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Background Paper prepared for the Global Assessment Report on Disaster Risk Reduction 2013

Modelling the economic and fiscal risks from natural disasters. Insights based on the CatSim model

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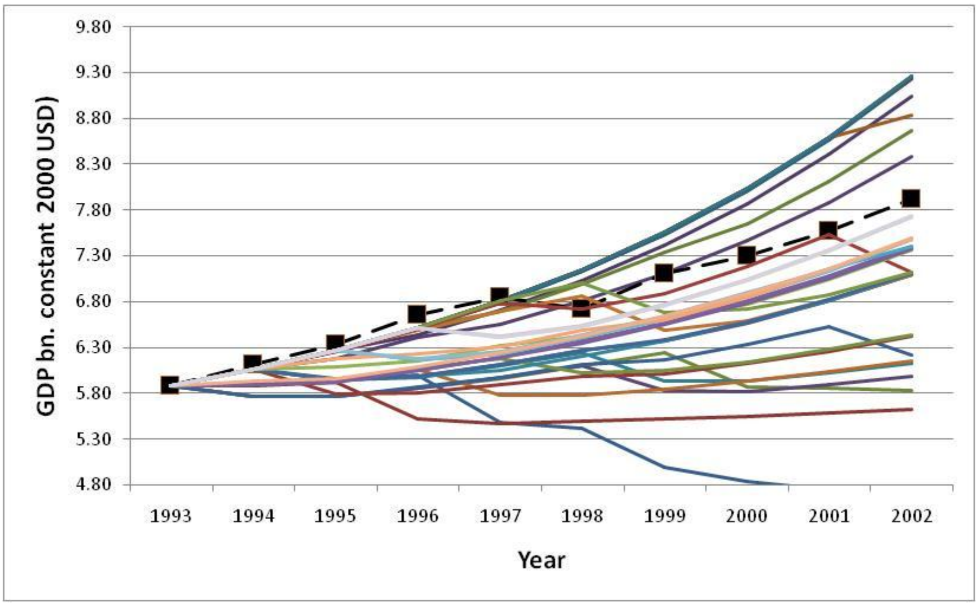
Final Draft

SUMMARY: KEY RESULTS AND MESSAGES

1. **Taking a risk-based perspective for modelling the indirect, economic losses arising from direct risk (damages) adds additional insights for managing disaster risk in highly-exposed and at-risk countries.**

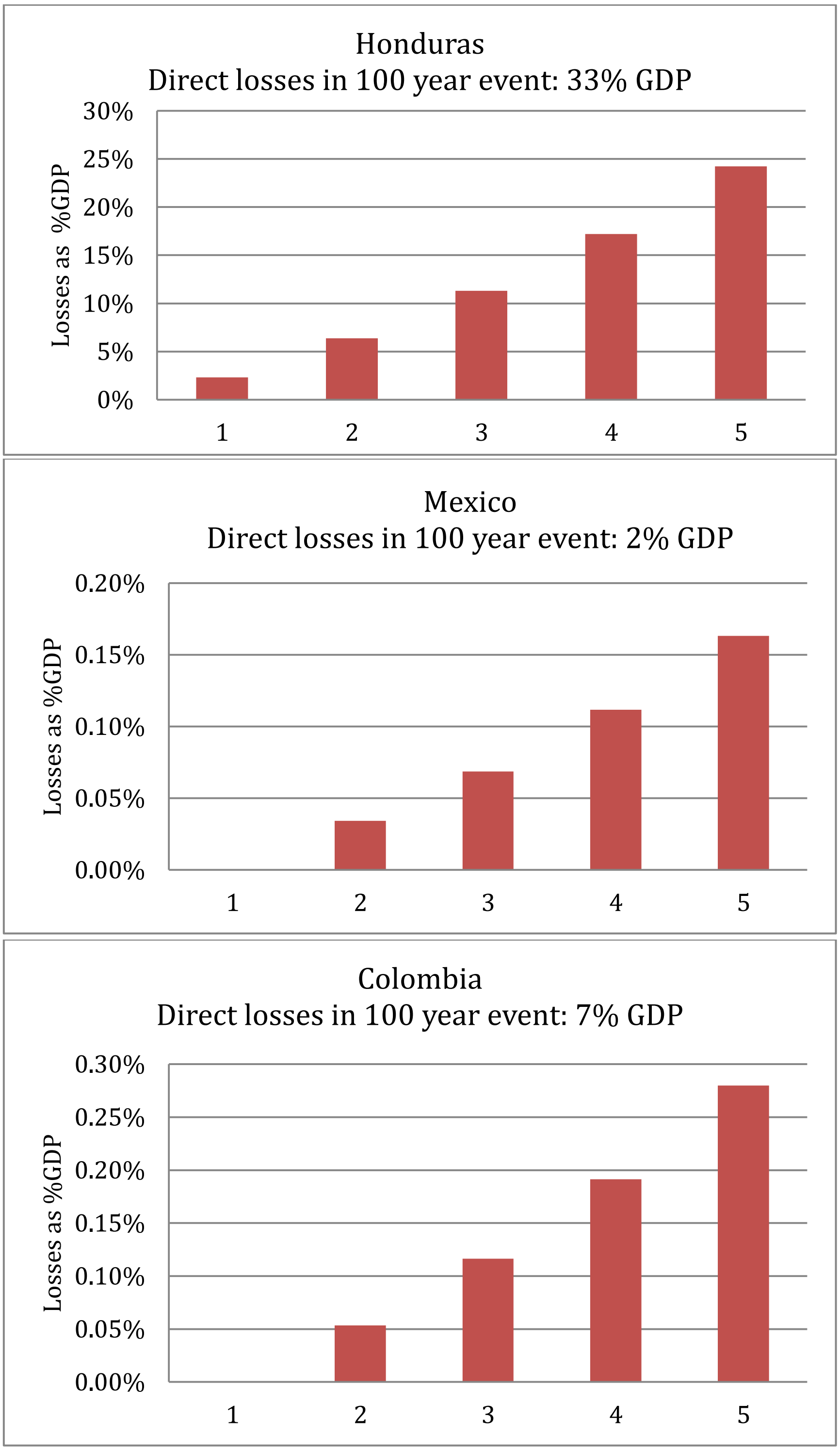
Based on historical evidence and probabilistic simulations of disaster risk including a consideration of fiscal vulnerability CatSim can be used to project GDP consequences. The chart shows estimates of GDP for Honduras when disaster risk is factored in, and exhibits that many different outcomes are possible based on timing and size of events. The dashed line shows empirical evidence in terms of observed GDP pre and post Hurricane Mitch in 1998, an event, which had a major negative effects on macroeconomic outcomes.



CatSim GDP projections for Honduras in comparison to observed GDP effects post Hurricane Mitch in 1998 (dashed line) (in billion constant 2000 USD)

2. **Economic impacts depend on the size of the event as well as economic and fiscal resilience.**

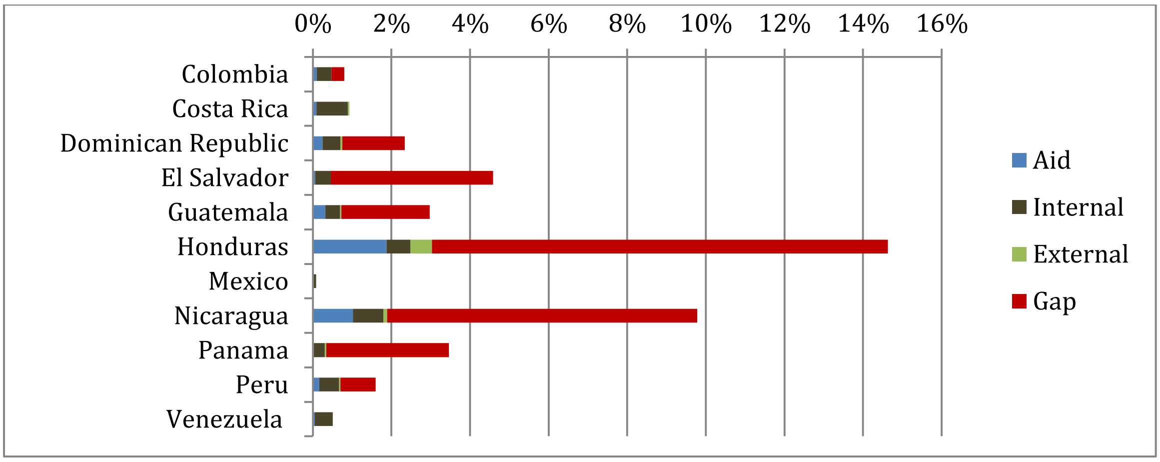
The figure below exhibits macroeconomic effects modelled over 5 year time periods for Honduras, Mexico and Colombia as a consequence of a 100 year event. Given limited fiscal resilience, Honduras not only has the largest direct risk, but is also subject to the largest modelled economic risk.



Modelled cumulative macroeconomic effects after a 100 year event for Honduras, Mexico and Colombia over a 5 year period (measured in terms of GDP in the year of the event).

3. **Projections of risk can be used to inform considerations for intercountry risk pooling, which helps to reduce the costs of risk bearing.**
   As one example, Central American countries participating in the Regional Insurance Facility for Central America (RIFCA) are differentially fiscally vulnerable and a mechanism for intergovernmental risk pooling offers benefits. Some countries exhibit high fiscal vulnerability in terms of fiscal gaps (shortfall of resources over needs) already

at 10 year events (Nicaragua), for others (Panama) a lack of financing would start roughly at a 100 year event.



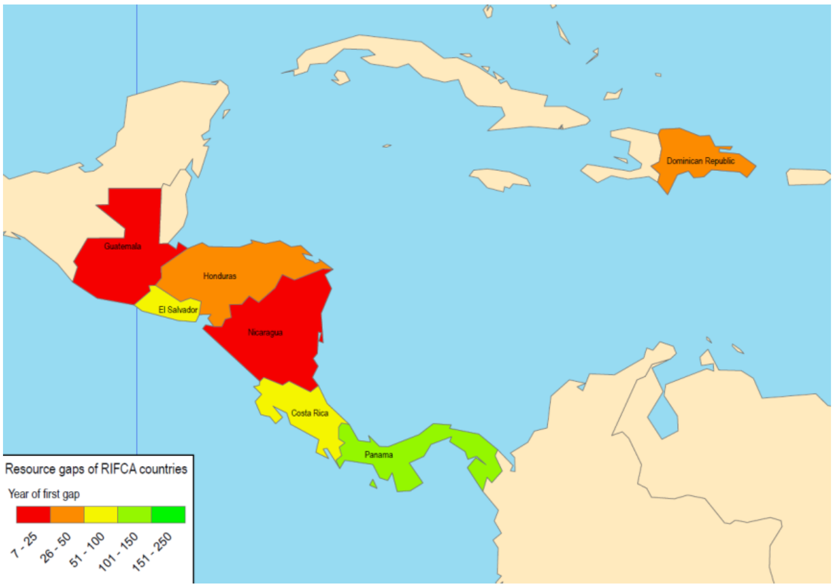
Governments' financial capacity to absorb public sector losses in a 1 in 100 year event (indicated in %of GDP)

Notes:

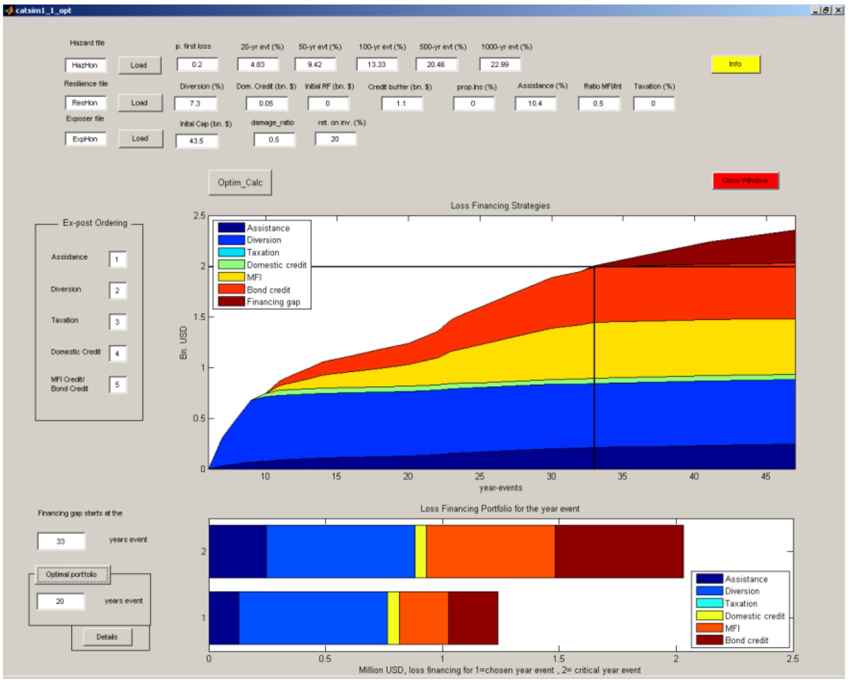
1. For Mexico and Colombia calculations of liabilities are based on bottom up exposure assessment. For other countries, a top down assessment based on key assumptions is used.
2. Internal resources comprise government diversion, reserve funds and risk financing (government insurance, such as for Mexico, or contingent financing such as for Colombia).

External resources comprise new borrowing from development banks and the financial markets, which is limited by debt thresholds.

3. Hazards covered: Mexico: earthquakes and storms, Colombia: earthquakes and storms, Honduras: earthquakes, storms, and drought, Others (Costa Rica, Dominican Republic, El Salvador, Guatemala, Nicaragua, Panama, Peru, Venezuela): earthquake, storms, and drought (CIMNE, 2012 data)



Fiscal gaps for countries participating in the RIFCA pool as a function of direct risk and economic/fiscal resilience can be used for a layered risk pooling scheme



Calculation of fiscal gap for Honduras

To provide more detail, the figure identifies governments' financial resources for a set of Central American and Latin American countries to absorb public sector losses in 1 in 100 year event. In addition to receiving add, governments can divest of internal resources comprising government diversion and reserve funds as well as risk financing, such as government insurance in Mexico, or contingent financing such as for Colombia. External resources comprise new borrowing from development banks and the financial markets, which however is often severely limited by debt thresholds. A number of countries would not be able to cover the liabilities and incur fiscal gaps.

1 Background and objectives

Natural disasters can exert important effects on aggregate economic outcomes, such as on GDP and the fiscal and debt position and impacts importantly depend on a country's economic resilience as well as the size of a shock in terms of direct risk. A good understanding of the impacts as well as the effects of different policy options forms the basis for implementing efficient, effective and acceptable measures for building resilience.

IIASA collaborates with UNISDR and other partners in the framework of the Global Assessment Report (GAR) in order to contribute to the improvement of our current understanding of the national economic and financial implications of economic risk. The contribution is based on IIASA's CatSim model, which is a modelling framework helping national decision-makers to assess disaster risk and build resilience by way of contingency planning and implementing risk management options. The initiative includes

- Calibrating modelling results with observed macroeconomic effects,
- Providing a risk-based estimate of the indirect economic effects,
- Assessing the scope of disaster risk on macroeconomic outcomes,
- Laying the foundations for gauging the benefits of disaster risk management and building resilience.

IIASA's contribution to the GAR 2013 is based on probabilistic risk distributions (direct risk, losses) received from the Centro International de Métodos Numéricos en Ingeniería (CIMNE), which are taken as an input to produce output in terms of economic effects (indirect risk). CatSim is run for a number of country/regional case studies. Each case study provides different insights based on the country/regional characteristics as follows:

- Honduras/Colombia/Mexico: What are the differential macroeconomic implications of disaster risk in lower-middle (Honduras), upper-middle income (Colombia) and OECD (Mexico) countries?
- Central America (Dominican Republic, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama): What is the basis for inter-country risk pooling given differential direct risk and fiscal vulnerability?

The modelling initiative lays the groundwork for future research on the economics of disaster risk management, informing not only the GAR 2013 process, but also the Global Platform 2013 sessions on the economics of disaster risk reduction.

This report is structured as follows:
In section 2 we provide insight into the mechanics of the CatSim model, in section 3 we assess the empirical evidence on the economic effects of disaster risk, which is used to calibrate CatSim. In section 4 we apply CatSim to assessing economic and fiscal gaps as well as macroeconomic effects for our cases study countries. In section 5 we broadly examine the case for risk financing and pooling. Section 6 concludes. The appendix provides more insight on CatSim.

2 Modelling the economic risks from disasters: The CatSim model

CatSim is an analytical framework to model the economic effects of disasters and improve disaster risk management. It forms part of an innovative methodological approach in which risk management of natural disasters is being mainstreamed with development planning processes to inform policy in terms of robust and acceptable outcomes (Mechler et al., 2006; Hochrainer, 2006; Mechler et al., 2010a; Hochrainer et al., 2013; Mechler et al., 2013).
CatSim probabilistically assesses the economic impacts of natural disasters within a risk-based economic framework, thus accounting for the macroeconomic impacts due to natural disasters as well as allowing for studying the costs and benefits of measures for reducing those impacts. The model is organized around a Solow-type growth model, considered one of the 'workhorses' of economic growth research (see Barro and Sala-i- Martin, 2004). CatSim's focus is on the potential for medium to longer term growth and development of aggregate economic variables given the explicit consideration of disaster risks. As one key application, CatSim can be used to assess risks, economic resilience and fiscal vulnerability of governments to extreme events, and finally assist policy makers in developing public financing strategies for disaster risk. Overall, the model shows how disaster risks may be absorbed by governments and the economy overall, assesses a government's contingent disaster obligations and the potential shortfalls for financing (fiscal vulnerability), as well as the costs and benefits of vulnerability-reducing options. CatSim incorporates rare disasters explicitly as probabilistic events. Decisions on risk management are thereby based on the whole range of possible future scenarios.

2.1 CatSim model in a nutshell

Public disaster risk emanates from explicit and implicit contingent sector liabilities, classified in table 1. The explicit liability consists of rebuilding damaged or lost infrastructure, which is due to the public sector's allocative role in providing public goods. Implicit liabilities are related to the commitment of providing relief due to the distributive function in reallocating wealth and providing support to the needy (see table 1).

Table 1 Government liabilities and disaster risk

Liabilities	**Direct:** obligation in any event	**Contingent:** obligation if a particular event occurs
Explicit Government liability recognized by law or contract	Foreign and domestic sovereign borrowing, Expenditures by budget law and budget expenditures	State guarantees for nonsovereign borrowing and public and private sector entities, **reconstruction of public infrastructure**
Implicit A "moral" obligation of the government	Future recurrent costs of public investment projects, pension and health care expenditure	Default of subnational government and public or private entities, **disaster relief**

Source: Modified based on Schick and PolackovaBrixi, 2004

Often, these contingent liabilities are hidden and not explicitly tackled in development and fiscal planning. To this purpose, CatSim provides a methodology to assesses, plan for and manage disaster risk accruing to the public sector (national and subnational governments). The tool approaches the modelling and decision problem in five steps (see figure 1).

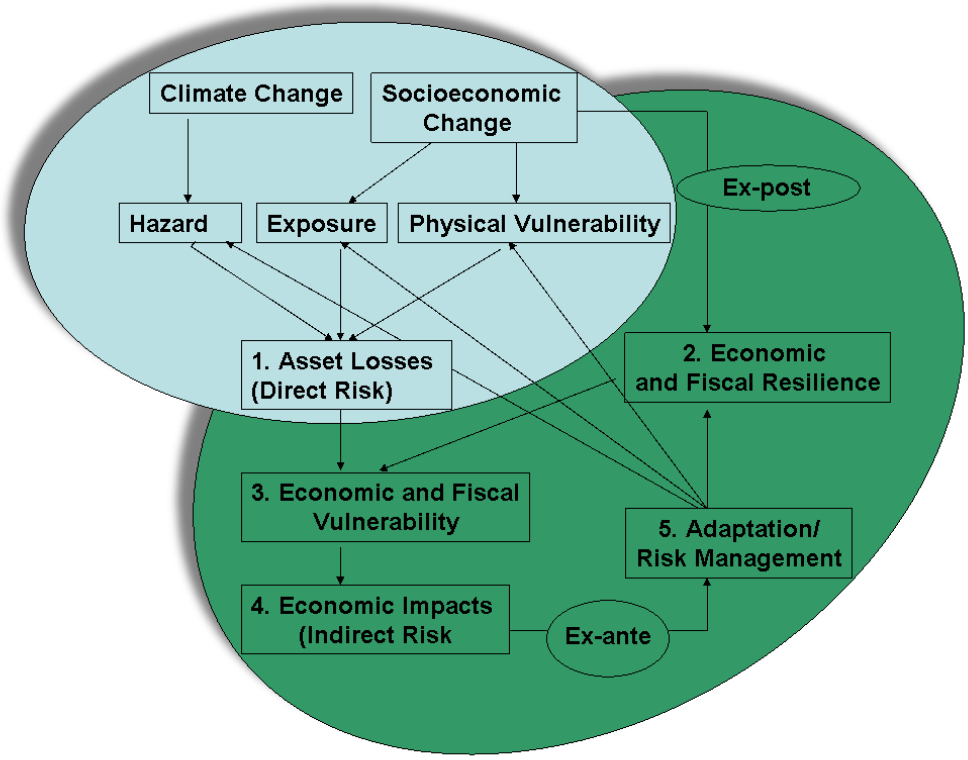


Figure 1 CatSim framework

Step 1: Assessing asset risk

In the first step, the risk is assessed in terms of the probability of asset damages (also called direct damages) in the relevant country or region. Consistent with general practice, risk is modelled as a function of hazard (frequency and intensity), the elements exposed to those hazards and their physical sensitivity. This step in the methodology of CatSim involves devising and applying damage-frequency distributions, which relate probabilities to damages of assets.

Step 2: Assessing economic and fiscal resilience

Another key aspect is the operationalisation of economic resilience. The focus is on the availability of internal and external savings of public sectors of a country or region, which can be used to refinance damages as well as increased post-disaster expenditure, e.g. for supporting the private sector during the relief and recovery phases.

Step 3: Measuring fiscal vulnerability by the "resource gap"

Using the information on direct risks to the government portfolio and fiscal resilience, fiscal vulnerability can be evaluated. Fiscal vulnerability is thus defined as the lack of access to domestic and foreign savings for financing reconstruction investment and relief post-disaster. The shortfall in financing is measured by the term resource gap (or fiscal/financing gap). The resource gap is understood as the lack of financial resources to restore assets lost due to natural disasters and to continue with development as planned.

Step 4: Mainstreaming disaster risk into development planning

Ultimately the implications of disaster risk on economic development and other "flow variables" is of major interest when mainstreaming disaster risks into development planning and macroeconomic management. For that matter, fiscal risk, fiscal vulnerability and the prevalent economic conditions are combined in order to derive at an estimate of potential fiscal and macroeconomic impacts, such as on GDP.

Step 5: Devising risk management strategies

Vulnerability and resilience must be understood as dynamic characteristics as economic and social systems can be adapted and managed. There are two types of policy interventions: those that reduce the risks of disasters by reducing exposure and physical vulnerability, and those that build resilience. CatSim can illustrate the pros and cons of strategies for building economic and fiscal resilience using ex-ante financial instruments. Overall, the development of risk management options, including risk financing strategies, has to be understood as an adaptive process, where measures are revised after their impact on fiscal vulnerability and risk has been assessed within the modelling framework.

2.2 Using CatSim

The CatSim model was designed by IIASA researchers to help policymakers, particularly in developing countries, devise public financing strategies to be implemented in both the pre- and post-disaster context. National data can be input into CatSim allowing policy advisers to pose "what if" questions. The model will then show the best combination of financial strategies to suit current national circumstances. The model was developed as part of research carried out for the Inter-American Development Bank's Integrated Disaster Risk Management Approach to support hazard-prone countries. This research for the first time identified countries with a potential "fiscal gap," that is, countries where disasters were considered highly likely to swamp the government's ability to finance the recovery process. Subsequently, the model was heavily expanded. Providing some fast facts, CatSim has been used

- by Mexico to assess the fiscal risks from earthquakes in 2007; this lead to the first-ever government-issued catastrophe bond against natural disasters,
- in a training workshop with most Caribbean countries in 2007 in the run-up to the "Caribbean Catastrophe Risk Insurance Facility (CCRIF)," (see photo below),
- in research for the World Bank to estimate disaster risk and fiscal implications in more than 80 countries (see Mechler et al., 2010b),
- During 2011-12 to inform the Government of Madagascar on their exposure to disaster risk and fiscal disaster risk planning measures.

Figure 2 CatSim in use to inform planning for disasters with officials from Grenada and other Caribbean countries, Barbados, June 2006

A standalone, web-based software application has been developed for use in policy workshops to make it easier for those responsible for implementing risk management strategies to understand the scientific basis of CatSim as well as change parameters and devise strategies. This web-based version provides customized data for countries that have participated in workshops in order to interactively assess their risk to extreme events. Further detail on CatSim is provided in the appendix.

3 Model calibration: Building the evidence base on the economic effects of disasters

3.1 Observed impacts

The evidence base on the macroeconomic effects from disasters is rather limited, but growing. We provide evidence found for our key case study countries. As one source of information, Post Disaster Damage and Needs Assessments (PDNA) provide detailed information on damages (physical damages of buildings, infrastructure etc.) and indirect losses (economic losses as consequences of physical damages) after severe events based on teams sent to the countries to examine the impacts (GFDRR, 2013). Figure 3 shows examples of damages and losses due to recent catastrophic events in our countries of study. We can see that for these countries, disaster risk differs substantially what concerns both the direct risk (damages) as well as indirect risk (losses).

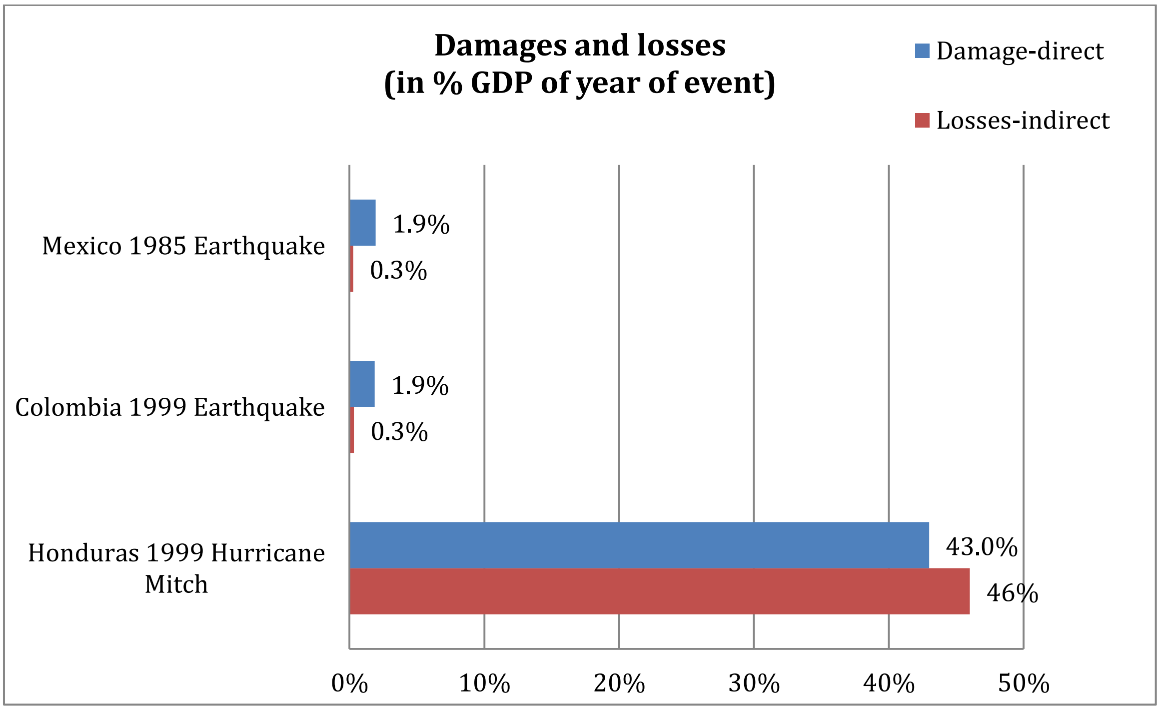


Figure 3 Observed damages and losses after key natural disasters in case study countries
Source: GFDRR, 2013

Particularly for Honduras, the effects are very pronounced and a magnitude higher than for Mexico and Colombia (table 2).

Table 2 Observed damages and losses in key events in 3 cases study countries

Event	Damage (Mill USD)	Loss (Mill USD)	Damage (%GDP)	Losses (%GDP)	Loss/Damage Multiplier
Honduras 1999 Hurricane Mitch	2,450.6	2622.31	43.0%	46%	1.07
Mexico 1985 Earthquake	3,589.0	515	1.9%	0.3%	0.14
Colombia 1999 Earthquake	1,611.8	290.45	1.9%	0.3%	0.18

3.2 Observed impacts in the case study countries

We now discuss these observed damages and losses in more detail. We study effects across key disasters of the recent past, where data were available.

3.2.1 Honduras: The macroeconomic impacts of Hurricane Mitch

Honduras may be considered a good illustration of a country subject to high disaster risk (severe exposure to hurricanes, flooding, drought and earthquakes), limited economic diversification with a reliance on cash crops such as bananas, and tight financial and fiscal constraints due to high indebtedness and high prevalence of poverty. Honduras was heavily hit by Hurricane Mitch at the end of 1998, killing 6,000 people, leaving an estimated 20% of the population homeless and causing assets damages of about 2.5 billion USD, 43% of GDP or 18% of capital stock (see Mechler, 2004). Important macroeconomic effects ensued and, according to a post-disaster impacts assessment, indirect losses were calculated at about 46% of GDP, when measured against GDP in the year of the event.

Another way of assessing the indirect effects in Honduras is examining projected and observed GDP. Figure 4 shows actual GDP in absolute terms (pink line) as well as pre-disaster projections by IIASA (fixed growth rate, green line). GDP growth in Honduras became negative in the year after the event (shown as the downward spike of GDP in absolute terms), but then rebounded later on with substantial inflow of foreign assistance, which increased by about 500 million USD or from about 6% pre disaster to close to 16% of GDP post disaster.

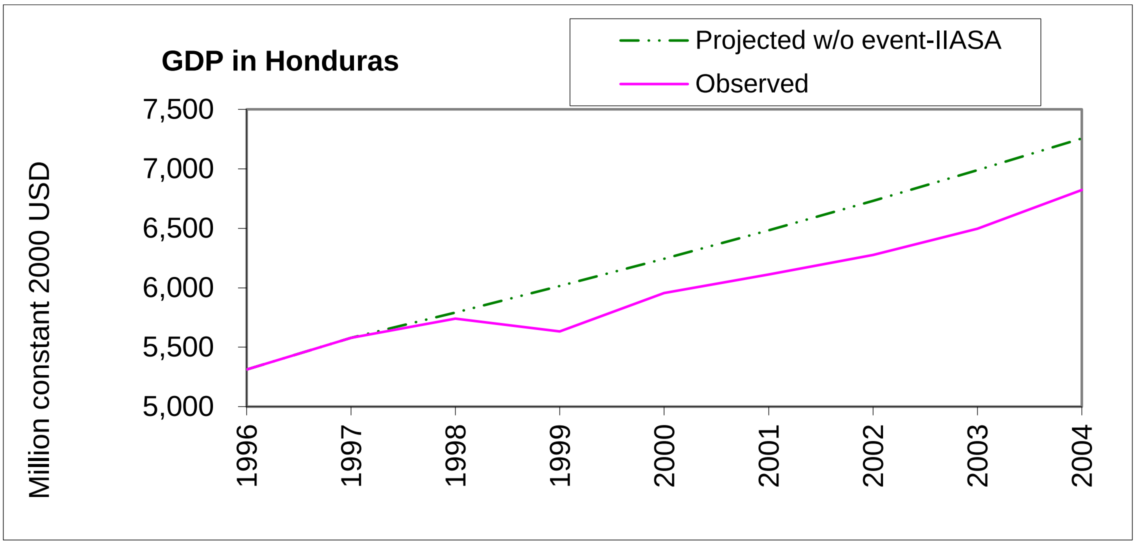


Figure 4 Observed GDP in Honduras with events vs. projected growth without events. Source: Mechler et al. 2006

Using this approach for Honduras, a “GDP gap” can be identified as the difference between projected and observed GDP. When taking such an approach, and aggregating the difference between those measures across time, we can estimate the following GDP gaps (see figure 5). Clearly, there are other factors affecting macroeconomic aggregates such as GDP, and this way of measuring is inexact. Yet, when comparing the values between the on-the–ground assessment based on PDNA with the accumulated effects based on macroeconomic projections, it emerges that the values are rather close, indicating that indeed disasters have led to important macroeconomic implications in Honduras.

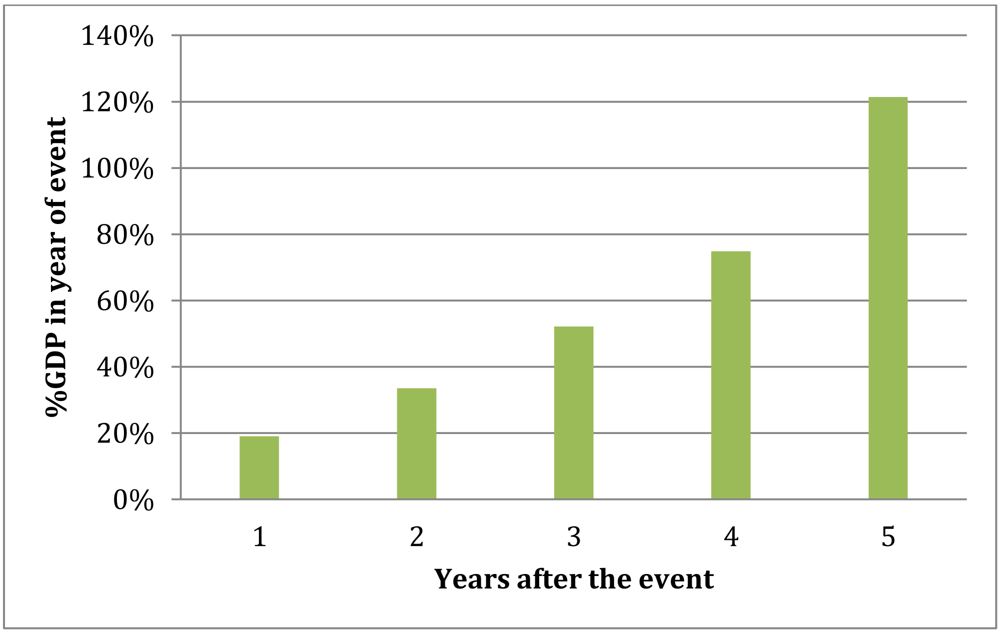


Figure 5 Measuring the GDP gap as the different between projected and observed GDP

3.2.2 Mexico: The macroeconomic impacts of the Michoacán earthquake in 1985 on Mexico

Figure 6 shows damages from natural disasters over the time horizon 1950-2010. One of the worst earthquake disasters in modern Mexican history occurred in September 1985. The magnitude 8.1 earthquake at 7:19 a.m. on Thursday 19 September 1985 lasted a full two minutes. It was followed by a magnitude 7.5 earthquake 36 hours later. The Michoacán earthquake in Mexico led to damages, which contributed 89% to the total damage burden from geological events over the period 1980-1999.

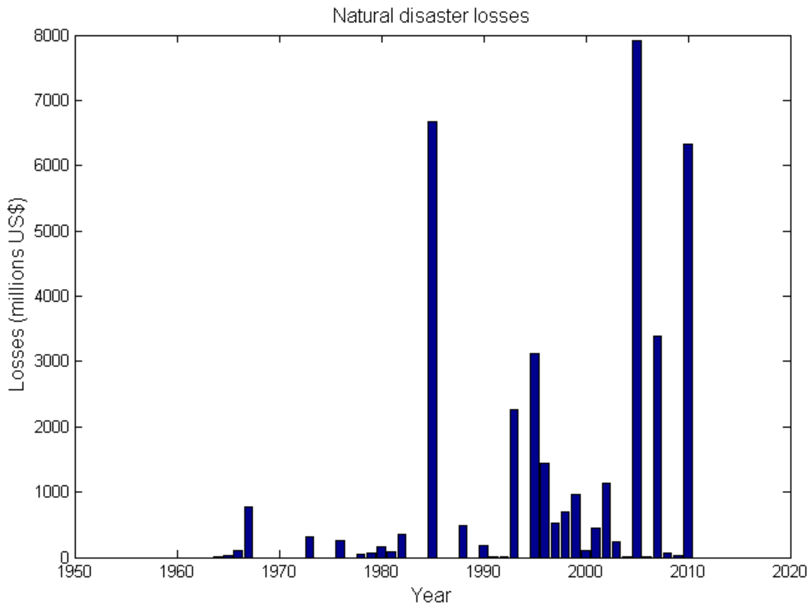


Figure 6 Natural disaster damages in Mexico during the period 1950 – 2010
Source: CRED, 2013

This earthquake lead to 6,000 deaths, 50,000 injured and 100,000 homeless. More than 500 buildings collapsed, and a further 600 of the 3,000 damaged structures were subsequently raised to the ground. Yet, the direct event in relative terms was a magnitude lower than the Honduras event at about 1.9% of GDP in 1985.The indirect, observed effect was even smaller at 0.3% GDP. It thus seems very difficult to use macro aggregates to make a similar case as for Honduras, and GPD has anyway been rather volatile over this period due to other factors.

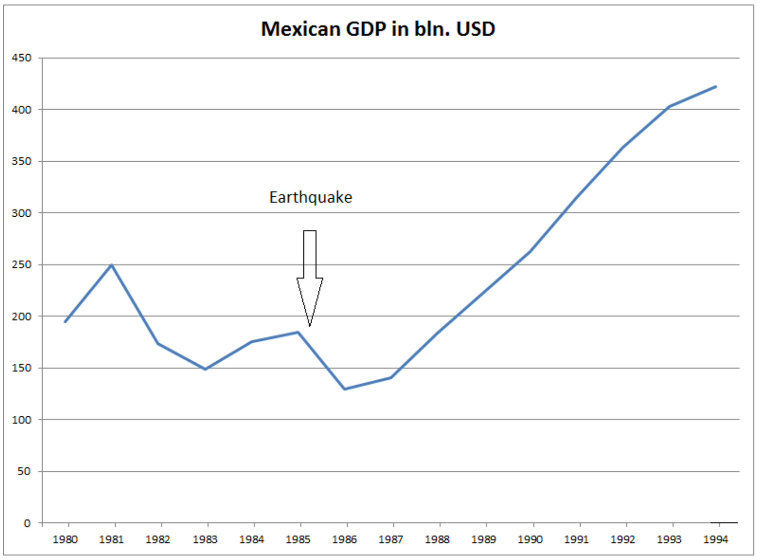


Figure 7 GDP in Mexico before and after the 1985 earthquake.

3.2.3 Colombia: The macroeconomic impacts of the earthquake in 1999 on Colombia

Economic damages caused by the earthquake, which hit Colombia’s coffee-growing region on 25 January in 1999 were estimated at US$1.6 billion and amounted to 17% of the value of the country's exports in 1998. At a national level, one percent of the population was affected and damage amounted to the equivalent of just over 1.9% of GDP. In terms of indirect effects, production losses were estimated at about 0.3% of GDP. Similarly to Mexico, macroeconomic statistics are not as telling as for the Honduras case (see figure 8). This suggests there is value in adopting a model-based approach for gauging the fiscal and macro effects.

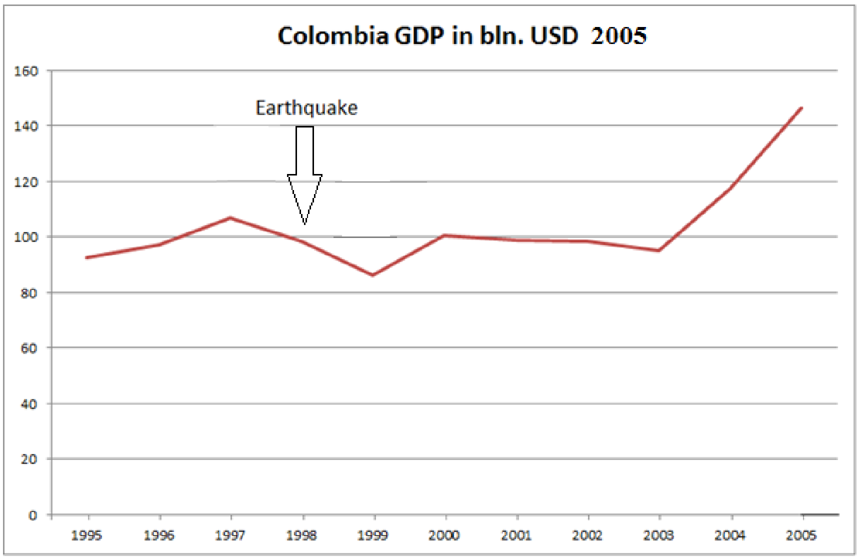


Figure 8 The behavior of GDP in Colombia before and after the earthquake.

4 Running the simulations

We now demonstrate CatSim for the case of Honduras, then turn to Colombia and Mexico.

4.1 Honduras

We use direct risk data as received from CIMNE (2012) in form of a hybrid damage exceedance curve; the curve convolutes risk from different hazards. The estimated risk is essentially a combination of two curves, an empirical and an analytical one. While the former is mostly based on empirical data from recorded disaster damages, the latter is constructed by the use of catastrophe modelling approaches. Figure 9 shows the hybrid damage exceedance curve for aggregate risk in Honduras.

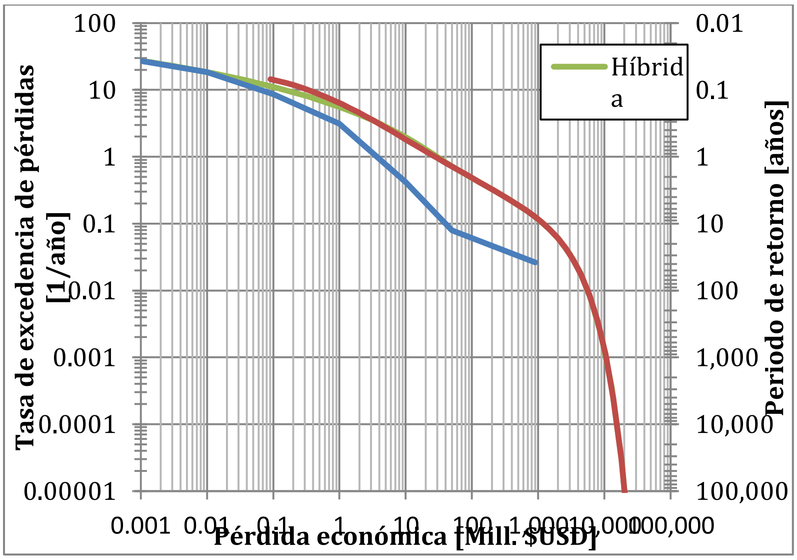


Figure 9 Direct risk distribution for Honduras
Source: CIMNE, 2012

CatSim uses this input and figure 10 shows a screen shot of the CatSim model illustrating the cumulative damage exceedance curve for public sector assets plus anticipated relief to the private sector.

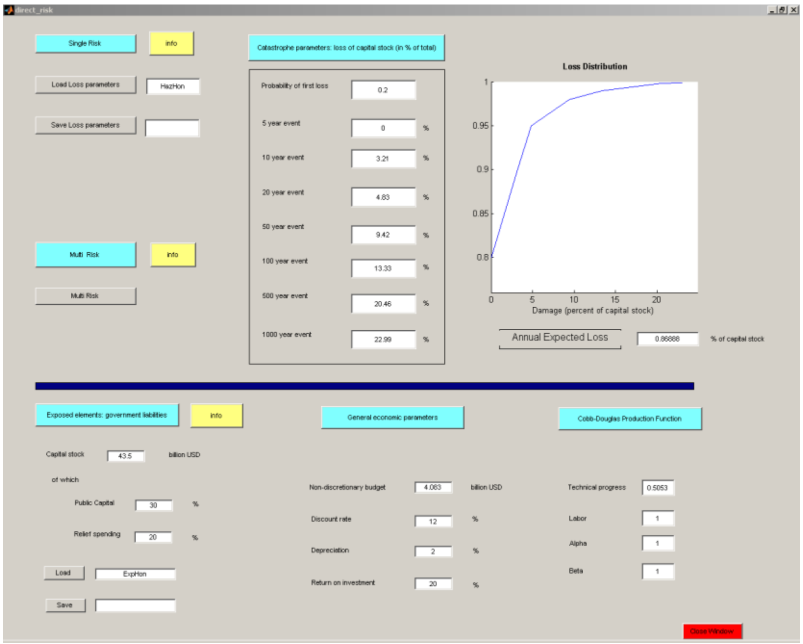


Figure 10 Cumulative probability distribution of direct asset risk in CatSim

Figure 11 displays a CatSim screen shot illustrating the fiscal vulnerability of the Honduran government to disaster risk.

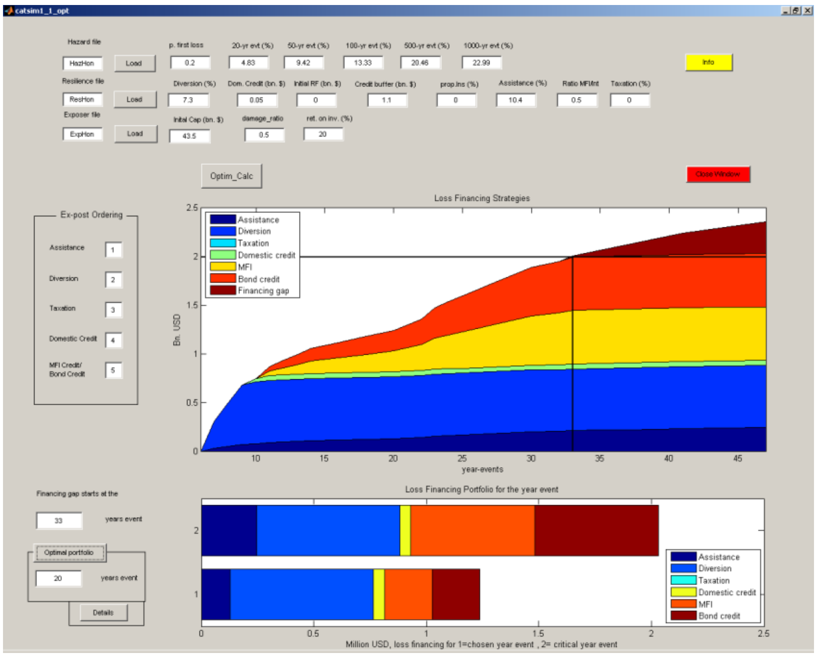


Figure 11 Fiscal vulnerability and resource gap

As shown in this figure, the government depends on traditional sources to finance the losses from moderate flood and storm. For events starting from a return period of 33 years, there is a sizable fiscal gap. This means that Honduras will not be able to provide sufficient relief to private victims nor repair its infrastructure in a timely way, which can set Honduras back significantly in its economic development.

Summarizing all potential sources, CatSim provides an estimate of the government’s fiscal gap for its storm and flood exposure. Given the data, the risk of a fiscal gap for the Honduran government is shown in figure 12. Combining direct risk with resilience, we estimate fiscal and macroeconomic impacts. Fiscal impacts in terms of a reduction in the discretionary (flexible) government budget arise due to relief and reconstruction spending needs post disaster.

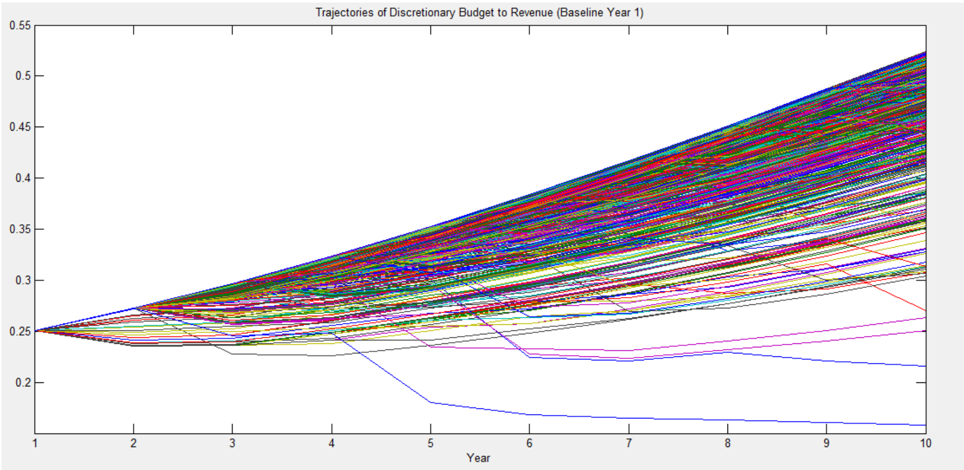


Figure 12 **Potential fiscal impacts due to disaster impacts.**

Similarly, macroeconomic performance may be affected. In figure 13, GDP trajectories are shown. The figure shows the GDP trajectories of some CatSim projections in comparison to the Hurricane Mitch scenario (event assumed to occur in year 5). As indicated, there are many possible scenarios, which would lead to various growth trajectories, and Mitch having been an event with estimated recurrency of 100 years is just one manifestation of disaster risk. Dependent on which risk is realized, different future impacts and pathways will be observed.

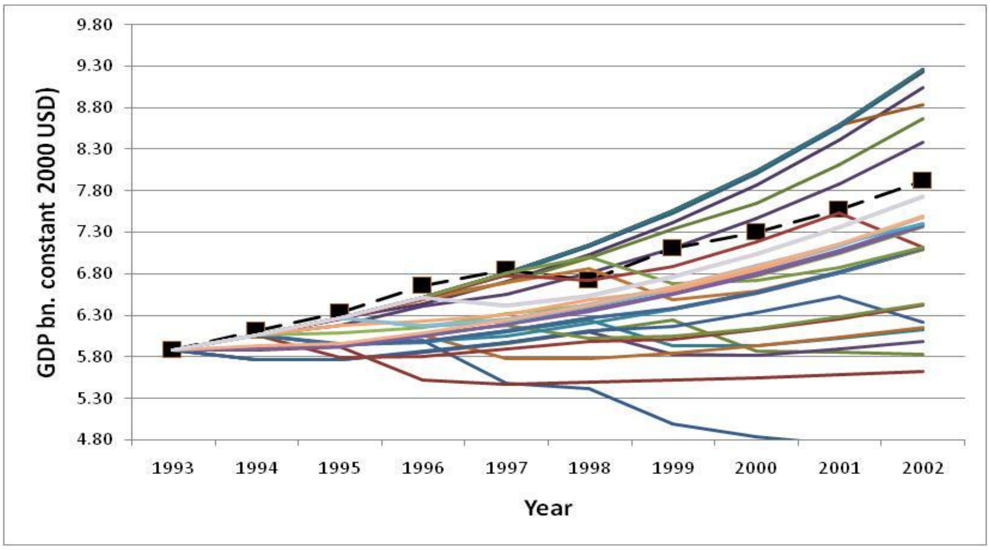


Figure 13 **CatSim GDP projections and observed GDP effects after Hurricane Mitch (dashed line)**

These estimations underline the value of taking a risk-based perspective when assessing the indirect, economic losses arising from direct risk adding additional insights for managing disaster risk.

4.2 Colombia

In figure14, GDP trajectories are outlined. Due to higher economic resilience, the effects are much less pronounced as compared to Honduras.

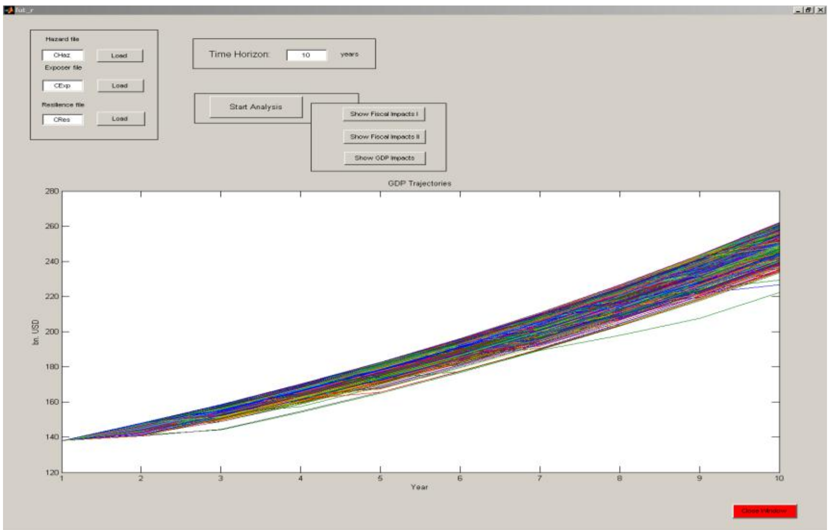


Figure 14 **Potential GDP impacts to Colombia due to disaster impacts.**

Fiscal effects for the short term (1 year ahead) are unlikely to be massive, as Colombia is taken to be able to divert savings to reconstruction and relief. However, for a longer time period, i.e. up to 10 years into the future, problems could occur. For example, the probability of having a fiscal gap is around 80 percent and a decrease in macro-economic performance can be expected (decrease of around 2-3 percent over this time horizon).

4.3 Mexico

An understanding of the sources for financing a disaster in Mexico, including the costs and constraints, is crucial for planning a disaster risk management strategy. In this case, while losses can be huge, compared to GDP these are small and also effects on the macro-level seem rather negligible.

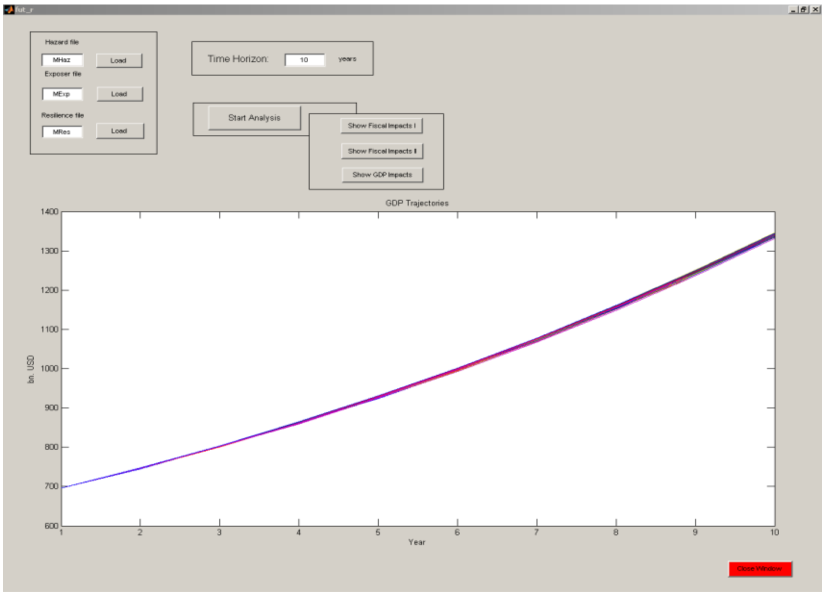


Figure 15 **Potential GDP impacts to Mexico due to disaster impacts.**

However, if multiple events over a given time horizon are considered there is some fiscal risk for Mexico. Calculations have shown that with a probability of 8 percent in the next 10 years some fiscal problems could emerge due to the realization of natural disaster risk. Furthermore, there is a risk in increase in indebtedness in the future due to such events.

4.4 Bolstering fiscal resilience

Information on fiscal gaps is informative in two regards:

1. It indicates when country resources are exhausted both in terms of domestic savings (taxes and budget diversion), as well as external savings (new debt), requiring additional measures such as sovereign risk financing to brace against gaps. Here, the exact return period (fiscal gap year) when a fiscal gap would occur is relevant.
2. For certain return periods, such as 100 year events, information on the monetary scale of resources and gaps can be used to devise risk financing instruments.

Figure 16 charts our governments' financial resources to absorb public sector losses in 1 in 100 year event and associated fiscal gaps for the case study countries. The impacts and gaps in Honduras are highest followed by Nicaragua and El Salvador, while Mexico, Costa Rica and Venezuela would not incur gaps according to the data used.

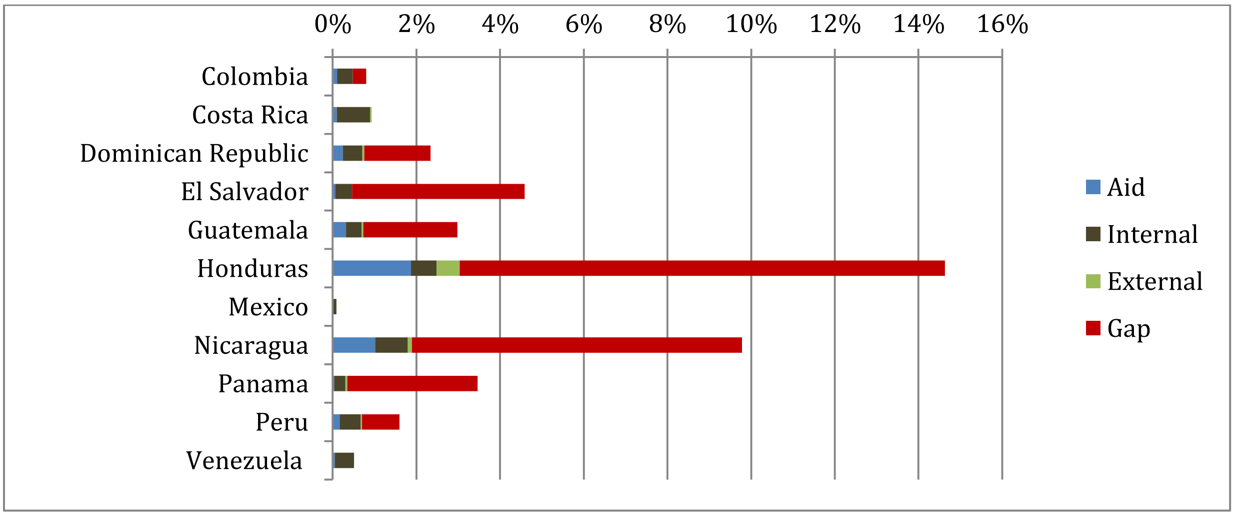


Figure 16 **Governments' financial resources to absorb public sector losses in 1 in 100 year event (indicated in %of GDP)**

Notes:

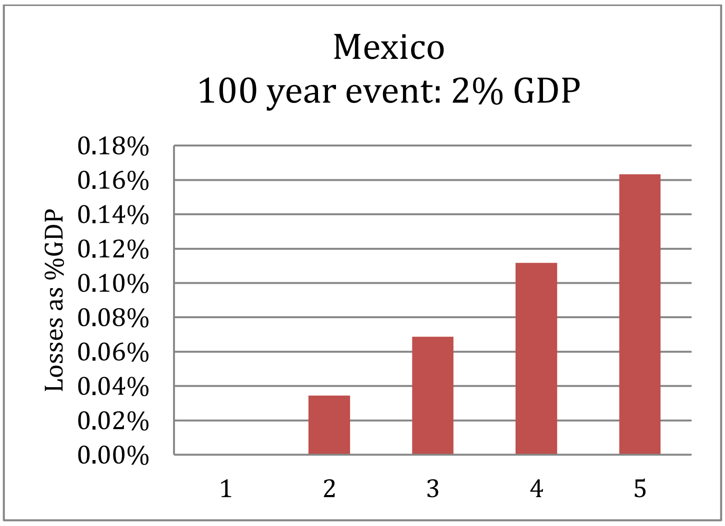
1. For Mexico and Colombia calculations of liabilities are based on bottom up exposure assessment. For other countries, a top down assessment based on key assumptions is used.
2. Internal resources comprise government diversion, reserve funds and risk financing (government insurance, such as for Mexico, or contingent financing such as for Colombia).

External resources comprise new borrowing from development banks and the financial markets, which is limited by debt thresholds.

3. Hazards covered: **Mexico:** earthquakes and storms, **Colombia:** earthquakes and storms, **Honduras:** earthquakes, storms, and drought, **Others (Costa Rica, Dominican Republic, El Salvador, Guatemala, Nicaragua, Panama, Peru, Venezuela):** earthquake, storms, and drought (CIMNE, 2012 data)

4.5 Comparing the effects of a 100 year event across countries

Comprehensive assessments have to be based on an estimate of risk as well as resilience, and we assess the indirect effects of 100 year events in Honduras, Colombia and Mexico. As explained above, Figure 17 shows that countries are exposed to differential direct risk and exhibit differential fiscal resilience, which leads into differential indirect risk.



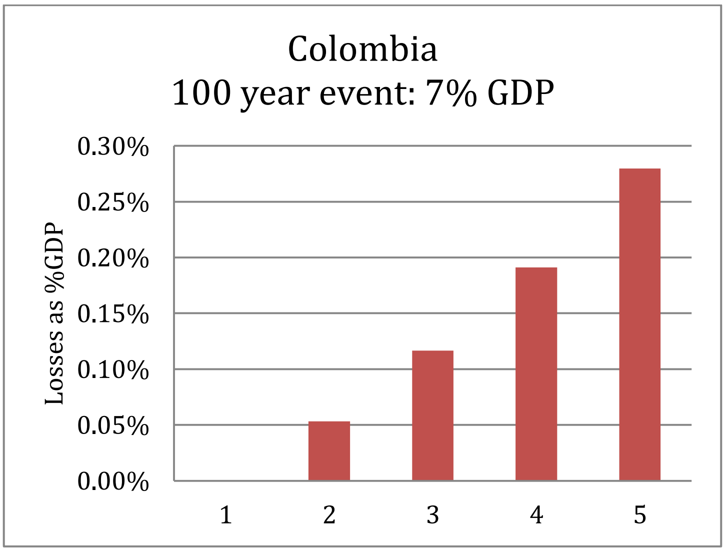


Figure 17 **Simulated indirect GDP effects after 100 year events in Honduras, Mexico and Colombia**

These effects are based on a dynamic model, whereas effects for Honduras shown in figure 5 for Hurricane Mitch (considered approximately a 100 year event) are based on statistical projections of GDP as compared with observed GDP, and effects recorded by the PDNAs. Our modelled effects are lower than both the "on-the-ground" and projected impacts, suggesting that these are conservative effects and other effects play a role (such as effects due to business interruptions).

5 Risk financing: Planning for and pooling of disaster risk

We now turn to examining the case for risk financing and pooling generally as well as for the Central American countries.

5.1 Rationale for public sector financial disaster risk management

Should governments insure or purchase alternative risk financing instruments to protect themselves from catastrophic losses? According to an early theorem by Arrow and Lind (1970) governments should not insure if they are not averse to risks, i.e. if financial risks faced by the government can be absorbed without major difficulty. In theory, thus, governments are not advised to incur the extra costs of transferring their disaster risks if they carry a large portfolio of independent assets and/or they can spread the losses of the disaster over a large population. Because of their ability to spread and diversify risks, Priest (1996) refers to governments as "the most effective insurance instrument of society." Furthermore, the extra costs of insurance can be significant; for example Froot (2001) reports cost up to seven times greater than the expected loss, due to high transaction costs, uncertainties inherent in risk assessment, the limited size of risk transfer markets and the large volatility of losses.

The case against sovereign insurance, however, may not hold for highly exposed developing country governments, especially those that are not sufficiently diversified or cannot spread losses over the tax-paying public. In these cases governments may justifiably act as risk-averse agents. This means that the Arrow-Lind theorem may not apply to governments of countries that have:

- high natural hazard exposure;
- economic activity clustered in a limited number of areas with key public infrastructure exposed to natural hazards; and
- constraints on tax revenue and domestic savings, shallow financial markets, and high indebtedness with little access to external finance (Mechler, 2004).

These conditions are fundamental to determining the financial vulnerability of a state. Governments are financially vulnerable to disasters if they cannot access sufficient funding after a disaster to cover their liabilities with regard to reconstructing public infrastructure and providing assistance to households and businesses. Such a *fiscal gap* is a useful measure of sovereign financial vulnerability. The repercussions of a fiscal gap can be substantial. The inability of a government to repair infrastructure in a timely manner and provide adequate support to low-income households can result in adverse long-term socio-economic impacts. As a case in point Honduras experienced extreme difficulties in repairing public infrastructure and assisting the recovery of the private sector following Hurricane Mitch in 1998. Five years after Mitch's devastation the GDP of Honduras was 6% below pre-disaster projections.[1] In considering whether Honduras and other highly exposed countries should protect themselves against fiscal gaps and associated long-term negative consequences, it is important to keep in mind that risk management measures have associated opportunity costs, which means that they can reduce GDP by diverting financial resources from other public sector objectives, such as undertaking social or infrastructure investments.

5.1 Risk financing options for reducing financial vulnerability

Governments can choose among a variety of traditional and novel pre-disaster risk financing instruments for reducing their financial vulnerability. The most common are discussed below:

- A *reserve fund* holds liquid capital to be used in the event of a disaster. Ideally, the fund accumulates in years without catastrophes; however, from experience there is

[1]Own calculations.

considerable political risk of fund diversions to other pressing government needs, especially after long periods without serious disaster incidence.

- *Insurance and other forms of risk transfer* provide indemnification against losses in exchange for a payment. The most common form of risk transfer is insurance or reinsurance. Insurance is an important pre-disaster, risk-transfer institution in that it distributes disaster losses among a pool of at-risk households, businesses and/or governments and to the reinsurance markets. With primary and re-insurance markets attracting capital from international investors, insurance has become an instrument for transferring disaster risks over the globe. In the early 1990s large losses from U.S. catastrophes strained the capacity of the reinsurance markets and raised the price of reinsurance. This insurance crisis led to the development of new financial instruments to transfer catastrophe risk exposures, including *catastrophe bonds*, but also to other types of index-based securities that are traded on the equity markets. A catastrophe bond (cat bond) is an instrument whereby the investor receives an above-market return when a specific catastrophe does not occur (e.g. an earthquake of magnitude 7.0 or greater), but shares the insurer's or government's losses by sacrificing interest or principal following the event.

- *Contingent credit* arrangements do not transfer risk spatially, but spread risk intertemporally. In exchange for an annual fee, the risk cedent has access to a pre-specified post-event loan that is repaid at contractually fixed conditions. In the case of sovereign risk financing, international finance institutions offer such instruments. Contingent credit options are commonly grouped under alternative risk-transfer instruments.

Due to the extreme nature of the losses and the substantial costs involved in such transactions, disaster insurance and other risk financing instruments generally absorb only specified *layers* of risk, defined by an attachment and exit point (with the lower and upper limits based on the recurrency period of the events). Low layers of risk, for which the risk cedent is able to raise sufficient funds for financing the losses, will typically be retained. Extreme layers of risk will also not be transferred to other agents because of the high and exponentially increasing costs of transfer one important factor being the uncertainty associated with extreme losses, which necessitate large sums of backup capital "reserved" by the agent accepting the risks in order to fulfill its obligation in case of an event.

An example of a layered risk-transfer portfolio is illustrated in figure 18 for the CCRIF. In this case, the lower threshold (attachment point) is the 100-year event (an event with an annual probability of less or equal to one percent) with losses of $1 billion. The upper threshold (exit point) is the 200-year event with losses of $2 billion. The lower threshold is determined by the government's fiscal vulnerability since it specifies the disaster risk for which the government is in need of additional financial resources for protecting its portfolio of public assets and providing emergency response and relief.

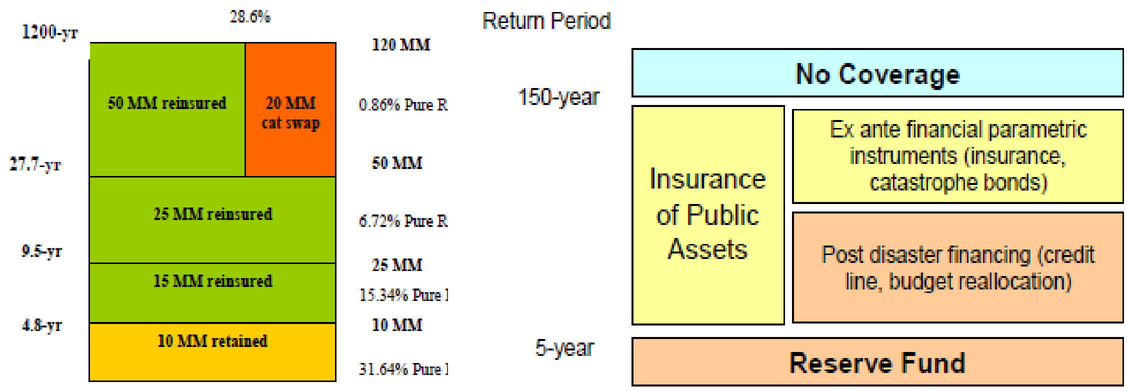


Figure 18 **Concept of risk layering and the Caribbean Catastrophe Risk Insurance facility**
Source: Cummins and Mahul, 2009

5.2 Pooling risk across Central America: the RIFCA

Since 1975, disasters in Central America & the Caribbean have on average affected 4.7 million people annually, causing 5,300 deaths and USD 3.3 billion in physical damages per year (EM-DAT, 2013). As Catastrophe Insurance Pools can help countries establish regional and national vehicles to pool risks and access international catastrophe reinsurance markets on competitive terms, the Inter-American Development Bank (IADB) and Swiss Re established an insurance mechanism (the Regional Insurance facility for Central America RIFCA) for countries in Central America and the Dominican Republic in order to mitigate economic effects of natural disasters in the previously mentioned countries via the use of a two-tiered mechanism for covering disaster damages.

Contingent credit provided by IADB allows for up to USD 100 million in financing, with the ability to obtain insurance for amounts higher than that covered by credits. Sovereign countries are able to obtain coverage either singly or jointly via collective agreements with other nations in the pool. Both mechanisms are designed to be parametric, with payments based on an estimate of population affected by a disaster based on population and event location and intensity data, reducing transaction costs involved and allowing for rapid access to post-disaster funding.

The Dominican Republic was the first country to participate in the scheme, taking on USD 50 million in contingent credits for both earthquakes and hurricanes, beginning in 2012, with further steps to be taken in the future by other nations in the pool.

Under the Regional insurance facility for Central America (RIFCA) the Dominican Republic, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama are now planning to jointly pool and finance their risks. RIFCA has a decentralized structure in which each participating country is a sole owner of a captive but shares administration services with other RIFCA participants. Countries individually transfer risk to the international reinsurance and capital markets, although countries are able to enter into collective arrangements that would enable them to jointly place reinsurance in the international market. Each government has established a captive insurance company, itself supported by the international reinsurance and capital markets:

- Each captive issues to its national government a single parametric natural catastrophe cover, usually for earthquakes and hurricanes;
- The government pays a premium for this coverage, typically USD 2.5M for a USD 50M limit;
- The scheme pays in case of natural disaster affecting more than 5% of the population.

The RIFCA will provide participating governments with quick access to insurance proceeds following a disaster. This approach allows them to plan more effectively and reduces the need for costly post-disaster debt financing.

5.3 Results for RIFCA countries and other Latin America countries

We now calculate risks and fiscal gaps in order to understand whether it is rational to think about risk financing for the RIFCA countries. Fiscal gaps are calculated as follows for key countries, for which detailed risk information was available, including the RIFCA countries (table 3, figure 19).

Table 3 Modelled fiscal gaps

Country	Fiscal gap starts at year event of	In RIFCA pool
Colombia	43	
Costa Rica	66	x
Dominican Republic	37	
El Salvador	60*	x
Guatemala	7	x
Honduras	33	x
Mexico	>500	
Nicaragua	10	x
Panama	106	x
Peru	13	
Venezuela	>500	

*Risk information based on IIASA calculations

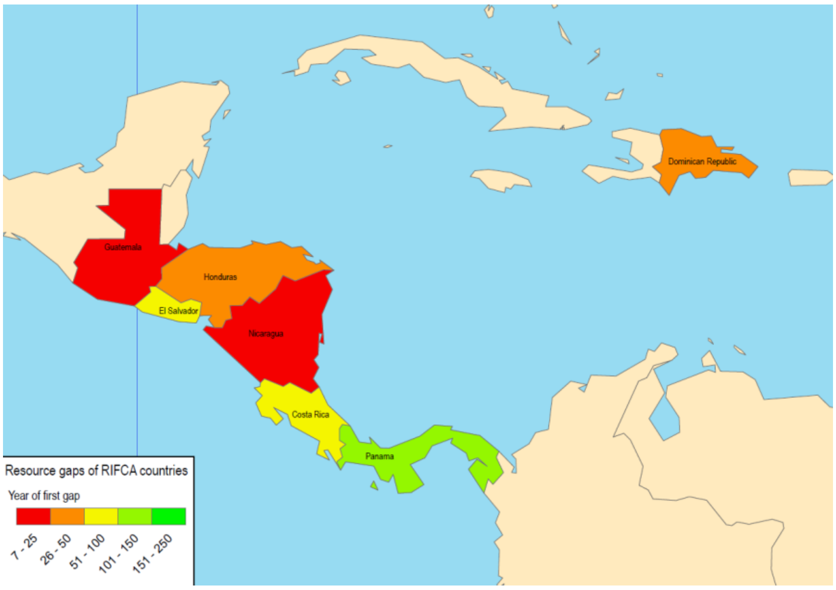


Figure 19 Fiscal gaps for RIFCA countries

The estimates suggest Central American countries participating in the Regional Insurance Facility for Central America (RIFCA) are differentially fiscally vulnerable and indeed an insurance-related mechanism is well worth considering. Some countries exhibit gaps already at 10 year events (Nicaragua), for others (Panama) a lack of financing would start roughly at a 100 year event. Such calculations are input to deliberations regarding strategies to employ. The decision problem regarding whether and how to use risk financing cannot be easily reduced to an optimization problem, but there are many perspectives to be taken into account, such as the costs of the instruments, the benefits in terms of cover provide, the incentives for mitigation and any risks associated with these tools. Table 4 outlines the characteristics, and costs and benefits of the three broad types of ex ante risk financing instruments.

Table 4 Costs and benefits of ex-ante financing instruments

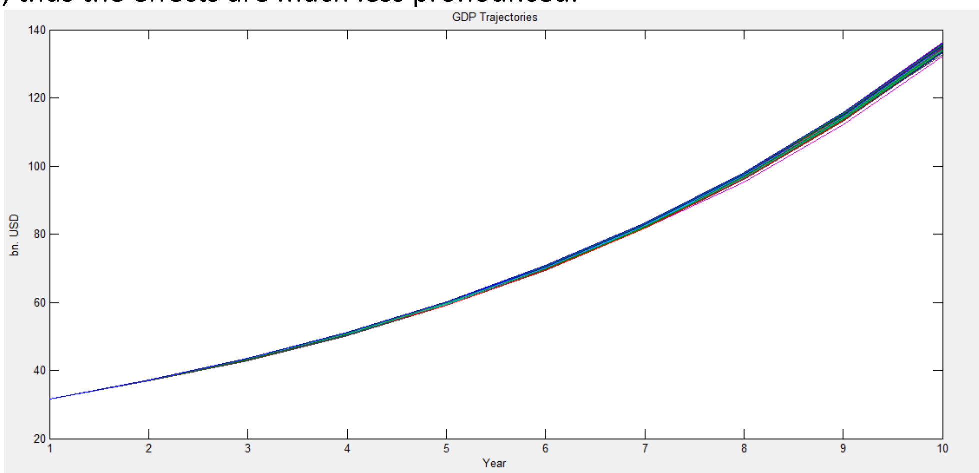
	Risk transfer e.g. insurance	Reserve fund	Contingent credit
Cost before event	Premium times number of years before event	Opportunity cost of the alternative uses for the accumulated fund	Holding fee times number of years before event
Benefit after event	• Damage indemnification for elements insured • Increased capital inflows from abroad	• Reserve funds and interest available • Funds will not be lost in case of no event	• Funds available immediately • Increased capital inflows from abroad
Cost after event	None	None to the extent that enough reserve has been accumulated	• Additional debt service. • Reduction in ability to take out future debt
Incentive for mitigation?	Yes	Only if risk is known	No
Risks	Theoretical risk of (re)insurer going bankrupt	• Risk of depletion before disaster due to other needs. • Risk of insufficient funds.	• Theoretical risk of financial entity going bankrupt

Source: Mechler, 2004

In the case of financial risk management, there are a variety of issues to be considered, including issues associated with (i) data, (ii), methodology, (iii) modelling, and (iv) the difficulties to put the results in a broader context in the decision-making process. While (i) and (iii) are more technical questions from a policy perspective, (ii) and (iv) are most important. If decision makers understand the methodology behind the results, it is easier to grasp the complex relationships between the various variables which constitute vulnerability and risk, while at the same time specific preferences can be incorporated into the whole risk-management process. From the authors' experience, policymakers expect a methodology that is based on sound scientific understanding and allows for interactions and stakeholder input. Furthermore, results have to be shown in such a way that they are easy to understand while complex enough to incorporate the main characteristics of the risk and vulnerability under evaluation. The core idea of the methodological approach for CatSim was that variables used to assess fiscal vulnerability can be operationalized in such a way that they are directly linked to a catastrophe (risk-based) model. Graphical user interfaces (stand-alone application software) interactively guide the user through the methodology and outline crucial variables, parameters and results of the simulation, which can be modified to assess different kinds of strategies. The underlying philosophy is that policy makers actively assess ideas and strategies rather than being served with results. The methodology and user interfaces are directly connected, so that each step of the methodology is also represented by user interfaces with the corresponding variables and results.

5.4 Stylized analysis of the effects of risk pooling

In order to illustrate the effect of pooling in catastrophic risk-management we consider a new artificial region which consists of the members of the RIFCA pool. Although this pool is limited to the mutual insurance up to 50 million USD, we tested the effect of a complete risk and financial pool of the RIFCA member countries using CATSIM. We study the costs and benefits of a complete risk pooling. In Figure 20, GDP trajectories for the pool of RIFCA countries are outlined. Due to the pooling effect, the economic resilience of the pool is largely higher than for each country in the pool separately (for example, Honduras – see Figure 2), thus the effects are much less pronounced.



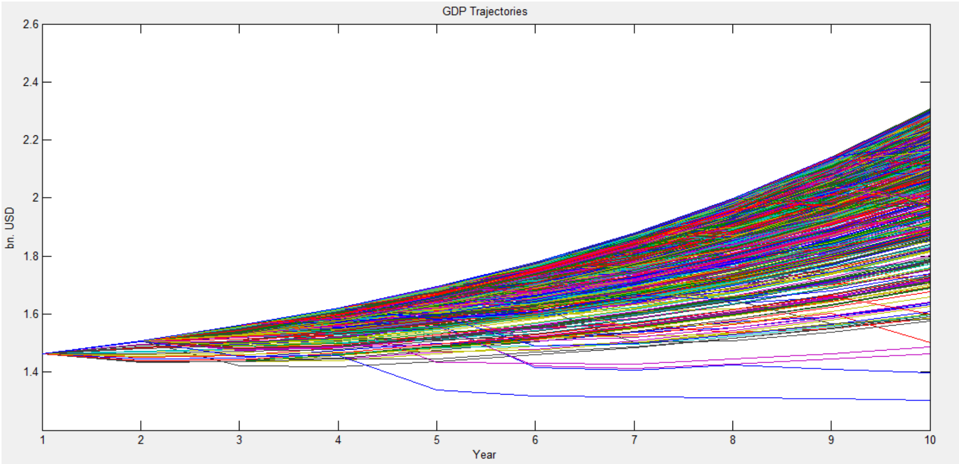


Figure 20 Potential GDP impacts to pool of RIFCA Member countries due to disaster risk

To measure the future risk for Honduras and for the pool of RIFCA countries we estimated the coefficient of variation (standard deviation divided by the mean) of the probabilistically projected future GDP paths using CATSIM. Figure 21 shows the predicted coefficient of variation for Honduras and for the pool of RIFCA countries from 2013 to 2022.

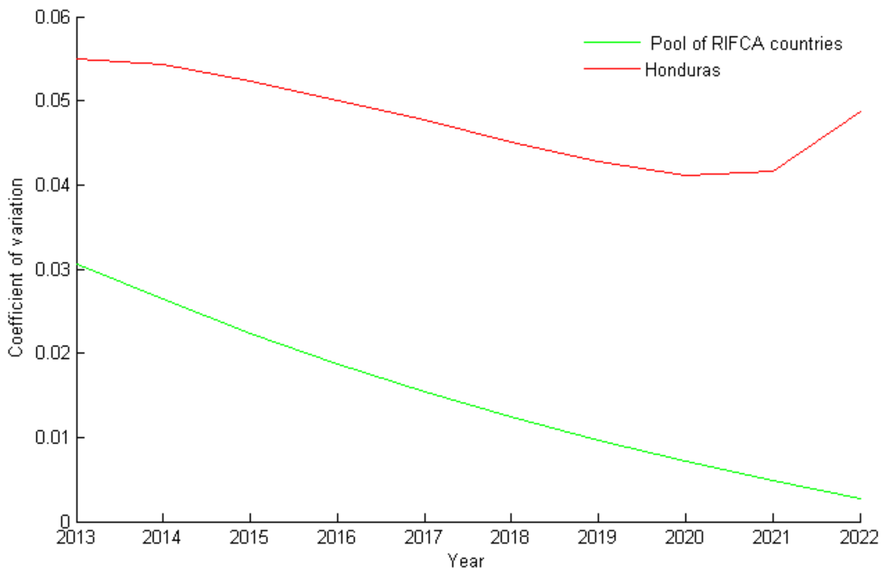


Figure 21 Comparison of future risk for Honduras and for the Rifca pool.

With the coefficient of variation shown, the risk is always distinctively lower for the RIFCA than for Honduras: this illustrates the risk reduction effect by pooling. Low-risk countries are more attractive for investors and allow better planning for the respective governments, while the uncertainty in the future adds extra costs. A high coefficient of variation is a sign of a high financial vulnerability to disasters. It is also remarkable that the pool of RIFCA countries shows a decreasing coefficient of variation over the years indicating that the economic growth leads to less vulnerability, while for Honduras after a few years there is a kink in the curve indicating that at a certain level risks becomes pervasive and increasing.

6 Conclusions: Understanding the developmental and economic risks from natural disasters

Natural disasters can lead to significant aggregate economic effects depending on the size of the potential shock and fiscal and economic resilience. While this is generally understood, there are many questions and gaps in the literature and analyses. Key information gap relate to sound probabilistic information reading disaster risk as well as indirect economic consequences of disaster shocks. The information provided in this report organized around the IIASA CatSim model may contribute to the improvement of our current understanding of the national economic and financial implications of economic risk. The IIASA CatSim model is a framework for assessing the economic consequences arising from disaster risk and building resilience by way of risk management options. It is here used to inform national–level decision-makers on issues pertaining to fiscal risks and options for sharing and spreading this risk.

Based on input received, this background report shows how to address salient question for countries exposed to large disaster risk such as:

1. What are the differential developmental and macroeconomic implications of disaster risk in countries with different risks and fiscal resilience profiles? The report demonstrates that in lower-middle income (Honduras), upper-middle income (Colombia) and OECD (Mexico) countries risks differ substantially, and the confluence of large disaster risk and high fiscal vulnerability, can lead to large macroeconomic risks.

2. What is the basis for inter-country risk pooling given differential direct risk and fiscal vulnerability? The report shows that there is value to pooling risk based as the cost of risk bearing is reduced due to diversifiying risk. Particularly, for the Central American region (Dominican Republic, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama) analysed here, with many countries at high risk, there seem are substantial benefits to pooling risks across countries. Clearly, the benefits depend on the specific arrangements and concrete options, which need close scrutiny, yet was not the purpose here.

As the GAR 2013 strongly works towards developing probabilistic risk information with global resolution, it is hoped that the information provided here may contribute to the improvement of our current understanding of the national economic and financial implications of economic risk and lay the foundations for the implementations of policy options that help building resilience.

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Appendix: Details of the CatSim model

Step 1: Assessment of public sector liabilities

We calculate direct risk (potential damages and their probabilities) accruing to a national government's for disaster events. The calculation is done as a function of hazard, exposure (assets) and the physical vulnerability of assets. We only focus on assets (produced capital), and do not account for the risk to human and environmental capital. We calculate damage distributions in terms of 50, 100, 250 and 500 year events.

In this first CatSim step the risk of direct damages is assessed in terms of the probability of asset damages in the relevant country or region. Consistent with general practice, risk is modelled as a function of hazard (frequency and intensity), the elements exposed to those hazards and their physical vulnerability (Burby, 1991; Swiss Re, 2000). [2] In more detail, **natural *hazards*,** such as hurricanes, or floods, are described by their intensity (e.g. peak flows for floods) and recurrency (such as a 1 in 100 year events, i.e. with a probability of 1%). We focus on sudden-onset climate-related events only such as tropical cyclones, floods and winter storms. Generally, for the sudden-onset events analysts generally equate given damage and risk data with asset damages.[3]

Exposure of elements at risk: From an economic perspective, governments are exposed to natural disaster risk and potential losses due to three functions: (i) the allocation of goods and services (security, education, clean environment, (ii) the provision of support to private households and business in the case of market failure, (iii) and the distribution of income as shown on Figure22 (see Musgrave, 1959).

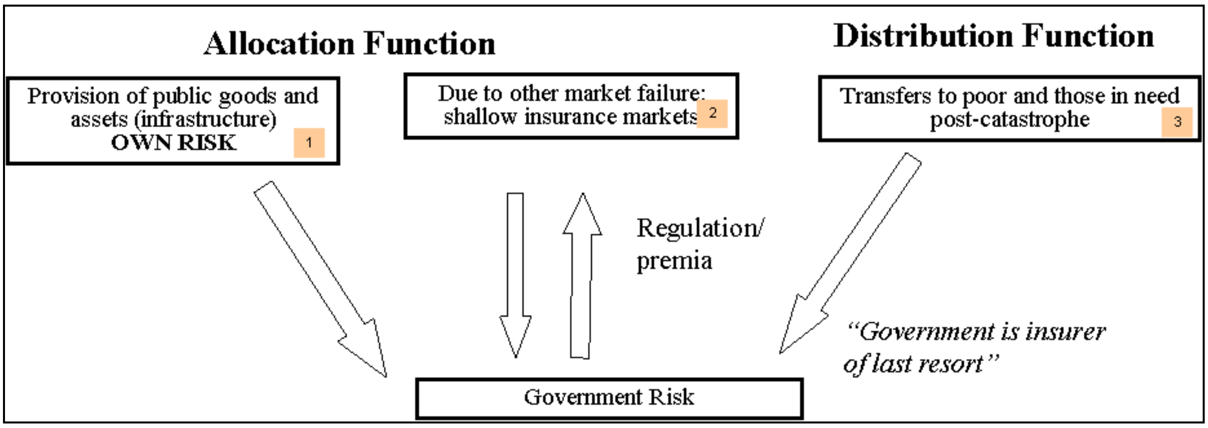

Figure 22 **Sources of government disaster risk**

Total capital stock for each country is taken from Sanderson and Striessnig (2009). These estimates are based on a perpetual inventory method using Penn World tables with data on investments starting in 1900 and assuming annual growth and depreciation of 4 percent. To compute public sector liabilities, due to a lack of globally comparable data, we take the

[2] In the hazards and risk community, "sensitivity" is referred to as "vulnerability", and often exposure is included in the sensitivity component; thus, risk is defined by hazard and vulnerability. In catastrophe models carried out for insurance purposes, the contract specifications of the underwritten and exposed portfolios are added as a fourth component (e.g. Swiss Re, 2000).

[3] An indication that this assumption can be maintained is the fact that loss data are usually relatively quickly available after a catastrophe, which indicates that flow-indirect impacts emanating over months to years, are usually not considered.

following assumptions: (i) Based on World Bank (1994) we use an estimate of 20% of total capital stock as the infrastructure component (category 1 in the chart), and then add another 30% for relief and reconstruction to affected households and business (categories 2 and 3 in the chart). From a normative view, this share a government should be prepared to refinance, can be broadly justified by examining the very limited empirical evidence on actual spending in events (see figure 5).

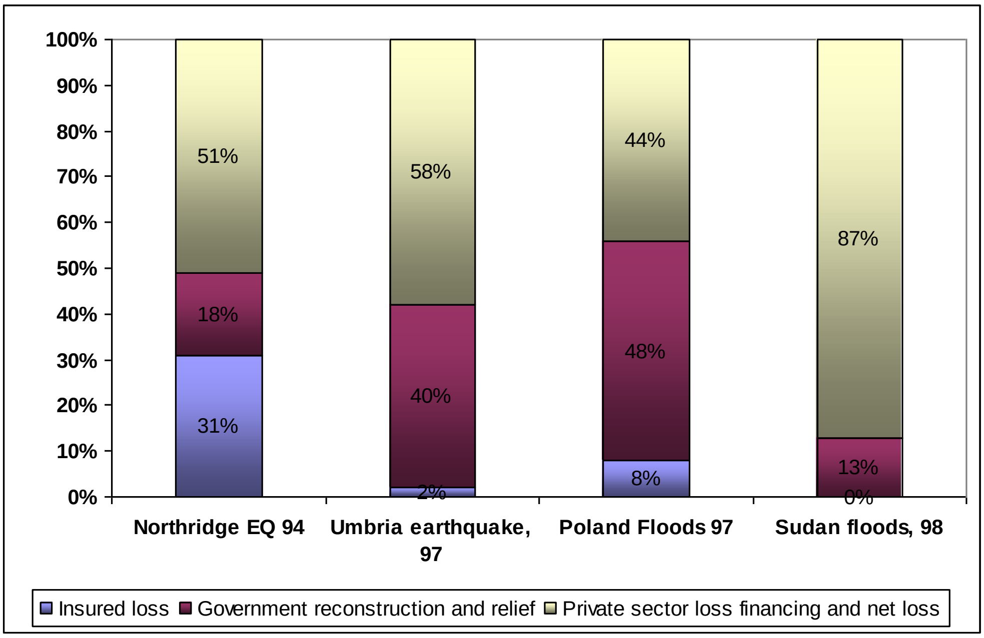

Figure 23 **Insurance and government assistance for selected disasters as a percentage of direct losses (Source: Linnerooth-Bayer and Mechler, 2007)**

Physical Vulnerability describes the degree of damage to the capital stock due to a natural hazard event. The method commonly used here are fragility curves setting the degree of damage in relation to the intensity of a hazard.

Based on data on the return period and damages in percent of capital stock, CatSim generates damage frequency distributions describing the probability of specified damages occurring, such as a 100-year event causing a damage of 200 million USD, a 50-year event causing a 40 million USD loss, and so on.[4] It should be kept in mind that top-down estimates at this broad scale are necessarily rough. Since most disasters are rare events, there is often little in terms of historical data; furthermore it is difficult to include dynamic changes in the system, for example, population and capital movements and climate change. To improve the data information, bottom-up assessments can be undertaken that involve a detailed analysis of the occurrence of hazards in certain areas, the exposed elements and vulnerabilities of structures on a more micro scale level.

As already indicated risk and potential damages are summarized by means of damage-frequency distributions, which relate probabilities of damage to assets destroyed. For example, figure 24 shows a cumulative damage-frequency distribution for flood risk in a hypothetical country. The horizontal axis shows the fraction of capital stock destroyed by a disaster, and the vertical axis represents the probability that damages will *not* exceed a given

[4] It is standard practice to refer to 20-, 50-, 100-, 500- and 1000-year events.

level. For example, with a probability of 0.9 (90%) flood damages will not exceed 250 million LCU; inversely, there is a 0.1 (10% chance) that such a damage and larger will occur.

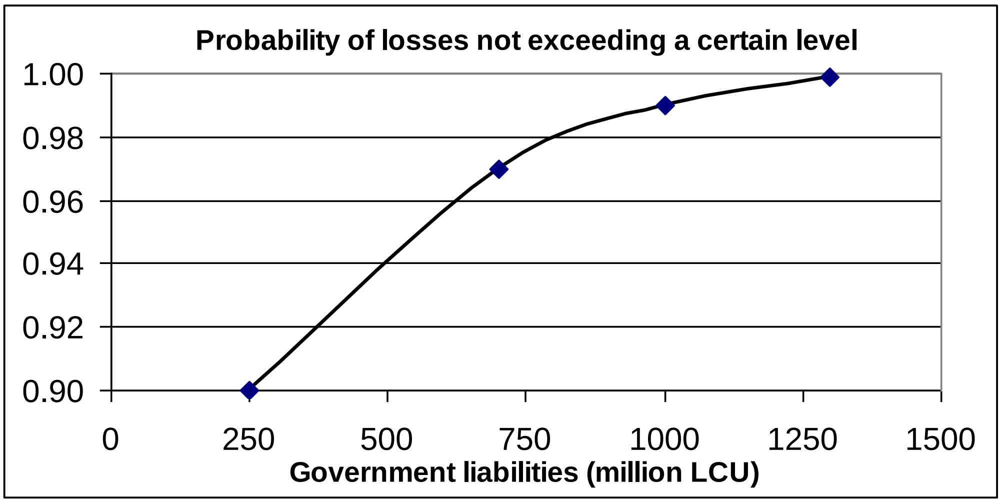

Figure 24 **Risk of damages as measured by a cumulative damage-frequency distribution**

An important summary measure of this distribution is the annual expected damages, or the damages to be expected on average every year. The annual expected damage is the sum of all damages weighted by the probability of occurrence. Graphically, the expected damages are represented by the area above the cumulative distribution curve. However, it has to be kept in mind that disasters are not average events, rather they are extreme events occurring very rarely. Over a specified time period, like 100 years, catastrophes may occur, and the damages suffered over this period will be close to the sum of annual expected damages over these years. Based on available information, potential damages due to earthquake events in terms of percent of capital stock lost can be established for a country, state or region.

Step 2: Estimation of the public sector's financial resilience

Given limited resources to reduce human and economic losses, governments need to be financially resilient, or be able to provide sufficient funds to finance reconstruction of public capital, provide relief to households and support business in their recovery efforts. Sources of funding for reconstruction include aid, budget diversion as well as multilateral and international lending. However, these are not infinite and come at a cost. Based on the information on direct risks to the government portfolio, financial resilience can be evaluated by assessing the government's ability to finance its obligations for the specified disaster scenarios. Financial resilience is directly affected by the general conditions prevailing in an economy, i.e., changes in tax revenue have important implications on a country's financial capacity to deal with disaster losses. The specific question underlying the CatSim tool is whether a government is financially prepared to repair damaged infrastructure and provide adequate relief and support to the private sector for the estimated damages of 10- 50- 100- and 200-year events? For this assessment, it is necessary to examine the government's sources, including sources that will be relied on (probably in an ad hoc manner) after the disaster and sources put into place before the disaster (ex ante financing). These sources are described below (based on Mechler, 2004 and Hochrainer, 2006).

Ex post financing sources

The government can raise funds *after* a disaster by accessing international assistance, diverting funds from other budget items, imposing or raising taxes, taking a credit from the Central Bank (which either prints money or depletes its foreign currency reserves), borrowing by issuing domestic bonds, borrowing from the IFIs and issuing bonds on the international market (Benson, 1997 a,b,c; Fisher and Easterly, 1990). Each of these financing sources can be characterized by costs to the government as well as factors that constrain its availability, which are assessed by this CatSim module (see table 5).

Aid inflows from abroad after a catastrophe include private and public donations from private institutions, government agencies and inter-governmental agencies in the form of relief, technical assistance, grants, commodities and money (Albala-Bertrand 1993). The amount of aid is as much dependent on the event as on the will of the donors to grant assistance. Thus there is considerable uncertainty as regards the amount of aid obtained post-catastrophe necessitating a case by case examination. As discussed, a value of 10.4% of direct damages for this parameter was estimated. It is assumed that all aid inflows will be divided up between the public and the private sector in relation to their share of infrastructure (government) and non-infrastructure (private sector) in total capital stock. As there is uncertainty whether aid will in fact be made available, the availability of aid is assumed to be constrained in three scenarios: 0, 50, 100% made available, i.e. 0% of losses are financed by aid, 5.2% and 10.4%. These scenarios will be looked at in combination with the scenarios on the availability of foreign borrowing as is explained below.

Table 5 Ex Post and ex-ante financing sources for relief and reconstruction

TYPE	SOURCE	CONSIDERED IN MODEL
Ex-post sources		
Decreasing government expenditures	Diversion from budget	x
Raising government revenues	Taxation	-
Deficit financing *Domestic*	Central Bank credit	-
	Foreign reserves	-
	Domestic bonds and credit	X
Deficit financing *External*	Multilateral borrowing	X
	International borrowing	X
	Aid	X
Ex-ante sources		
Reserve funds		X
Insurance		X
Contingent Credit		X

Budget diversion means using funds that were earmarked for other purposes and thus implies foregoing the returns and benefits of these projects. As well, there is often high political cost to diversion when money is taken from ministries. It is assumed that the government is able to divert some funds from government spending to reconstruction activities. In recent research maximum diversion post-disaster for the four Latin American countries Bolivia, Colombia, Dominican Republic and El Salvador was estimated at 5-10%of current expenditure (government spending) (Freeman et al. 2002). For this report, we use an average value of 7.5% will be used for both Honduras and Argentina.

Establishing additional *taxes* after a catastrophe will decrease private savings when consumption is to stay constant and exert additional depressionary effects on the economy. Furthermore, disaster taxes are expensive to administer. For this reason, no additional tax revenue is assumed.

Given a budget deficit, *deficit financing* options are accessing credit from the Central Bank or the private sector (commercial banks and private households), tapping into the foreign reserves of the central bank, obtaining loans from IFIs or selling bonds abroad (Benson 1997c).

Central bank credit is usually granted by selling government bonds to the Central Bank resulting in money creation which is potentially inflationary if money growth is not held in proportion to real GDP growth (Fischer and Easterley, 1990). Using *foreign exchange reserves* of the central bank creates the potential for a balance-of-payment crisis due to the lack of needed reserves for imports. The sources reserves and central bank credit are generally considered to be particularly problematic, e.g. an assessment of a World Bank and IMF team on reconstruction financing options in El Salvador after the earthquakes in 2001 stated:

> Under any monetary system, a country needs to maintain a strong underlying fiscal position and a sound credit policy, with an adequate cushion of net international reserves, to preserve macroeconomic stability. Expanding the money supply or reducing the central bank's net international reserves are never optional sources of financing for reconstruction costs. (IMF and World Bank, 2001).

Central Bank credit and tapping into reserves are used in practice as deficit financing sources, but from a normative planning point of view, they should not be considered in the case study countries in Latin America where inflation and external debt issues are important policy issues (Ferranti, 2000). For these reasons, these two sources will not be considered as viable sources for ex-post catastrophe finance in this report.

Borrowing domestically also incurs costs: domestically, credit may be compressed particularly so in shallow credit markets resulting in a rise of the interest rate and a crowding-out of domestic investment. Borrowing from the private sector via issuing domestic government bonds is another option. However, it is a common characteristic that in developing countries domestic bond or financial markets are rather shallow (Ferranti 2000). We assume 10% additional government borrowing from the private sector, which seems an optimistic assumption given the post disaster crunch and shallow domestic financial markets in most of the disaster vulnerable countries studied.

A major source of a country's ex-post disaster funding is *foreign borrowing*. The importance of (foreign) borrowing for reconstruction is demonstrated by the following statement that also came from the post-earthquake IMF and World Bank mission to El Salvador.

> From the standpoint of macroeconomic policy, the key question is how much and how rapidly can the government afford to borrow to finance the reconstruction costs, while keeping fiscal policy on a sustainable path (IMF and World Bank, 2001).

We consider borrowing to be constrained by the existing country debt. CatSim assumes that the sum of all loans cannot exceed the so-called *credit buffer* for the country. In the Highly

Indebted Poor Countries Initiative (HIPC) the credit buffer is defined as 150% of the typical export value of this country minus the present value of existing loans (HIPC, 2002).

Ex ante financing sources

In addition to accessing ex post sources, a government can arrange for financing before a disaster occurs. Ex ante financing options include reserve funds, traditional insurance instruments (public or private), alternative insurance instruments, such as catastrophe bonds, or arranging a contingent credit. The government can create a reserve fund, which accumulates in years without catastrophes. In the case of an event, the accumulated funds can be used to finance reconstruction and relief. A catastrophe bond (cat bond) is an instrument whereby the investor receives an above-market return when a specific catastrophe does not occur, but shares the insurer's or government's damages by sacrificing interest or principal following the event. Contingent credit arrangements call for the payment of a fee for the option of securing a loan with pre-arranged conditions after a disaster. Insurance and other risk-transfer arrangements provide indemnification against damages in exchange for a premium payment. Risk is transferred from an individual to a (large) pool of risks. These ex-ante options can involve substantial annual payments and opportunity costs; statistically the purchasing government will pay more with a hedging instrument than if it absorbs the damag directly. While a number of countries have reserve funds implemented (albeit generally with low nominal amounts), insurance and contingent credit options are only currently being considered with prime examples being Mexico, Colombia and the countries participating the in the Caribbean pool. Table 6 shows the ex post and ex ante instruments that can be accessed to finance post-disaster needs. Another critical point suggested in this chart is the time dimension, which generally is in favour of ex ante instruments releasing financing rather quickly.

Table 6 Ex-post vs. ex ante financing instruments

	Immediate hours/days	Short term 1-3 months	Medium term 3-9 months	Long term Over 9 months
Financial needs for post disaster operations				
Relief				
Recovery				
Reconstruction				
Financing tools				
Ex-post financing	Budget contingencies	Relief Budget reallocation	Domestic/ external credit	Donor assistance Tax increase
Ex-ante financing	Reserve fund	Parametric RT, Contingent debt	Traditional RT	

Source: Cummins and Mahul, 2009.

Step 3: Assessment of financial vulnerability and the "resource gap"

Using the information on direct risks to the government portfolio and financial resilience, financial vulnerability can be evaluated. We define financial vulnerability as the (probabilistic) availability of government finances for paying for relief and reconstruction. The resource gap is the difference between the cost of a disaster (step 1), and the funds available to the government to rebuild and provide relief and assistance with recovery efforts.[5] The following figure 25 illustrates the calculation of this metric for a hypothetical case.

Given damages due to a certain event, such as the 100 year event (public sector damag of 4,000 local currency units (LCU)), the algorithm evaluates the sources for funding these damages. An implicit ordering of these sources is assumed according to the availability and marginal opportunity costs of the sources: grants from donors and international financial institutions (IFIs) would have the least costs associated as these are donations; thus they would be used first. Second, diversions from the budget could be used, then domestic credit, followed by borrowing from IFIs and the international markets (bonds). While in this illustration a 100 year event could be financed, for a 200 year (public sector damages of 10,000 LCU), there would be lack of (ex-post) sources and consequently a resource gap. Ghesquiere and Mahul (2007) added another important dimension related to the timing of resource flows.

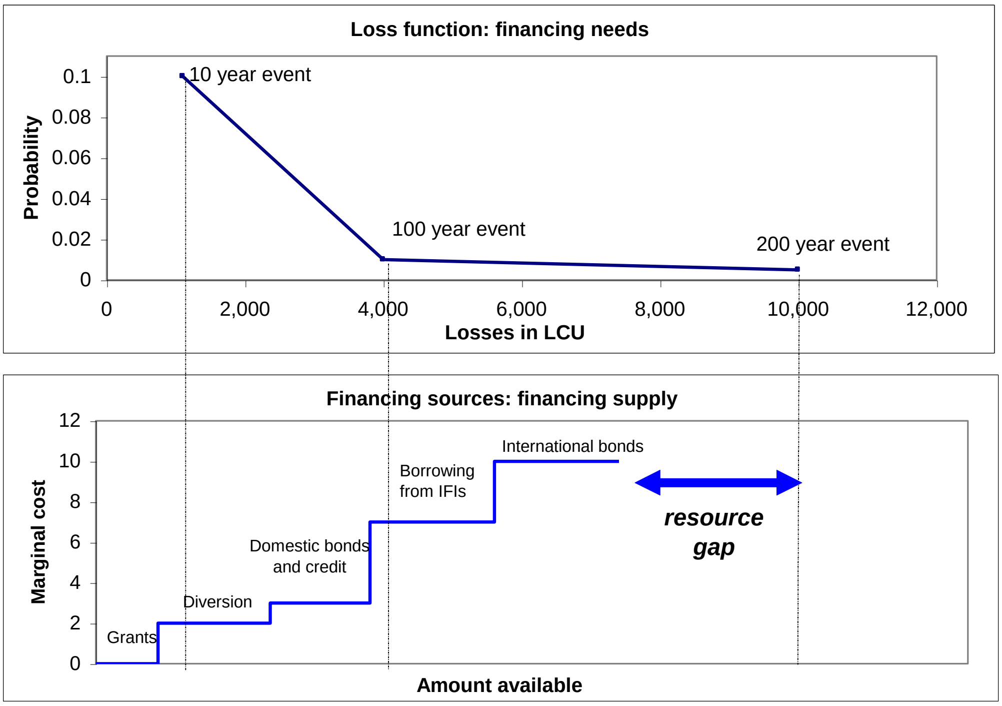

Figure 25 **Illustration for calculating the disaster resource gap**

As illustratively shown on figure 25, while enough funding may be available over time, yet there may be a sporadic resource gap, as generally in the aftermath of a disaster event,

[5] The term resource or financing/resource gap has been heavily used in the economic growth modeling literature as the difference between required investments in an economy and the actual available resources. In this report, this tradition is followed and the financing gap is understood as the lack of financial resources to restore assets lost due to natural disasters and continue with development as planned.

urgent expenditure needs are high and immediately available financial resources often very limited. As an example how the resource gap is calculated here we refer to box 3.

Due to the focus of this work till step 3, we do not go into more detail on steps 4 and 5 in this report but rather present a small overview for the sake of completeness of the CatSim methodology.

Step 4: Illustrating the developmental consequences of a fiscal gap

Fiscal and economic vulnerability can have serious repercussions on the national or regional economy and the population. If the government cannot replace or repair damaged infrastructure, for example, roads and hospitals, nor provide assistance to those in need after a disaster, this will have long-term consequences. The consequences on long-term economic development can be illustrated by the CatSim tool. Generally, economic welfare will be higher on average if the government does not allocate its resources to catastrophe insurance or other risk management, but the economy has fewer extremes and is more stable with public sector insurance. Investing in the risk financing instruments can thus be viewed as a trade-off between economic growth and stability. Budgetary resources allocated to catastrophe reserve funds, insurance and contingent credit (as well as to preventive damage-reduction measures) reduce the potential fiscal gap, and thus can ensure a more stable development path. On the other hand, ex ante financing and prevention measures come at a price in terms of other investments foregone and will inevitably have an adverse impact on the growth path of an economy. The IIASA model assesses this trade-off by comparing the costs of selected ex-ante measures with their benefits in terms of decreasing of the possibility of encountering a fiscal gap.

The macroeconomic module is currently set out as a simple growth framework, as for example standardly used by international finance institutions to design financial and economic assistance plans (as for example the *Revised Minimum Standard Model* (RMSM) used by the World Bank (World Bank, 1997). It is organized around an intertemporal production function and follows the logic:

- Capital stock (private and public), labor and reserve fund are initialized.
- Capital stock can be destroyed by natural disasters. As the occurrence of disasters is modeled stochastically, stocks and flows produced by means of stocks become stochastic variables
- GDP is produced with the inputs labor and capital. Government revenue is a function of GDP.
- There is a fixed government budget to be used for consumption and investment. Reconstruction of destroyed stocks has to be financed from the budget as well. Also debt service payments (e.g. due to incurring new debt for purposes of reconstruction) have to be paid from this budget.
- The investment sub-budget can be used for investing in new capital stock (or maintaining existing) or for protecting these assets by the ex-ante risk management measures mitigation or risk financing. This is the major trade-off.

The purpose of the economic module is not to develop estimates for main economic variables, but to contrast cases with and without additional ex-ante protection against natural disasters and study the effects over a certain time horizon. Currently work is underway to include more behavioral detail, better account for the private sector and its vulnerability and design the model as open-economy.

Step 5: Risk Management StrategiesReducing financial vulnerability and building resilience

Vulnerability and resilience must be understood as dynamic. In contrast to ecological systems, social systems can learn, manage and actively influence their situation. There are two types of policy interventions for reducing public sector financial vulnerability: those that reduce the risks of disasters by reducing exposure and sensitivity and those that build financial resilience of the responding agencies. Based on an assessment of the fiscal gap and potential economic consequences, CatSim illustrates the pros and cons of strategies for building financial resilience using ex-ante financial instruments. Four ex ante financing policy measures are currently considered in the CatSim tool: insurance, contingent credit, reserve funds and cat bonds. Also, one generic option for damage reduction measures has been implemented in the model in order to analyze the linkage with risk financing.