of a predefined catastrophe. The specified value limit of the cat bond is paid out when a pre-determined indemnity level, index or parametric trigger occurs (see Box 1). The parametric trigger based on scientifically measurable characteristics of a hazard (e.g., wind speed, earthquake intensity) is the most

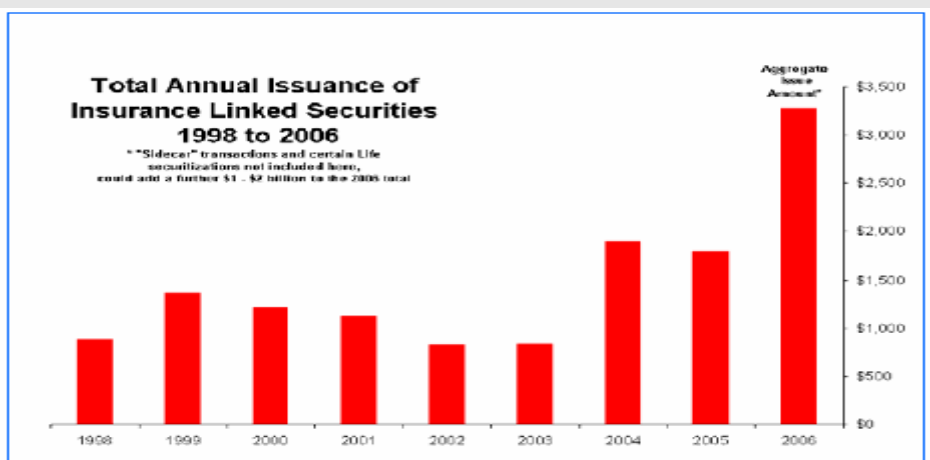
frequent because it protects investors from moral hazard and provides for quick payments. Introduced in the mid 1990's, these ILSs mainly cover losses caused by wind and earthquake. Although it is still an experimental market, the annual stream of cat bond issues has been around US\$2 billion over the last three years, with a peak at US\$3.3 billion in 2006.

Box 1. Catastrophe Bonds

Capital raised by issuing the bond is invested in safe securities such as Treasury bonds, which are held by a special-purpose vehicle (SPV). This arrangement keeps the transaction off the balance sheet of the issuer and insulates investors from the counter-party credit risk. The bond issuer holds a call option on the principal in the SPV with triggers spelled out in a bond contract. Those can be expressed in terms of issuer's losses from a pre-defined catastrophic event, by hazard characteristics, and/or its location. If the defined catastrophic event occurs, the bond-issuer can withdraw funds from the SPV to pay claims, and part or all of interest and principal payments are forgiven. If the defined catastrophic event does not occur, the investors receive their principal plus interest equal to the risk-free rate (e.g., London Inter-Bank Offered Rate (LIBOR)), plus a risk spread usually between 300 to 500 basis point over LIBOR.

The average size of issue is around US\$100 million, varying from US\$10 million to almost US\$600 million. The typical maturity of cat bonds is between one year and ten years, with an average maturity of 3 years. Issuers include insurance and reinsurance companies and, in some cases, insureds. These securities offer countries an alternative to sovereign insurance.

The cat bond market has developed slowly but steadily since it was launched in the 1990s as insurers have used the capital-market instruments as an alternative to using their own balance sheets to cover the potentially huge costs of a natural disaster, which could provoke massive insurance claims in a single area. A total of almost \$13 billion of cat bonds has been issued since the 1990s. About \$8 billion of cat bonds are outstanding, covering against natural disasters in the U.S., Western Europe, Japan, Taiwan and Australia and, more recently, Mexico.



Source: Lane Financial, 2006.

Contingent capital is an alternative risk transfer (ART) product through which capital funding is provided to the client after the occurrence of some specific risk-related loss, often on pre-loss financing terms. It is designed to provide immediate and less expensive capital to the client when it is most needed (e.g., after an economic loss) and/or most scarce (e.g., after a regional disaster). Contingent capital facilities can be viewed as put options on paid-in capital. More specifically, this is essentially a commitment by a capital provider to provide paid-in capital on pre-agreed terms if the buyer of the facility exercises that right on or before the expiration of the contingent facility. Just like a regular option, contingent capital can be characterized by the risk of underlying asset, exercise style, and strike price. While this facility can potentially provide a country with a lower cost capital relative to either a pure risk transfer solution (e.g., sovereign insurance) or accumulation of reserves, the major disadvantage is that once disbursed this

facility could exacerbate the debt burden of the country. The effectiveness of this facility would thus depend on the country's post-disaster financial profile, and more specifically on its post-disaster ability to service debt.

Box 2. Innovative Catastrophe Risk Financing Strategies in Latin America

Due to its location, Colombia is highly prone to natural disasters. The country strides the Andean mountain region and the Pacific "belt of fire," where high seismic potential combines with volcanic activity. In the last 25 years, the country has suffered six major earthquakes, three volcanic eruptions, major landslides, avalanches, petroleum and chemical explosions/leaks, and extensive flooding. The Government of Colombia and the World Bank designed a project that aims to reduce the fiscal vulnerability of the state to adverse natural events by strengthening national capacity to manage disaster risk, financed by a USD260 million World Bank loan. This loan includes a USD 150 million contingent credit line that would provide the Government with immediate liquidity in the event of a major disaster occurring in Colombia.

Mexico is another country highly exposed to natural hazards, including hurricanes and earthquakes. In March 2006, Mexico issued \$160 million of (binary) catastrophe bonds to cover against the risk of earthquakes. The Mexican earthquake bond, which has been sold to institutional investors in the U.S. and Europe, acts like an insurance policy for the Mexican government. Investors are paying \$160 million into a fund created by Swiss Re AG for the Mexican government; if an earthquake of a certain force hits in designated areas of the country within the next three years, the government will be able to draw from these funds. If no disaster occurs during the life of the fund, the money will be returned to the investors. This is the first time a sovereign country has issued a catastrophe bond.

Dynamic Liquidity Gaps

An efficient risk financing strategy should be designed based on the marginal cost of capital available in each phase of the post disaster operations. Ex-post disaster sources of funds will generally be cheaper than ex-ante instrument. Unfortunately, and as shown in Table 2, resources available through ex-post instruments are generally limited in the immediate aftermath of a disaster. Other factor such as the fiscal situation of a given country may also limit its capacity to rely on ex post borrowing or tax increases.

A first step in building an efficient risk financing strategy will consist in comparing estimated resource needs with estimated resource available in each phase of the post disaster operation. Figures on both sides of this equation will depend on the characteristics, and in particular the magnitude, of a potential disaster. Catastrophic risk modeling techniques and scenario analysis can provide estimates of potential needs that can be used to guide the policy maker (see Annex 1). Table 3 shows such exercise for a small to medium size state exposed to a variety of hazards. For illustrative purpose, the matrix of resource availability is built for a 1-in-100 year event to assess the potential deficit in the various phases of the post disaster operations. A more complete exercise would include similar analysis for various return periods ranging from 20 to 500 years or more. In doing so, one should bear in mind that some instrument such as budget reallocation or donor assistance will be easier to mobilize with disaster of greater magnitude. Conversely, the capacity of a government to call on domestic credit or increase taxes may be adversely affected by a major disaster.

Table 3. Resources Availability Post Disaster in Case of a One in a Hundred Year Event (illustrative example)

US\$ millions	Short term (1-3 months)	Medium term (3 to 9 months)	Long term (over 9 months)
Ex-post financing			
Budget contingencies (limited)	10		
Donor assistance (relief/limited)	6		
Budget reallocation		25	
Domestic credit		10	10
Donor assistance (reconstruction)		10	75
External credit			150
Tax increase			50
Ex-ante financing			
Reserve fund	4		
Contingent debt	0		
Index based insurance	0		
Catastrophe bonds	0		
Indemnity Insurance	4	26	
Estimated total available	24	71	285
Estimated needs	30	71	500
Resource surplus (gap)	(6)	-	(215)

Table 4 illustrates a more complete exercise where the analysis is done for various return periods. Such analysis can help policy makers assess where the estimated budgetary outlays would exceed the financial resources available at a given point in time after the occurrence of a disaster.

Table 4. Matrix of country fiscal vulnerability (illustrative example)

Return period (years) of the catastrophic event	Estimated post disaster needs (US\$ million)			Return period (years) of the catastrophic event	Dynamic funding gap (US\$ million)		
	20	100	500		20	100	500
Short term	5	30	50	Short term	-	(6)	(26)
Medium term	20	71	110	Medium term	-	-	(39)
Long term	300	500	1,200	Long term	(15)	(215)	(915)

In the example above, the country does not face any short term resource gap (or liquidity gap) in the case of a 1-in-20 year catastrophe event. If a 1-in-100 year catastrophe event occurs, the short term resource gap is estimated at US\$6 million and the long term resource gap is estimated at US\$215 million. A 1-in-500 year event would cause a US\$15 million short-term resource gap, a US\$215 million medium-term resource gap and a US\$915 million long-term resource gap.

The understanding of potential liquidity gap based on the timing at which resources will be needed can greatly influence the design/improvement of a catastrophe risk financing strategy aimed at reducing the funding gap at given period of potential post disaster operations. One approach is to start with more

frequent events and build up the response capacity of the state to an acceptable return period (e.g., 200 year event). The decision on this return period is arbitrary and depends on the scenario at play and financial capacity of the government considered.

A hypothetical risk financing strategy is illustrated in Table 5. It provides coverage up to the worst case scenario described in Table 4 (500 years return period). Parametric insurance, are used to cover short-term budget outlays (mainly relief and early recovery), assuming that the building of financial reserve is not politically feasible beyond a limit of US\$6 million. In the medium term, the country finances the expenditures through budget reallocation and domestic credit. Particular efforts can be put on broadening the state insurance program. Long-term expenditures (including mainly reconstruction costs) are financed with donor aid, external credit and tax increase.

Table 5. Hypothetical Risk Financing Strategy

Time horizon	Liquidity gap (US\$ million)	Risk financing strategy
Short term	26	Building of reserve for US\$6 million Purchase of parametric insurance for 20 million coverage
Medium term	39	Broadening and optimization of the state insurance program
Long term	915	Conservative fiscal policies to expand potential access to external capital

The use of dynamic financial analysis also illustrates the need to differentiate between the concept of liquidity gap, which is the difference between resources needed and available at specific time in the aftermath of a potential disaster event; and the overall resource gap faced by a country, which is the difference between the resources available post disaster overall compared to the needs that would be generated by a potential disaster event.

Financial strategies can easily be devised to limit the risk of liquidity gap post disaster. These strategies can be highly effective in ensuring that resources are available to finance post disaster operation when needed. A good understanding of the timing in the needs for resources can help optimize such strategy.

A resource gap tends to indicate a deficit in the resources needed to address disaster losses in the long-run. This is often the case for countries with high debt to GDP ratio, which would not be able to access external credit to the full extent their needs in case of disaster. These countries have literally lost the possibility of spreading risk over time. Recent analysis conducted by the IADB (2005) show that a number of countries in Latin America face resource gap for return period a frequent as 100 years.

For these countries, there is an urgent need to engage both in risk reduction activities to reduce their overall exposure and in conservative fiscal policies that would over time increase their capacity to mobilize resources should a disaster event occur.

Box 3. Hurricane Ivan in Grenada

Grenada provides a good example of the difficulties faced by a small island states hit by a major disaster. Hurricane Ivan struck Grenada on September 7, 2004. Classified as a Category 3 hurricane with sustained winds of 120 mph and gusts of up to 135 mph, Ivan left tremendous devastation in its wake. A damage assessment jointly conducted by the Organization of Eastern Caribbean States (OECS) and the United Nations Economic Commission of Latin America and the Caribbean (ECLAC) estimated damage over US\$800 million or twice Grenada's Gross Domestic Product (GDP).

Following the passage of Hurricane Ivan, Grenada experienced a dramatic decline in revenues combined with immediate needs for liquidity to finance relief, cleanup and emergency rehabilitations. Between September and December 2004, the revenue shortfall was approximately 5 percent of GDP. The Government which had only limited reserves quickly faced serious problem financing the public service bill. It also became evident that the country would not be able to meet its debt obligations as they fell due.

To face this situation, the country engaged in a three prong approach to try to find the necessary liquidity:

Donor Assistance – Following the damage assessment, the Government convened a donor conference pledged in excess of US\$150 million to assist in the reconstruction of the island. These pledges included a US\$10 million from DfID to support payment of salaries in the education sector and US\$ 2 million from the World Bank for the financing of critical imports. While these contributions were particularly generous, it is interesting to note that these were the only two donors able to provide immediate liquidity to the government despite the urgent needs expressed at the conference. The remainder of the funds was earmarked for reconstruction project that were implemented over the following two years.

Debt restructuring – October 4, 2004, less than one month after Hurricane Ivan, the Ministry of Finance issued a press release on announcing Grenada's intention to seek the cooperation of creditors in light of the economic crisis precipitated by the hurricane. . With financial and legal assistance financed by USAID and DfID, the government developed an exchange offer to its creditors to restructure over 85 percent of the Government commercial debt (approx. US\$265 million) had agreed to an exchange offer.

Tax increase – The government also passed revenue-enhancing measures yielding over 2 percent of GDP. These included: (i) an increase of about 45 percent in the retail price of fuel; (ii) an increase in excise taxes on alcohol and tobacco; (iii) a special levy on incomes over US\$375 per month for a five year period; and (iv) improved tax administration.

Despite all these efforts, Grenada's fiscal situation remained challenging and the country still faced a financing gap of 4.5 percent of GDP for 2005 with total debt projected to increase to 150 percent of GDP.

4. Sovereign Insurance for the Caribbean Islands

Caribbean countries are highly exposed to adverse natural events, which can result in disasters affecting their entire economic, human, and physical environment. On average, at least one major hurricane and numerous tropical storms cross the Caribbean each year. Other types of catastrophic events including earthquakes, volcanic eruptions, and tidal waves are less frequent can be as devastating, as demonstrated by the near total destruction of the island of Montserrat by a volcanic eruption in 1995. For many reasons, ranging from the growing concentration of assets to poor environmental management, the loss burden from natural disasters is increasing. Because of their small size, Caribbean countries have limited financial capacity to respond to adverse natural events. Larger countries can generally absorb the impact of these events by subsidizing the affected region with revenues from unaffected regions. This type of geographic diversification of risk is limited in the small island states of the Caribbean. The inability to respond effectively, physically and financially, often slows recovery, which exacerbates the poverty impact of natural disasters.

While Caribbean countries have limited capacity to spread risk geographically, their constrained borrowing capacity also prevents them from spreading their risk over time by accessing credit. An analysis of economic statistics from Caribbean Community and Common Market (CARICOM) indicates an average ratio of external debt to GNI of 86 percent, compared to 34 percent for low-income countries, and 20 percent for middle-income countries. Caribbean countries affected by natural disasters generally

see their access to credit dramatically reduced right at the time when they need it most, limiting their capacity to respond to emergency needs. The limited lines of credit that are available, including IMF contingent facilities, often take time to materialize and add to the debt burden as they must usually be repaid in a very short time frame.

In these circumstances, Caribbean governments affected by natural disasters have generally relied on extensive financing from international donors to finance post-disaster needs. While ex post disaster funding from bilateral and multilateral agencies can be an important component of a government's catastrophe risk management strategy, over-reliance on this approach has obvious limitations. Donor assistance can take a long time to materialize and usually is earmarked for specific investments, with limited possibilities to finance general budget outlays such as civil servants' salaries, debt services, and other government obligations.

Finally, Caribbean governments' access to traditional catastrophe insurance and reinsurance markets is limited because of the high transaction costs resulting from the relatively small business brought to the reinsurance market. In the absence of well-functioning catastrophe insurance markets, most of the economic loss is borne by governments and households, with a disproportional impact on the poor.

The concepts of liquidity gap and social cost of catastrophic risk bearing are illustrated in the case of the Caribbean catastrophe risk insurance initiative. The Caribbean Catastrophe Risk Insurance Facility (CCRIF) aims to provide participating countries with an insurance instrument that would help shelter them from natural disasters. The Facility, launched on June 1 2007, enables governments to purchase catastrophe insurance coverage against hurricanes and earthquakes, such as a major earthquake or the passing of a hurricane (see Box 4).

As of June 1, 2007, fifteen Caribbean countries have purchased catastrophic insurance for a total premium volume of US\$17 million and a total sum insured of US\$444 million. This high level of enrollment allows the CCRIF to efficiently diversify its portfolio and thus access reinsurance on better terms. Reinsurance capacity of US\$110 million has been purchased on the reinsurance market which, with the initial US\$10 million retention, ensures that the Facility would sustain a 1-in-1000 year event.

Box 4. The Caribbean Catastrophe Risk Insurance Facility

- ***The Caribbean Catastrophe Risk Insurance Facility*** (CCRIF) allows CARICOM governments to purchase insurance coverage to finance immediate post-disaster recovery needs.
- ***The Facility acts as a risk aggregator.*** The CCRIF allows participating countries to pool their country-specific risks into one, better-diversified portfolio. This diversification should result in a substantial reduction in premium cost of up to 40 percent.
- ***Claims payments depend on parametric triggers.*** Index-based (or parametric) insurance instruments pay claims based on the occurrence of a pre-defined event rather than an assessment of actual losses on the ground. This measurement, made remotely by an independent agency, allows for transparent, low settlement costs and quick-disbursing contracts.
- ***Insured countries pay an annual premium commensurate with their own specific risk exposure.*** Parametric insurance products will be priced for each country based on the individual country risk profile. Annual premiums will typically vary from US\$200,000 to US\$4 million for coverage ranging from US\$10 million to US\$50 million. As of June 1, 2007, fifteen Caribbean countries are members of the Facility. The total premium volume is US\$17 million for a total sum insured of more than US\$400 million.
- ***The Facility is created with financial support from donors.*** Donors have pledged almost US\$50 million to support the establishment of the Facility. These funds will be used to pay for operational expenditures, reinsurance costs, etc. This will thus allow the Facility to build up reserves from countries' insurance premiums and participation fees more quickly.

- ***The Facility transfers the risks it cannot retain to the international financial markets.*** CCRIF was able to secure US\$110 million of claims paying capacity on the international reinsurance and capital markets. The reinsurance structure consists of four layers: CCRIF retains the first layer of US\$10 million; reinsurers underwrite the second (US\$15 million) and third layers (US\$25 million); the top layer (US\$70 million) is financed with reinsurance (US\$50 million) plus US\$20 million coverage through a catastrophe swap between the World Bank (IBRD) and CCRIF. IBRD hedged its risk through a companion cat swap with Munich Re. The US\$20 million swap between IBRD and CCRIF is the first transaction to enable emerging countries to use a derivative transaction to access the capital market to insure against natural disasters. It is also the first time a diversified pool of emerging market countries' catastrophe risk is placed in the capital markets.
- ***The Facility develops a financial strategy for surviving 1-in-1000-year events.*** Should the total insured losses exceed its claims-paying capacity, payouts will be prorated based on the total amount of expected claims compared to the remaining available funds. The CCRIF will then seek donors' contributions and/or private capital for its recapitalization.
- ***The CCRIF is established as an independent legal entity.*** It will be created as an Insurance Captive Special Purpose Vehicle (SPV) owned by a trust. Both entities will be registered in the Cayman Islands, a market leader in Insurance Captives. The CCRIF will be managed by a Captive Manager under the supervision of a Board of Directors composed of representatives from the donors and client. This Board will be supported by the technical advice of a specialized Facility Supervisor. The Bank will not sit on the Board, but will retain control in the initial phase through a financing agreement with the Facility defining how donor funds can be used.
- ***The Facility could serve as a pilot program to be extended or replicated to other small states (such as the Pacific Island states).*** Extending the pool to small states beyond the Caribbean that face similar natural hazards would provide further opportunities for risk diversification, thus lowering the cost of insurance. This extension would require the development of sophisticated probabilistic risk models for the regions involved (Pacific and Indian Ocean).

Source: Ghesquiere and Mahul (2007).

The Facility allow CARICOM governments to purchase coverage akin to business interruption insurance that would provide them with an immediate cash payment after the occurrence of a major earthquake or the passing of a hurricane. Because of the speed at which a claim payment will be processed, the instrument will be particularly useful to finance the immediate post-disaster recovery, giving the affected government time to mobilize additional resources for longer-term reconstruction activities. This insurance instrument does *not* intend to cover all losses faced by the governments, but just to address the liquidity crisis governments may face in the aftermath of a disaster.

Government deficit losses due to natural hazards are estimated using state-of-the-art catastrophic risk modeling techniques. They include: damage of government buildings; reduction of annual tax revenue due to loss of commercial facilities, business interruption, loss of import taxes and tourism taxes, damage of infrastructure and government relief expenditures. Each of these loss components are estimated first and then combined to find the overall deficit loss for a country.

Loss due to damage to government buildings. These are direct damage to government buildings.

Reduction of annual tax revenue due to loss of commercial facilities, business interruption, loss of import taxes and tourism taxes. The reduction of tax revenue is estimated from the damage degree of commercial buildings in the country using a piecewise-linear relationship of annual tax reduction with the damage ratio of commercial buildings. Tax revenue values are the total national tax revenue less the property tax.

Loss due to damage to infrastructure (bridges, roads, pipelines, hospitals...). The damage to infrastructure is estimated based on the total damage to the residential buildings in the same area. From the damage information in the past hurricanes in the Caribbean countries (see ECLAC reports), the loss amount from the damage to infrastructure ranges from 15% to 129% of the residential buildings (Grenada 15%, Cayman islands 29%, Jamaica 62%, and Bahamas 129%). Assumptions were made on the ratio of infrastructure loss to residential building loss by hazard and by country.

Government relief expenditures. Government relief expenditures after natural disasters are assumed to be 1% of the total damage to the residential buildings in the same area by referring the information from ECLAC reports.

Government deficit “loss exceedance curves” are built for every Caribbean country and parametric indices are developed for both hurricanes and earthquakes to fit the estimated government deficit loss curve.

It is estimated that short term resources represent up to 20% of the government deficit loss. Therefore, a cost-effective risk financing strategy should be designed to secure funds to be immediately available to cover these losses in the aftermath of a disaster

Catastrophe insurance offered by the CCRIF aims at financing hurricanes and earthquake events with a return period between 25 years and 150 years. Each participating country purchased coverage between US\$4 million and US\$50 million for hurricane risk, and between US\$2 million and US\$50 million for earthquake risk, with an aggregate coverage not to exceed US\$50 million. CCRIF insurance is shown to be cost-effective for this layer of risk, compared to self-retention: the CCRIF premium is shown to be on average 68% lower than the cost of self-retention (World Bank 2007).⁴

5. Conclusion

The Arrow-Lind Public Investment Theorem is usually presented as the rationale for countries to apply the policy of risk neutrality in the evaluation of public investment. This paper has discussed how the net present value of a project should be evaluated under uncertainty: it depends on the discount rate, which is independent of the risky project under consideration, and the risk-adjusted expected social net benefit. This benefit is equal to the expected cash flow of the project if and only if the project risk is independent with the macroeconomic risk, leading to the Arrow-Lind theorem.

This assumption of risk neutrality has been challenged when countries are exposed to natural disasters using an alternative model which captures the correlation among individual losses (caused by natural disasters) and the liquidity constraint the government faces. We have shown that countries should evaluate the cost of natural disasters on the basis of a value higher than the expected loss, i.e., the social cost of catastrophic risk bearing is positive, if the catastrophic losses affect a large fraction of the population, the government faces liquidity constraints in the aftermath of a disaster, and the marginal opportunity cost of holding reserves is positive. These conditions are met by most of developing countries exposed to natural disasters, and particularly small state islands. This offers a rationale for the use of ex ante risk financing instruments, including insurance.

⁴ The country still needs to build individual reserves to cover losses caused by events with return periods of 25 years or less. The optimal risk financing strategy is not discussed here. See Gurenko and Mahul (2003) and Mahul and Gurenko (2006) for a conceptual discussion.

However, the indiscriminate use of financial instruments may lead to inefficient use of risk capital to the policy maker. This paper has proposed a dynamic approach to design risk financing strategies that take into account the timing in mobilization of resources post disaster. This approach relies first on the use of ex-post resources readily available and reduces the use of ex-ante instruments to mainly fund short-term liquidity gaps.

By ensuring that sufficient liquidity exists very soon after a disaster, modern funding approaches can help to speed recovery, ensure that scarce government funds are well used and reduce the risk of moral hazard. In addition, catastrophe risk management can assist countries in the optimal allocation of risk in the economy, which may result in higher growth, better mitigation, and more effective poverty alleviation.

These concepts are being used under the Caribbean catastrophe risk insurance initiative, which aims at providing Caribbean governments with insurance coverage to finance immediate post-disaster recovery needs. This financial instrument is shown to be less expensive than self-retention to finance the catastrophic risk layer.

References

- Arrow, K. and R.C. Lind (1970). Uncertainty and the Evaluation of Public Decisions, *American Economic Review* 60(3), 364-378.
- Caballero, R. (2003). The Future of the IMF and the World Bank, *American Economic Review* 93(2), 31-38.
- Cochrane, J. (2001). *Asset Pricing*. Princeton University Press.
- Cox, J., J. Ingersoll and S. Ross (1985). A Theory of the Term Structure of Interest Rates, *Econometrica* 53, 385-403.
- Cummins, D. (2005). Should the Government Provide Insurance for Catastrophe? Presentation at the 30th Annual Economic Policy Conference, Federal Reserve Bank of St Louis, October 20-21, 2005.
- Fisher, A. (1973). Environmental Externalities and the Arrow-Lind Public Investment Theorem, *American Economic Review* 63(4), 722-725.
- Foldes, L.P. and R. Rees (1977). A Note of the Arrow-Lind Theorem. *American Economic Review* 67(2), 188-193
- Freeman, P., M. Keen, M. Mani (2003). Dealing with Increased Risk of Natural Disasters: Challenges and Options. *IMF Working Paper* WP/03/197.
- Gardner, R. (1979). The Arrow-Lind Theorem in a Continuum Economy, *American Economic Review* 69(3), 420-422.
- Ghesquiere, F., L. Jamin and O. Mahul. (2006). Earthquake Vulnerability Reduction Program in Colombia: A Probabilistic Cost-Benefit Analysis, *World Bank Policy Research Working Paper* 3939.
- Gollier, C. (2003). To Insure or Not to Insure?: An Insurance Puzzle, *The Geneva Papers on Risk and Insurance* 28, 5-24.
- Grenko, E. and R. Lester (2004). Rapid Onset Natural Disasters: The Role of Financing in Effective Risk Management, *World Bank Policy Research Working Paper* 3278.
- Gurenko, E. and O. Mahul (2003). Combining Insurance, Contingent Debt and Self-Retention: An Optimal Corporate Risk Financing Strategy. *World Bank Policy Research Working Paper* 3167.
- Hofman D. and P. Brukoff (2006). Insuring Public finances Against Natural Disaster: A Survey of options and Recent Initiatives, *IMF Working Paper* WP/06/199.
- Magill, M. (1984). On the Arrow-Lind Theorem, *Journal of Mathematical Analysis and Applications* 102, 211-219.
- Mahul, O. and E. Gurenko (2006). The Macro Financing of Natural Hazards in developing Countries, *World Bank Policy Research Working Paper* 4075.
- Rasmussen, T. (2004). Macroeconomic implications of natural Disasters in the Caribbean, *IMF Working Paper* WP/04/224.
- World Bank (2007). Caribbean Catastrophe Risk Insurance Facility: Background Document, February 2007.

Annex 1: Using Catastrophe Risk Models to Assess Potential Financial Needs

Probabilistic risk modeling is a common tool used by insurers faced with the challenge of assessing risks. In recent years, a growing number of analyses have tried to adapt such models to estimate the impact of potential natural disasters on the government budget. These models generally build on the usual hazard, exposure, vulnerability and damage module of standard insurance package which are then used to derive the potential magnitude of relief and recovery costs, impact on government revenue and cost to assets which are the responsibility of the government.

The financial impact of natural disasters on government budget is different from the impact on the portfolio of insurance business risk modeling firms are used to assess. It thus requires an innovative risk assessment model using a different risk management paradigm than the one applied for the insurance industry. To the best of our knowledge, this is the first time that latest catastrophe modeling techniques have been used to address the impact of natural disasters on the government budget.

Hazard module: The hazard module defines the frequency and severity of a peril, at a specific location. This is done by analyzing the historical event frequencies and reviewing scientific studies performed on the severity and frequencies in the region of interest. Once the hazard parameters for each peril are established, stochastic event sets are generated which define the frequency and severity of thousands of stochastic cyclone or flooding events. This module can analyze the intensity at a location once an event in the stochastic set has occurred. This module models the attenuation/degradation of the event from its location to the site under consideration and evaluates the propensity of local site conditions to either amplify or reduce the impact.

Exposure module: The exposure values of “assets at risk” are estimated either from available secondary data sources or are derived from the distribution of population. This “proxy” approach is used when the preferred specific site by site data is not available. Based on these data, the module then computes the value for all types of exposures as a product of multiplication of the area of total building inventory and the average replacement cost per unit of inventory.

Vulnerability module: The module quantifies the damage caused to each asset class by the intensity of a given event at a site. The development of asset classification is based on a combination of construction material, construction type (say, wall & roof combination), building usage, number of stories and age. Estimation of damage is measured in terms of a *mean damage ratio* (MDR). The MDR is defined as the ratio of the repair cost divided by replacement cost of the structure. The curve that relates the MDR to the earthquake intensity is called a *vulnerability function*. Each asset class and building type will have different vulnerability curves for each peril.

Damage module: To calculate losses, the damage ratio derived in the Vulnerability module is translated into dollar loss by multiplying the damage ratio by the value at risk. This is done for each asset class at each location. Losses are then aggregated as required. Government assets or assets that are likely to be financed with government resources can be easily isolated and an assessment of financial needs for reconstruction calculated. Based on the likely timing for reconstruction, these costs can be ventilated between short, medium and long term financial needs.

Relief and recovery costs module: Based on the estimated damage to buildings and infrastructure, it is generally possible to apply metrics of occupancy rate and derive assessments of the likely number of people injured, killed or left homeless. This information can then be used to assess the likely cost of government relief and recovery operations.

Government revenue tax loss module: Assessing the impact of disaster on government revenue is made particularly difficult because of the variety of effect a disaster can have on a national economy. While most local businesses are likely to experience losses the increase in economic activity related to reconstruction operation may lead to an increase in economic activity both in the affected region and in the country as a whole. An analysis of assets likely to be impacted by a disaster can give indications at to the potential sectors of society that will be most affected and the time it will take to recover. This information combined with historical and economic analysis of past disaster can provide a good indication of the extent and timing of revenue losses for the government.

Figure A1. Assessing Government losses due to Natural Disasters

