DISASTER RISK MANAGEMENT
WORKING PAPER SERIES NO. 4

Catastrophes and Development

Integrating Natural Catastrophes into Development Planning

Paul K. Freeman
Leslie A. Martin
Reinhard Mechler
Koko Warner
with Peter Hausmann

The World Bank

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Acronyms

ADB	Asian Development Bank
CEP	Centro de Estudios de Producción
CRED	Centre for Research on the Epidemiology of Disasters
DFG	German Research Foundation
ECLAC	Economic Commission for Latin America and the Caribbean
EMDAT	Emergency Events Database
ESDB	Economic and Social Database
GDP	Gross Domestic Product
GIS	Geographical Information System
ICOR	Incremental capital output ratio
IDA	International Development Assistance
IDB	Inter-American Development Bank
IFRC	International Federation of Red Cross and Red Crescent Societies
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
K	Capital stock
OAS	Organization of American States
OECD	Organization for Economic Cooperation and Development
PIT	Prices and Interest Rates worksheet
RMSM	Revised Minimum Standard Model
TRA	Trade worksheet
UNDP	United Nations Development Programme
USD	US dollar
USGS/ESIC	United States Geographical Survey Earth Science Information Center
YSSP	Young Summer Scientist Program

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Acknowledgements

Development efforts are frequently disrupted by natural disasters. These extreme events can cause sharp increases in poverty and slow the pace of social and economic development. Reducing disaster vulnerability may very well be one of the most critical challenges facing development in the 21st Century. To address this challenge, the World Bank's Disaster Management Facility (DMF) and the ProVention Consortium undertook this study with the International Institute for Applied Systems Analysis (IIASA), which explores the potential impact of natural disasters on macroeconomic growth.

The Disaster Management Facility provides proactive leadership in introducing disaster prevention and mitigation practices in development activities at the World Bank. The ProVention Consortium is an international coalition of public, private, non-governmental and academic organizations dedicated to increasing the safety of vulnerable communities and to reducing the impact of disasters in developing countries.

This report summarizes the findings of research conducted over a period of one and half years. The report was prepared by a team of researchers at the International Institute for Applied Systems Analysis (IIASA) with substantive collaboration from Swiss-Reinsurance Company, the World Bank's Disaster Management Facility, its office of Development Economics, and World Bank staff in the country departments for Argentina, Honduras and Nicaragua.

The IIASA team members acknowledge the cooperation of Gordon MacDonald, former director of the International Institute for Applied Systems Analysis (IIASA), who provided the initial momentum for this project and set aside the institutional resources to study these important issues.

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The preparation of this study reflects a very productive partnership established among members of the ProVention Consortium, including IIASA, the DMF, Swiss-Re, the Research and Country Departments at the World Bank, and the international donors who financed the endeavor, including the Department for International Development (DFID) of the Government of the United Kingdom of Great Britain, the Japanese Government through a PHRD grant to the World Bank for the preparation of a disaster mitigation project in Honduras, the Natural Disasters Program at the University of Karlsruhe, and the German Research Foundation (DFG). We acknowledge their important support and their contribution to making this effort possible.

Executive Summary

Often perceived as "acts of God," natural catastrophes have frequently been overlooked in policy planning. On an aggregate level, the consequence of this limited planning is a serious challenge to socioeconomic development as scarce funds are diverted from longer-term development objectives to short-term emergency relief and reconstruction needs. This working paper aims to present an original approach to estimating the macroeconomic and poverty impacts of catastrophes for planning purposes. By incorporating disasters as a component of macroeconomic projections, effective planning options at the country and international level can be more fully explored.

In a series of three country exercises this study incorporates the probability of loss from natural disasters into a flexible macroeconomic modeling platform. In doing so, it first estimates annual expected losses due to natural catastrophes for each country. The results are an annual expected loss of $320 million a year for Argentina (representing 0.025% of capital stock), $64 million a year for Honduras (0.49% of capital stock), and $22 million a year for Nicaragua (0.43% of capital stock).

The country exercises then estimate the macroeconomic impacts of these direct losses. The Argentina example identifies potential sources of post-disaster financing and displays probabilistic projections of the macroeconomic impacts of the diverted funds. The Honduras and Nicaragua examples consider the case in which access to post-disaster financing may be limited. These exercises demonstrate that an inability to finance probabilistic annual losses to capital stock can stagnate expected future economic performance. The Nicaragua analysis extends the Honduras exercise by examining the impact of natural catastrophes and limited post-disaster financing on the poor. The results of the last exercise show that an inability to finance probabilistic annual losses to capital stock can stall or defeat poverty reduction measures. Finally, the study examines how the modeling for each country can be used to assist policy makers interested in exploring alternative funding sources for post-disaster reconstruction, like catastrophe insurance.

Three central messages emerged in the preparation of this study. The first lesson learned is that planning for the impacts of catastrophes is possible. The country examples presented in this report illustrate how these probable losses can be incorporated into development planning. The second lesson is that the ability to finance losses following a catastrophe is crucial to recovery. Hence, planning for catastrophes is also essential. The results of the Honduras and Nicaragua examples reinforce this message. Finally, evaluating the potential benefits of risk transfer alternatives requires a formal model like the one prepared for and described in this study. The paper also discusses the trade-offs involved in the insurance decision process.

The major policy recommendation that emerges from this study is that risk management must be a formal component of development planning for countries with high natural catastrophe exposure. Through planning, countries can reduce some of the negative impacts on development and improve the situation of the poor during and after crises. Such risk management involves three major steps: risk identification, mitigation and financing. The recommendations of this report address each of the steps of the risk management process and are directed both at governments and development agencies.

First, countries must identify potential sources and assess potential costs of natural catastrophe risk. For example, the potential effects of natural catastrophes should be included in infrastructure investment decisions, in Country Assistance Strategies (CAS) of the World Bank, and in the debt repayment projections at the core of Highly Indebted Poor Country (HIPC) proposals. Second, countries must weigh the costs and benefits of mitigation and risk financing measures. The evaluation of risk management measures is particularly important for two areas: planning for the protection of infrastructure and the livelihoods of the poor. Third, the international donor community should provide greater incentives for proactive risk management in countries affected by natural catastrophes. In particular, it should focus on the incentives and support necessary to foster risk identification, mitigation and risk transfer programs.

Chapter 1.

Assessing the Economic Costs of Natural Disasters

The increasing economic losses from extreme events continue to severely affect developing countries. During the past decade, the economic costs of rainstorms, floods, earthquakes, volcanoes, droughts and other extreme events have increased about 14-fold from the decade of the 1950's (Munich Re 2001). The annual losses were about $4 billion in the 1950's and have spiraled to $59 billion over the last 10 years. Approximately one-quarter of those losses were in the developing world (ibid).[1]

These totals are likely to increase substantially in the decades to come. Socio-economic changes worldwide, such as increased concentrations of populations in high-risk areas, will contribute to rising direct losses. In addition, the United Nation's Intergovernmental Panel on Climate Change (IPCC) estimates an increase of one to five degrees centigrade in surface temperature over the next decade. Changes in this range will increase the intensity and frequency of extreme weather events (IPCC 2000a). Whereas currently losses due to extreme weather events average $40 billion annually, a recent report estimates that if predicted increases in surface temperature hold true, losses could exceed $100 billion a year over the next century (Munich Re 1999). While few places in the world will escape climatic disruptions, developing countries are at high risk of adverse consequences from these changes (IPCC 2000).

Many countries in the developing world already face daunting challenges to increase economic growth and decrease poverty. Responding to substantial socioeconomic and climatic changes with its resultant impact on key economic sectors will add to an already difficult burden. Sudden-onset extreme natural hazard events are a chronic problem for a select group of developing countries: 28 have suffered direct losses of more than 1 billion USD from natural catastrophes in the past 20 years.[2]

The most vulnerable countries need to account for the costs of natural catastrophes as a component of overall planning. In creating country-level assistance programs, the international aid and finance community prepares macroeconomic projections and analyses of macroeconomic policies as a component of development strategies. Estimating levels of future growth and identifying the existing and prospective resources required to meet those growth objectives are key to developing economic projections. Historically, estimates have not accounted for potential natural disaster losses. To be meaningful, however, projections must account for items that significantly impact the estimates. As the size of the losses increase, the need to formally include disaster losses in the planning process has been recognized by the World Bank (Gilbert, Kreimer 1999), the United Nations (UNDP 2001), the Inter-American Development Bank (Clarke 2000), and the Organization of American States (Bender 1991).

Three reasons compel the need to incorporate catastrophes into economic projections. First, if disaster impacts are not anticipated, the diversion of scarce financial resources to relief and reconstruction efforts causes high opportunity costs as other projects contributing to economic growth and therefore efforts to reduce poverty cannot continue as planned. Second, the continuing and significant reallocation of resources post-disaster wrecks havoc on the budgetary planning process. The creation of annual budgets is often a complicated, politically difficult process. Shifting resources in response to disaster needs disrupts fragile compromises formed to create initial budgets. For many countries, this shift creates considerable institutional friction (Lewis, Murdock 1999). Third, poorer countries rely on international assistance to pay for a substantial portion of their losses. The resources available to the international development community

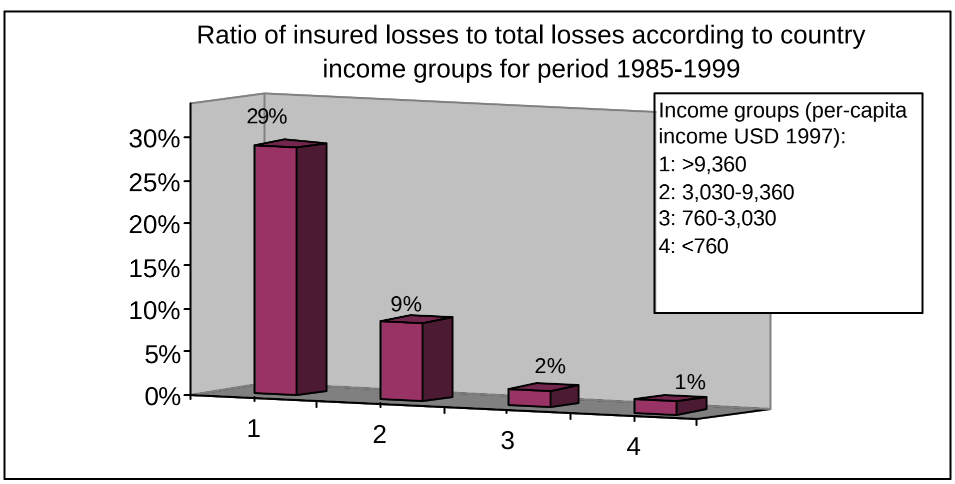
[1] All numbers, unless otherwise indicated, are in current US Dollars (USD).
[2] These are Algeria, Egypt, Mozambique, China, India, Bangladesh, Taiwan, Indonesia, Philippines, Korea, Afghanistan, Armenia, Georgia, Iran, Mongolia, Thailand, Argentina, Brazil, Chile, Colombia, Cuba, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Venezuela (Munich Re 2001).

are limited and have remained stagnant for nearly 10 years (OECD 2001a). As the cost of disasters increase, the demand on the international financial community to provide needed resources has also increased. For example, the Inter-American Development Bank has increased its average annual disaster related spending by a factor of 10 in the past five years in comparison to the previous 15 years (Clarke 2000). In consuming the limited funding available, natural disasters divert resources needed to support longer-term economic and social development objectives. The OAS notes, "funds intended for development are diverted into costly relief efforts. These indirect but profound econom ic effects and their drain on the limited funds now available for new investment compound the tragedy of a disaster in a developing country," (Bender 1991). A step in relieving pressure on domestic fiscal and international aid budgets is to quantify the potential exposure to disasters for the countries they assist. Once quantified, alternatives to plan for the disasters can be developed.

Planning for disasters is not simple: Planning requires both reliable estimates of the probable damages that a disaster may cause and a framework to incorporate catastrophe shocks to capital stock into economic models. Obtaining reliable estimates for future probable damages is challenging. As detailed earlier, the losses from disasters have been increasing at an accelerating rate. To estimate the economic impact of chronic exposure to natural disasters, one must measure both the expected *severity* and the expected *frequency* of catastrophic events. Once the severity and frequency of an event is determined, it must be matched to the assets at risk.

During the past decade, scientific understanding of the causes and consequences of natural catastrophes has dramatically improved. Models to predict the frequency and severity of catastrophe events have been blended with sophisticated techniques to identify assets at risk (Walker 1997). In the industrialized world, a substantial catastrophe risk insurance market has driven catastrophe modeling (Swiss Re 1999). The lack of extensive catastrophe insurance in developing countries means little catastrophe modeling exists for these countries. As shown in Figure 1.1, in the poorest countries, less than 1% of losses from catastrophes are insured in poorer countries.

Figure 1.1: Percentage of Total Losses Insured for Wealthy Versus Poor Countries



Source: MunichRe 2000, topics, p.24-25

Once the exposure of assets is assessed, the challenge remains to incorporate catastrophe shocks to capital stock into appropriate macroeconomic models. The focus of macroeconomics is on the flow of goods and services over time. Disasters, however, first and foremost impact stocks, such as infrastructure or other capital stock.[3] To incorporate catastrophes into economic projections one must understand how stock losses translate to flow responses.

In June 1999, the World Bank, the International Institute of Applied Systems Analysis (IIASA), the and the Swiss Reinsurance Company (Swiss Re) organized a research partnership under the umbrella of the ProVention Consortium to develop a methodology to incorporate future probabilistic losses from natural disasters into macroeconomic projection models. To obtain reliable estimates of the exposure of countries to loss, Swiss Re estimated capital stock at risk for three Latin American countries: Argentina, Honduras, and Nicaragua. IIASA then incorporated the estimates provided by Swiss Re into the World Bank's standard macroeconomic projection model: the Revised Minimum Standard Model (RMSM). The World Bank uses RMSM for undertaking economic projections and evaluation of macroeconomic policies with its client countries. Several outputs were produced from the integration of the hazard exposure data into the macroeconomic model. This report describes those outputs.

1.1 Current Mechanisms for Measuring Damages

There is a growing body of research on the economic impacts of disasters. Many studies of natural disasters discuss three types of damages caused by disasters: direct costs, indirect costs, and secondary effects of disasters. Direct costs relate to the physical damage to capital assets, including buildings, infrastructure, industrial plants, and inventories of finished, intermediate and raw materials destroyed or damaged by the actual impact of a disaster. Direct losses can therefore be roughly equated with stock losses. Indirect costs refer to the damage to the flow of goods and services. Indirect costs include lower output from damaged or destroyed assets and infrastructure and loss of earnings due to damage to marketing infrastructure such as roads and ports. Indirect costs may also include costs such as those associated with the use of more expensive inputs following the destruction of cheaper sources of supply. Secondary or macroeconomic effects concern both the short and long-term impacts of a disaster on aggregate economic variables (ECLAC 1999).[4]

Direct losses

A wealth of information exists about direct losses caused by natural disasters. Swiss Re publishes a series of articles on important insurance issues in its *sigma* series (Swiss Re 2001). Each year, an issue of *sigma* is devoted to describing the insured losses from all large natural disaster events from the prior year. In much the same way, Munich Re publishes an annual report on natural catastrophes for the prior year (Munich Re 2001). Munich Re tracks both insured and economic losses on a worldwide basis. From time to time, Munich Re and Swiss Re publish special reports that discuss specific issues related to natural disasters and often compare disasters to key economic indicators for hazard prone countries. The publications from both of these organizations are valuable primary information sources.

Since 1988, the World Health Organization collaborating Centre for Research on the Epidemiology of Disasters (CRED) has maintained an Emergency Events Database (EM-DAT) at the Université Catholique de Louvain in Brussels, Belgium (CRED 1999). EM-DAT contains essential core data on the occurrence and effects of over 12,000 disasters in the world from 1900 to present. The database contains links to other data sources.[5]

[3] Flows are quantities expressed per unit of time (like GDP and investment). Stocks are accumulations measured at a given point in time (like infrastructure, capital stock, or wealth).
[4] Secondary effects reflect direct and indirect damages as well as relief and reconstruction. Expressing total losses as the sum of direct, indirect, and secondary losses is incorrect as it would involve double-counting.
[5] The database can be accessed at http://www.cred.be/emdat.

Each year, the International Federation of Red Cross and Red Crescent Societies (IFRC) prepares a survey of natural hazard events, the World Disasters Reports (IFRC 2000). The annual surveys are based on information from the CRED database, IFRC experience in providing support to countries and regions severely hurt by natural disasters, and other data sources.

The data on direct losses from natural disasters is important because it provides the foundation for modeling projected future losses, and provides valuable information about the trending of disaster losses. Direct losses, however, do not describe the full costs of natural disasters. A series of case studies extend the analysis of direct losses to a broader discussion of indirect and secondary losses.

Indirect and secondary losses

The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has been studying the impact of catastrophes in Latin America since 1972. ECLAC has conducted about 25 specific country studies on the impact of disasters (ECLAC 1999). The studies quantify the direct losses from catastrophes and then examine the macroeconomic impacts of those events. Based on these studies, ECLAC demonstrates that catastrophes can have serious long-term impacts on some countries, while proving to be a minor economic disruption for others. A key determinant of longer-term consequences of disasters is the socioeconomic condition of the countries at the time disasters strike.

The Overseas Development Institute, with funding from the Department for International Development (DFID), has completed a series of case studies on natural disasters as well. These studies were done by Charlotte Benson and examined the Philippines, Vietnam, and Fiji (Benson 1997a, Benson 1997b, Benson 1997c). With the World Bank's Disaster Management Facility, Benson and Edward Clay have also worked on a case studies in Dominica, Bangladesh, and Malawi (Benson and Clay, forthcoming). The studies focus on the impacts of natural disasters on various sectors of the economy, and the role of government policy in amplifying or exacerbating the impact of catastrophes. By investigating the impacts on various economic sectors, the studies articulate the broad range of impacts caused by disasters. In so doing, the studies recognize the difficulty of analyzing economy-wide flow impacts from disasters. Isolating the impact of catastrophes from other factors is very difficult.

There are also a number of individual country studies from around the world (UNDP 2001). In varying degrees, these studies extend the direct losses from catastrophes to other economic indicators for a country.

Post-disaster recovery manual

As a result of its extensive experience with disaster case studies in Latin America, the Economic Commission for Latin America and the Caribbean (ECLAC) developed a manual to assist countries and international aid agencies to frame immediate post-disaster assistance (ECLAC 1999). The manual directs its user to systematically locate and assess potential direct, indirect, and secondary effects of a disaster in the immediate post-disaster period. This assessment identifies necessary rehabilitation and reconstruction needs and indicates the financing requirements for international cooperation. The methodology describes information to be collected in the post-disaster period. It also explains how to integrate the disaster-specific data with information about pre-existing socioeconomic conditions to estimate requirements for reconstruction. International aid needs to be provided in a way to lessen the impact of catastrophes, and ECLAC's methodology aims to direct aid to accomplish that purpose. In this way, the work is consistent with other research directed at insuring that aid given to alleviate suffering in the immediate aftermath of a disaster does not create long-term development problems (Cuny 1983, Anderson, Woodrow 1989).

Macroeconomic modeling of disasters

The most comprehensive macroeconomic analysis of disasters was done by Albala-Bertrand (Albala-Bertrand 1993). He statistically analyzes the macroeconomic impacts of 28 disasters in 26 countries over a twenty year period, from 1960-79, most of which occurred in developing countries. He then devises a macroeconomic model to explain why key economic variables are not impacted by a disaster. The provision of post-disaster international assistance is a systemic process of response in his model. He concludes, “At a macroeconomic level, disasters rarely affect performance negatively.”

While there is much to discuss in Albala-Bertrand’s analysis, three points are salient for this work. First, like ECLAC and Benson, the analysis examines the key economic indicators that may be affected by disasters. His work provides another approach for designing strategies to flow disasters through an economy. Second, the work links response strategies to the disasters themselves. As discussed earlier, if there is concern on the availability of post-disaster aid, the ability to disaggregate the hoped for response from the disaster event is important. Third, like ECLAC and Benson, he acknowledges that vulnerability to disasters is primarily a socio-economic and political issue.

The ECLAC, Benson, and Albala-Bertrand studies are not economic planning tools. They do not attempt to quantify future exposure to disaster for any country, nor do they show how to incorporate future losses into development strategies.

Disasters and the poor

One area that has received little quantitative analysis is the impact of natural disasters on the poor. People in low-income countries are four times as likely as people in high-income countries to die in a natural disaster (World Bank 2000a). In fact, the poor are particularly hard hit because injury, disability, and loss of life directly affect their main asset: their labor. Disasters also destroy the assets of the poor and disrupt social assistance programs. Long-term disability and destruction of assets can trap families in chronic poverty (World Bank 2000a). The poor are the primary victims of disasters, in part because they are priced out of safer areas and live in disaster vulnerable, often makeshift houses.

Because the poor are not well represented in a country’s formal economy, examining the macroeconomic statistics for a country hides the cost of catastrophes to them. The poorest countries and their weakest socio-political groups are generally the most affected by both direct and indirect losses (Albala-Bertrand 1993). While there is significant anecdotal evidence about the misery disasters cause the poor, little macroeconomic research exists to understand how the impacts of disasters are distributed within various socioeconomic groups.

1.2 Approach of this Study

It is one thing to know that disasters are a critical issue for development. But developing effective disaster policy is limited without a framework for thinking about disasters and a methodology for incorporating disasters into economic projections. This study presents such a framework and methodology. It presents a planning tool that incorporates the probability of loss from natural hazards into a flexible macroeconomic modeling platform. This platform can be used to understand the interrelationship between natural disaster exposure and a country’s macroeconomic performance and to illustrate the policy tradeoffs of alternative options to deal with disasters.

RMSM is the macroeconomic modeling platform used for the specific country analysis by the World Bank. RMSM was developed to quantify policy decisions, analyze the sustainability of policies, and compare the trade-off between policy packages. It is an interactive tool to foster dialogue between the World Bank, other creditors, donors, and borrowers.

The planning tool described in this report varies in several major respects from the other macroeconomic models described earlier. First, the methodology projects future losses instead of relying on historical exposure estimates. It forecasts future losses based on modeling techniques that incorporate changes in the frequency and severity of climate related events and accounts for increases in the concentration of assets in hazard prone regions. Second, rather than presenting historically observed impacts in the aggregate, the model in this report isolates individual impact and response mechanisms. By so doing, it permits a broad range of planning alternatives to be considered and compared. Finally, the methodology employs a fully operational macroeconomic model ready to use for planning purposes.

In this study, the planning model is used to address four critical planning issues. First, knowing the probabilistic direct damages to Argentina from floods, the model uses the estimate of direct damages to capital stock to derive an estimate of the flows required for emergency relief and reconstruction. The first country example identifies that to maintain growth objectives, the additional expenditure and investment requirements must come from private consumption or foreign savings. The model generates probabilistic projections of the macroeconomic impacts of the diverted funds.

The second country example considers the situation in which private consumption and foreign savings are not reliable sources of post-disaster reconstruction and relief funds. It looks at a small country with relatively low domestic resources and high disaster exposure, Honduras. The model forecasts the impact to Honduras assuming no access to foreign assistance to meet reconstruction needs. As expected, both investment and production suffer. An inability to finance probabilistic annual losses to capital stock stagnates expected future economic performance.

The third country example uses the model to better understand the impact of catastrophes on the poor. These impacts are analyzed within the context of Nicaragua. The Nicaragua analysis follows the same methodology as for Honduras, with an additional component. For Nicaragua, the impact of decreased economic growth was converted to real per capita GDP estimates. To translate the macroeconomic estimates to poverty estimates, the analysis supplements RMSM with a household level model. The household model provides data about the existing conditions of the poor. From this analysis, first proportional and then disproportional impacts of the probabilistic catastrophe losses at the country level are allocated to the poor. The results show that the inability to finance probable losses stalls or defeats poverty reduction measures.

Finally, the report analyzes how the modeling can be adopted to analyze the insurance decision-making process. Catastrophe insurance is virtually nonexistent in developing countries. As mentioned earlier, less than 1% of the losses from natural catastrophes are insured in the world's poorest countries. Several proposals exist to develop insurance as an alternative source to post-disaster financing for developing countries. Insurance involves a tradeoff between opportunities for higher but uncertain income levels and lower but safe income. The report discusses how the modeling done for the three country studies helps evaluate the insurance purchase tradeoff.

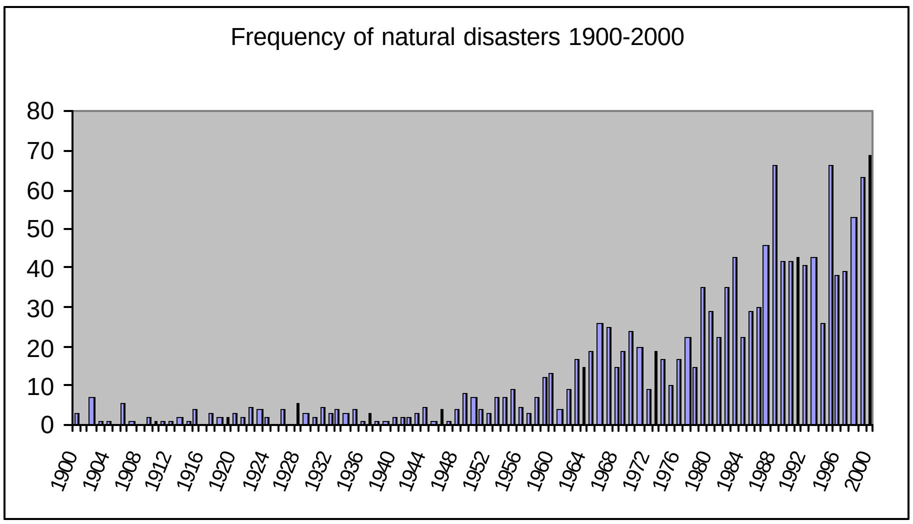
Chapter 2 discusses how Swiss Re created the probability estimates for each of the three countries, how the estimates were integrated into RMSM, and how simulations were developed to generate the described scenarios. The chapter presents the results for the work done specifically on Argentina, Honduras and Nicaragua. Chapter 3 discusses how the modeling can be adopted to address broader policy alternatives, like catastrophe insurance, to deal with the need for post-disaster financing. Chapter 4 concludes and outlines policy recommendations. The Appendices contain the technical detail of the modeling and are a complement to Chapter 2.

Chapter 2.

Country Cases

Latin America and the Caribbean are particularly prone to natural disasters. It is estimated that between 1990 and 1999 about 2.5 million people in the region became homeless due to natural disasters. Over the last thirty years there were on average more than 30 natural disasters per year causing a total of 226,00 fatalities or 7,500 per year. Latin America and the Caribbean rank second only to Asia in terms of disaster frequency. Furthermore, as shown in Figure 2.1, the number of natural disasters is rising. Total direct and indirect losses were estimated at more than $50 billion over this period (Charveriat 2000; ECLAC, IDB 2000).

Figure 2.1: Number of Natural Disasters per Year in Latin America



This chapter describes how to integrate catastrophe exposure into macroeconomic projections via a series of three country exercises: Argentina, Honduras, and Nicaragua. The Argentina exercise demonstrates probabilistically the macroeconomic impacts of funds diverted for post-event reconstruction and relief. The Honduras exercise forecasts the macroeconomic impacts of catastrophes as a function of the country's ability to access foreign funds. The Nicaragua example extends the Honduras approach to project the poverty implications of the macroeconomic impacts.

2.1 Identifying Capital Stock at Risk

Planning for natural catastrophes requires first and foremost an evaluation of capital stock at risk. Catastrophe exposure is calculated by combining natural hazard impacts with the distribution of a country's physical assets. Appendix A describes in detail the methodology used to produce the following catastrophe exposure estimates.

Capital stock at risk in Argentina

The most serious natural catastrophe risk in Argentina is flood risk. This risk is concentrated in the river regions in the north-eastern and central parts of the country: Great La Plata Basin with the main feeder rivers Rio Parana and Rio Uruguay. The affected areas are shown in Figures 2.2 to 2.5. Especially in the plains, large areas along the river courses are at high risk of flooding, including riverside areas near large cities such as Santa Fe, Resistencia, and the outskirts of Buenos Aires. The main loss potential can be found along the Parana.

Figures 2.2-2.5 display the areas at risk due to 10-, 1000-, and 10,000-year flood events.[6] These figures display the surface area affected by maximum credible events with a given return period. The return period is the inverse of the expected frequency of occurrence of an event. The term "10-year flood event" therefore means that, on average, one would expect a flood at least this severe once every ten years.

Important to note in the figures is whether the areas at risk for each return period include or exclude major urban areas. For example, Figure 2.2 shows that Resistencia lies outside of the 10-year flood-affected area, whereas in Figure 2.3 the 1000-year flood clearly inundates Resistencia. The values of capital stock located in Resistencia would therefore be included in the 1000-year risk scenario but ignored for the 10-year risk scenario.

[6] These return periods were chosen on the basis of data availability.

Figure 2.2: Areas at Risk Due to 1 in 10 Year Flooding of Panama and Paraguay Rivers

Figure 2.3: Areas at Risk Due to 1 in 1000 Year Flooding of Panama and Paraguay Rivers

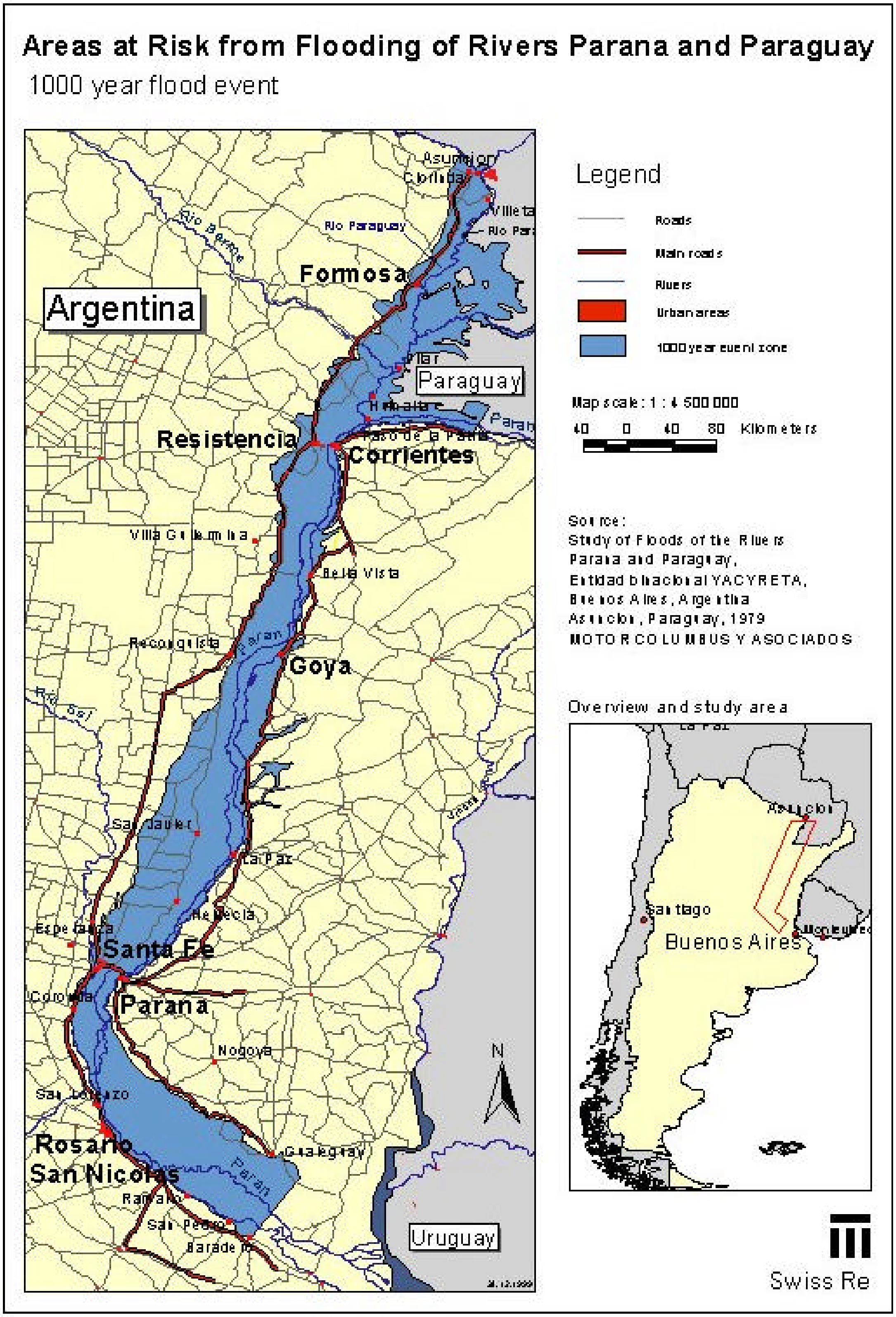
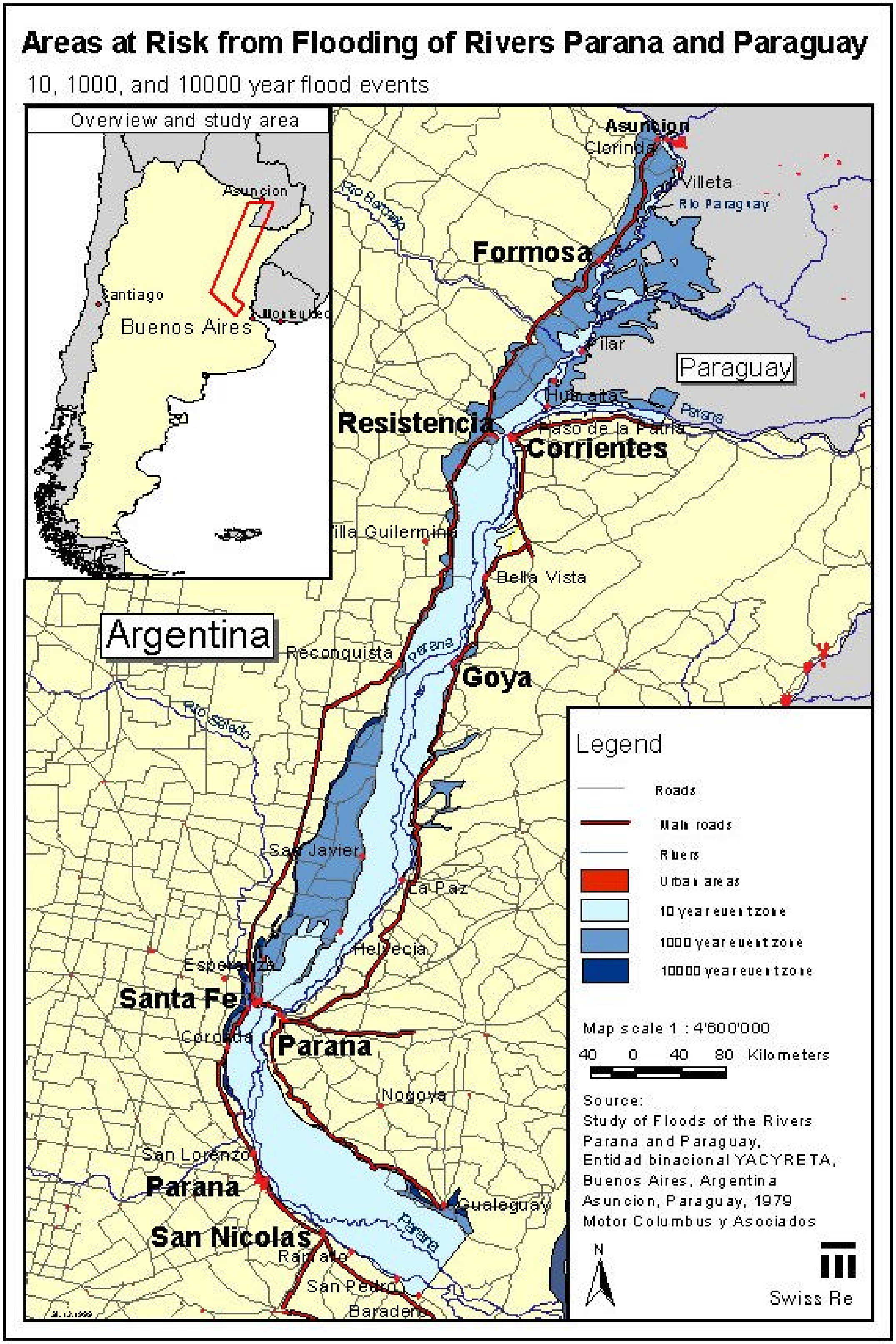


Figure 2.4: Areas at Risk Due to 1 in 10,000 Year Flooding of Panama and Paraguay Rivers

Figure 2.5: Summary of Flood Risk for Panama and Paraguay Rivers



Combining the hazard maps shown in Figures 2.2-2.5 with the distribution of assets determines flood risk in Argentina. Table 2.1 estimates the percentage of capital stock at risk from defined events.

Table 2.1: Expected Losses Due to Flooding in Argentina

Argentina Flood	
	% of capital stock destroyed
10-year loss	**0.10%**
100-year loss	**0.45%**
1000-year loss	**0.60%**
Annual Expected Loss for events > 10-year loss	**0.025%**

Appendix B details the process of deriving a probability distribution from the loss estimates and calculating the distribution's annual expected loss. Table 2.1 shows that the annual expected loss for Argentina is calculated at 0.025% of capital stock. Given the current estimate of capital stock in Argentina at $1.3 trillion, this annual expected loss represents $320 million. This means that, on average, Argentina will lose $320 million a year in capital stock to floods. Of course, natural catastrophes are not "average" events. Rather, $320 million represents the amount required to be set aside each year to cover events when they do occur.

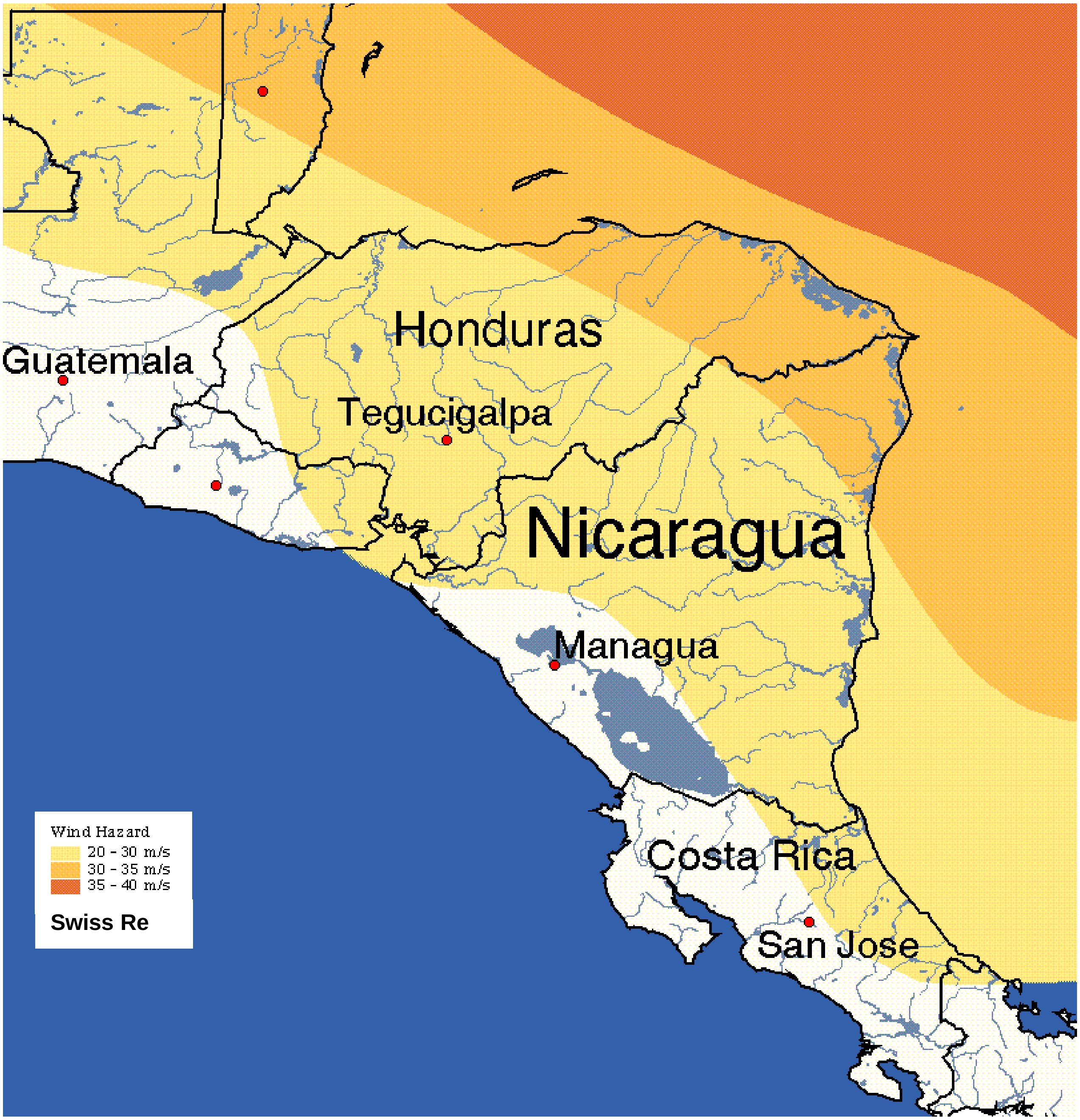
Note from Table 2.1 that in an extreme case—0.1% of the time—losses exceed 0.60% of capital stock. This extreme loss translates to a direct damage of almost $8 billion.

Capital stock at risk in Honduras

The major natural hazards impacting Honduras are hurricane, flood, earthquake and landslide events. The most serious threats are hurricanes and storms that cause floods and landslides along the northern coast, in the Gulf of Fonseca, and Tegucigalpa.

In Honduras, hurricane risk is principally risk of damage due to water rather than wind. Figure 2.6 shows that although water-related risk may be high, wind-related tropical cyclone hazard is low for Honduras. One can see in Figure 2.6 that most of Honduras is affected by a 50-year peak gust wind speed of 30-35 m/s. This range hardly falls within the lowest category hurricane on the Saffir Simpson scale, for which the low-end cut-off is 33 m/s winds (Meyer 1997). Figure 2.6 does show slightly higher wind speeds (still category 1 on the Saffir Simpson scale) for the Mosquitia region on the eastern Atlantic coast, but this area is scarcely populated and has very low levels of capital stock investment.

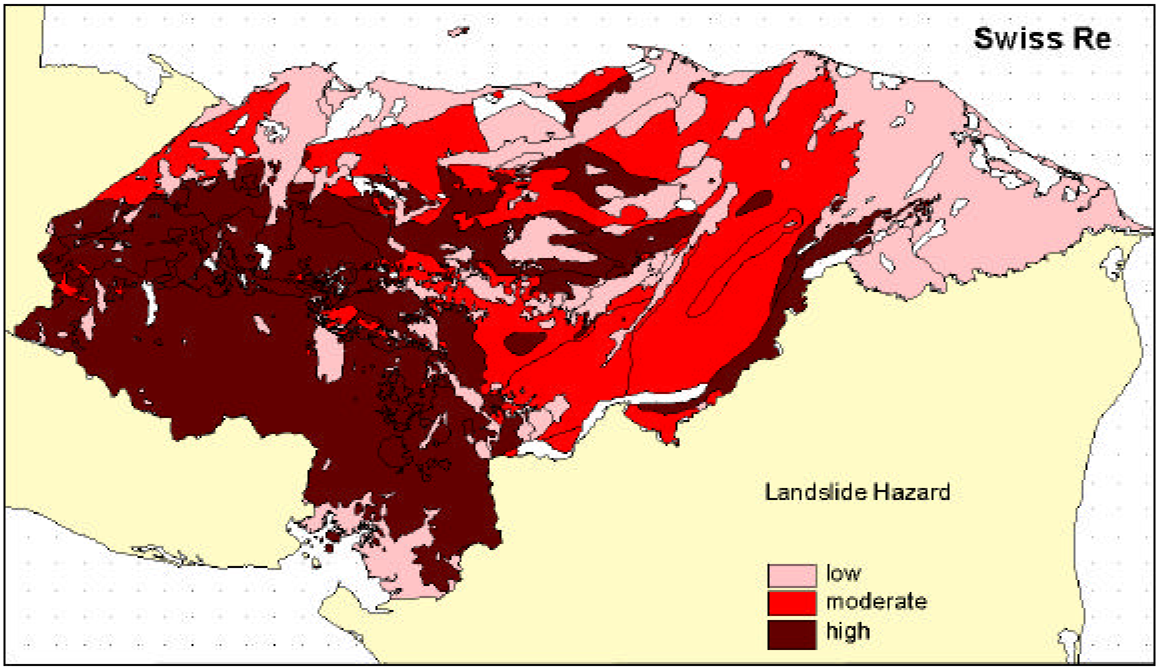
Figure 2.6: Wind Hazard in Central America



Flooding is most violent in the narrow valleys of the interior part of Honduras, however the most extensive floods take place on the coastal plains. The floods are highly correlated with landslides and erosion. Huge volumes of debris are usually transported and deposited in such events.

Figure 2.7 shows landslide risk is very high, especially in the western parts of the country.

Figure 2.7: Landslide Risk in Honduras (Source: USGS)



Landslides can also be triggered by earthquakes. Honduras has a moderate exposure to earthquake risk, as shown in Figure 2.8.

Figure 2.8: Seismic Hazard in Central Ame rica

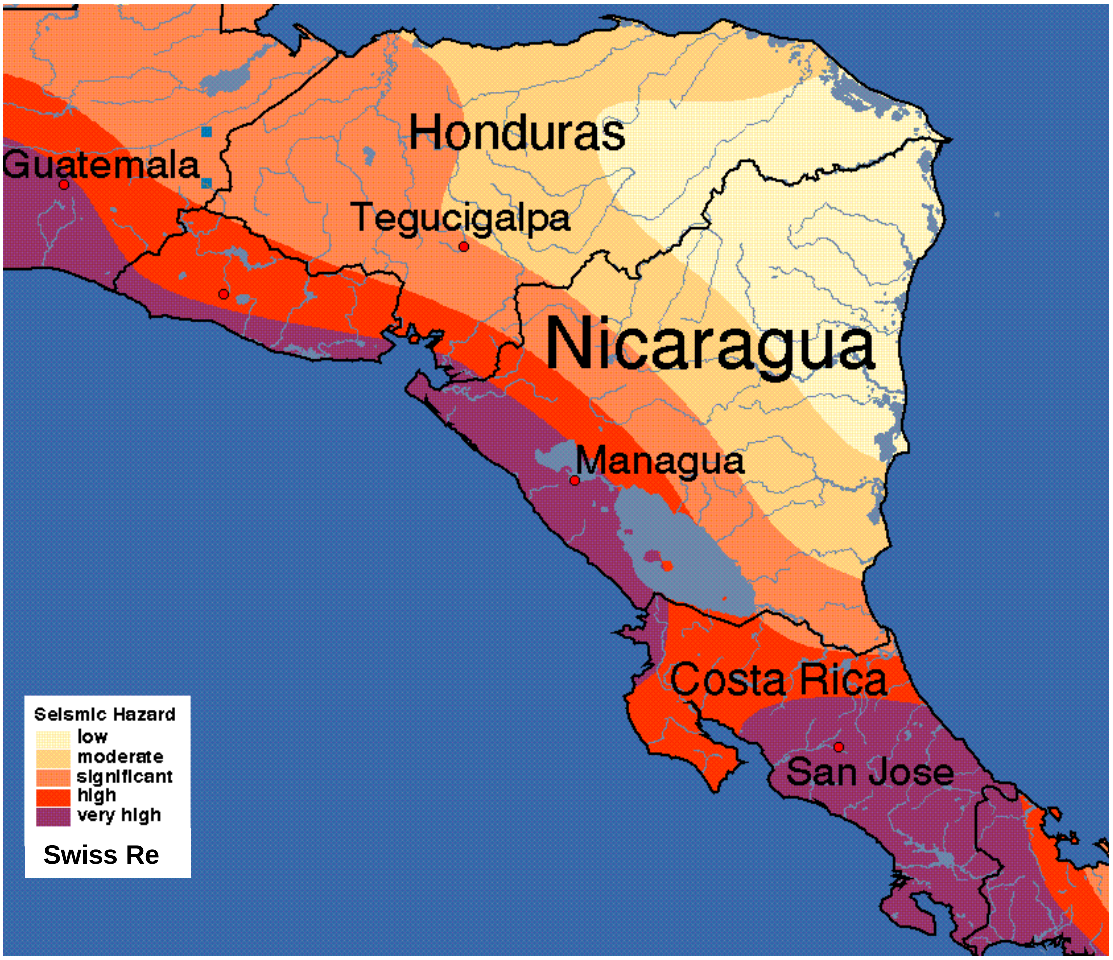


Figure 2.8 shows that earthquake risk increases from east to west. Fortunately, the high risk area is not densely populated. Tegucigalpa, the capital and home to 20% of the country's population, shown to have "significant" earthquake hazard in Figure 2.8 above, is estimated to experience a Modified Mercalli VII earthquake every 280 years. An earthquake of this intensity is defined as causing "negligible" damage in "buildings of good design and construction and "slight to moderate" damage in "well-built ordinary buildings" and "considerable" damage in "poorly built or badly designed buildings and adobe houses." (Gutenberg, Richter 1956) Overall risk is therefore only low to moderate.

Table 2.2 presents the results of the catastrophe exposure analysis for Honduras.

Table 2.2: Expected Losses Due to Natural Disasters in Honduras

Honduras		
	Earthquake (% capital stock lost)	Storm and Flood (% capital stock lost)
10-year loss	**0.1%**	**0.8%**
50-year loss	**0.8%**	**5%**
100-year loss	**1.4%**	**12%**
500-year loss	**4%**	**31%**
Annual Expected Loss for events > 10-year loss	**0.06%**	**0.43%**

As shown in Table 2.2, annual expected loss due to earthquakes in Honduras is calculated at 0.06% of capital stock, estimated at $13 billion, or $8 million in damages. Storm and flood exposure is 0.43% of capital stock, or $56 million. Total annualized hazard exposure is the sum of the separate annualized exposures, or 0.49% of capital stock, representing $64 million per year. Extreme losses with a 0.2% chance of occurring are estimated to potentially exceed $550 million due to earthquakes and $4 billion due to storms.

Capital stock at risk in Nicaragua

Nicaragua is at risk from several types of natural hazards: hurricanes, earthquakes, volcanic eruptions, and flooding. The most vulnerable region in Nicaragua is the Pacific region, which has 60% of the population and most of the country's poor. It is mainly affected by water- and weather-related phenomena. The northern Pacific coast regions of León and Chinandega are constantly vulnerable to flooding, tidal waves and volcanic activity. In April 1992, León was struck by a volcanic eruption from the Cerro Negro, and in September 1992 the most recent tidal wave, between León and Chinandega, resulted in 108 deaths. Floods, earth tremors, landslides and volcanic eruptions affect the capital, Managua, constantly.

Figure 2.8 demonstrates seismic risk for Nicaragua as well as for Honduras. The darkest band representing "very high" hazard risk follows the Pacific coast down from El Salvador and encompasses the capital, Managua. Twenty-five percent of the population of Nicaragua lives in the capital. The last major earthquake, in 1972, claimed about 10,000 victims. Managua is estimated to suffer a Modified Mercalli level VIII earthquake every 200 years. This level earthquake is defined as causing "slight" damage to structures "built especially to withstand earthquakes" and "considerable" damage in "ordinary substantial buildings" and "partial collapse" in others.

In Nicaragua, earthquake risk is compounded with risk of volcanic eruptions. León, Chinandega, Corinto, el Viejo, Masaya and Granada are the cities historically most affected by volcanic activity. Figure 2.9 demonstrates the chain of volcanoes and historical earthquake events along the Pacific Coast of Nicaragua.

Figure 2.9: Epicenters of Past Earthquakes and Volcanoes

The areas around Lake Managua of Masaya, Granada, and Rivas are exposed not only to volcanic eruptions but also to frequent hurricanes and landslides. Like Honduras, hurricane risk in Nicaragua is principally risk of damage due to water—not damage due to wind. Figure 2.5 demonstrates that although water-related risk may be high, wind-related tropical cyclone hazard is low in Nicaragua. Yet the regions of Puerto Cabezas and Bluefields on the Atlantic coast suffer regularly from major flooding, hurricanes and tropical storms. The most recent serious disasters were hurricanes Joan (1988), Caesar (1996), and Mitch (1998).

The aggregate results of earthquake and storm and flood exposure in Nicaragua are presented in Table 2.3 below.

Table 2.3: Natural Catastrophe Risk in Nicaragua

Nicaragua		
	Earthquake (% capital stock lost)	Storm and Flood (% capital stock lost)
10-year loss	0.4%	0.8%
50-year loss	2.6%	2.6%
100-year loss	5%	6%
500-year loss	13%	16%
Annual Expected Loss for events > 10-year loss	0.21%	0.22%

As shown in Table 2.3, annual expected loss from earthquakes is calculated at 0.21% of capital stock, or almost $11 million, given a current estimate of capital stock at $5 billion. Storm and flood risk creates an annualized exposure estimate of 0.22%, or exactly $11 million. Total annualized hazard exposure is the sum of the separate annualized exposures, or 0.43% of capital stock, representing $22 million per year. The extremes of the exposure estimated to occur once every 500 years are losses of $660 million due to earthquakes and $788 million due to storms and flood.

Comparing catastrophe exposure

Although the fraction of capital stock at risk in Argentina is significantly lower than in Honduras or Nicaragua, loss estimates are much greater due to the much higher accumulation of capital stock.[7] In terms of relative loss, earthquake risk is more than three times greater in Nicaragua than in Honduras but dollar values associated with that risk are similar because Honduras has 250% more capital stock. Accumulation of capital stock in high risk areas naturally increases the value of capital stock at risk.

It is also important to note that the distribution of losses differs between Argentina, Honduras and Nicaragua. Because of topography and the distribution of values at risk, Argentina is estimated to suffer from frequent moderate events. Honduras and Nicaragua will be subject not only to frequent moderate events but also to infrequent extreme events.

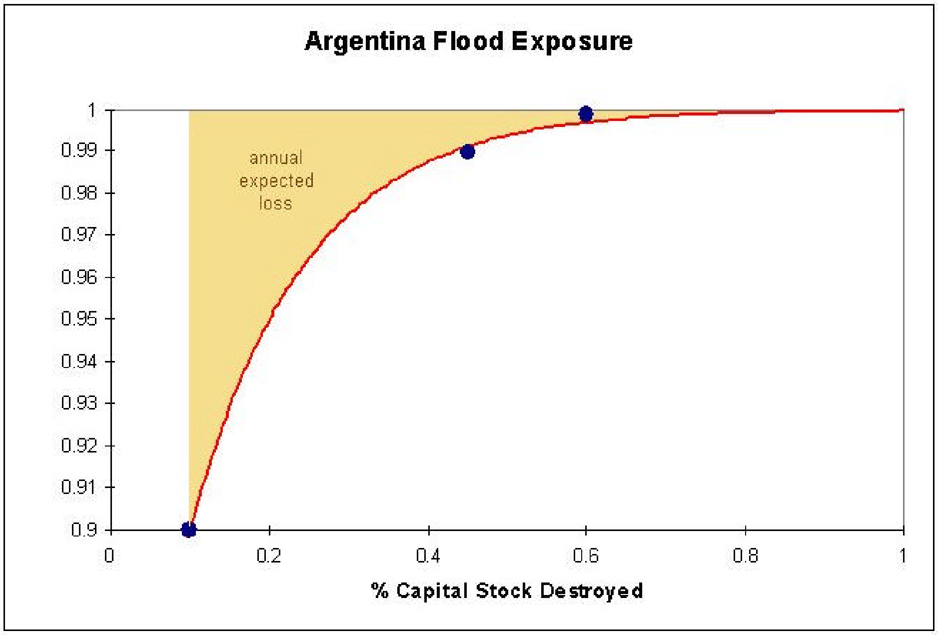
2.2 Catastrophe Exposure Expressed as Probability Distributions

In order to incorporate catastrophe exposure into planning, the exposure estimate must be expressed in terms of a probability distribution. Catastrophe exposure is expressed as the set of fractional damage to capital stock associated with maximum credible events with a given probability of occurrence in a given time period. The return period is the inverse of the expected frequency of occurrence of an event. The term "10-year event" therefore means "on average, one would expect an event at least this severe once every ten years." This statement is equivalent to saying that the *probability* of an event exceeding the indicated fractional loss in any given year is 1-in-10 or 0.1.

IIASA uses the results of the Swiss Re scenario analyses to fit a probability distribution of the fraction of capital stock destroyed. Appendix B describes in detail the fitting process. This resulting distribution, frequently called a *loss-frequency distribution*, contains information about the range of possible events and the likelihood of those events occurring. Figure 2.10 displays the loss-frequency distribution used for Argentina.

[7] Compare the $1.3 trillion worth of capital stock in Argentina to the $13 billion in Honduras and the $5 billion in Nicaragua.

Figure 2.10: Loss-Frequency Distribution for Argentina



The horizontal axis represents the range of the percentage of capital stock (K) destroyed. The vertical axis represents the probability that losses do not exceed any given level of damage. Specifically, the loss-frequency distribution is a cumulative distribution function of the form:

P(In a given year damage $\leq X_1$% of K) = 0.9 (10-year event)
P(In a given year damage $\leq X_2$% of K) = 0.99 (100-year event)
P(In a given year damage $\leq X_3$% of K) = 0.999 (1000-year event)
Note that this probability distribution only considers events above a certain "catastrophic" threshold (ones that occur less frequently than once every ten years).

The most important features of the distribution are the annual expected loss and the magnitudes and probabilities associated with the upper extremes of the distribution. The annual expected loss is the sum of all the possible losses weighted by the probability of each loss occurring in any given year. The annual expected loss is represented by the area above the cumulative distribution curve.

2.3 Methodology Used to Incorporate Catastrophe Exposure into a Macroeconomic Projection Model

The Revised Minimum Standard Model (RMSM) is the macroeconomic modeling platform used for the specific country analysis in this study. RMSM was developed by the World Bank to quantify policy decisions, analyze the sustainability of policies, and compare the trade-off between policy packages. RMSM is a flow-of-funds accounting model to ensure consistency between the sources and uses of funds in a national accounting framework. Users enter assumptions and RMSM generates internally-consistent macroeconomic projections for all of the major sectors in the economy.

To incorporate catastrophe exposure into RMSM the authors developed a separate catastrophe (CAT) module for RMSM. This CAT module receives as its input a series of samples from the loss-frequency distribution of natural catastrophe damages to capital stock. As an output it identifies reconstruction and relief requirements and adjusts macroeconomic variables within RMSM depending on the availability of those funds. Because the natural catastrophe inputs are stochastic,[8] the extended RMSM model is solved in Monte Carlo fashion[9] and results are expressed probabilistically.

Appendix C presents the RMSM model; appendix D provides an overview of the development of the CAT module; and appendices E-G describe in detail the specific formulation of the CAT module for each of the country examples. The following sections describe the results of incorporating catastrophe exposure in each of the country examples.

2.4 Argentina: Incorporating Catastrophic Exposure into Macroeconomic Projections

The first study uses the capital at risk estimates described in the previous sec tion to calculate the flows required for emergency relief and reconstruction in Argentina. The study identifies that to maintain growth objectives additional expenditure and investment requirements must come out of private consumption or foreign savings. T his section demonstrates how modeling can generate probabilistic projections of the macroeconomic impacts to Argentina of the diverted funds.

For a country to achieve its growth projections, financial resources must be available to replace damaged capital stock and fund needed future investment. In addition, governments must finance costly emergency relief programs. Relief and reconstruction require resources which, if not specifically set aside for this purpose, must be diverted from planned uses.

The possible sources of relief and reconstruction financing can be identified from the national accounting identity that defines gross domestic product (GDP) as the sum of investment, private and public consumption, and the balance of transactions with other countries, the resource balance. The resource balance is defined as the difference between exports and imports and determines foreign savings. If there is an increase in investment, then government consumption must be compensated by a decrease in either private consumption and/or an increase in foreign savings. Otherwise, GDP will change. Tapping into these sources has measurable macroeconomic impacts.

The following subsections present the adjusted macroeconomic projections obtained from applying the CAT module to the RMSM simulation for Argentina.

Government consumption

After a disaster, funds are needed for reconstruction investment and emergency response. Increasing government consumption funds disaster relief (Otero, Marti 1995). This section describes the range of adjustments to government consumption from the modeling exercise for Argentina.

Stochastically sampling from the probability distribution of stock losses for Argentina and applying the output to the RMSM model generates a set of all possible consequent macroeconomic projections and their associated likelihood. The appendices describe the shocks and the macroeconomic model in detail. Tabulating the changes in government consumption with each sampling generates the following probability density function shown for a sample year in Figure 2.11.[10] The horizontal axis represents probable

[8] Stochastic means that the probability of an event of a given size occurring is known but whether or not that event occurs in any given year is unknown.

[9] In Monte Carlo simulation the distribution of possible outcomes is generated by a software package that recalculates all of the macroeconomic variables 5,000 to 50,000 times, each time using different randomly selected values from the input probability distribution for catastrophic events.

[10] Although the simulation outputs results for each of the 8 years for which RMSM provides data, for illustrative purposes the following figures represent the results for the year 2006. Results may vary slightly for other years depending on the assumptions embedded in RMSM for those years.

increases in government consumption. The vertical axis represents the relative observed frequency from the stochastic simulation of the increases occurring.

Figure 2.11: Government Consumption of Argentina

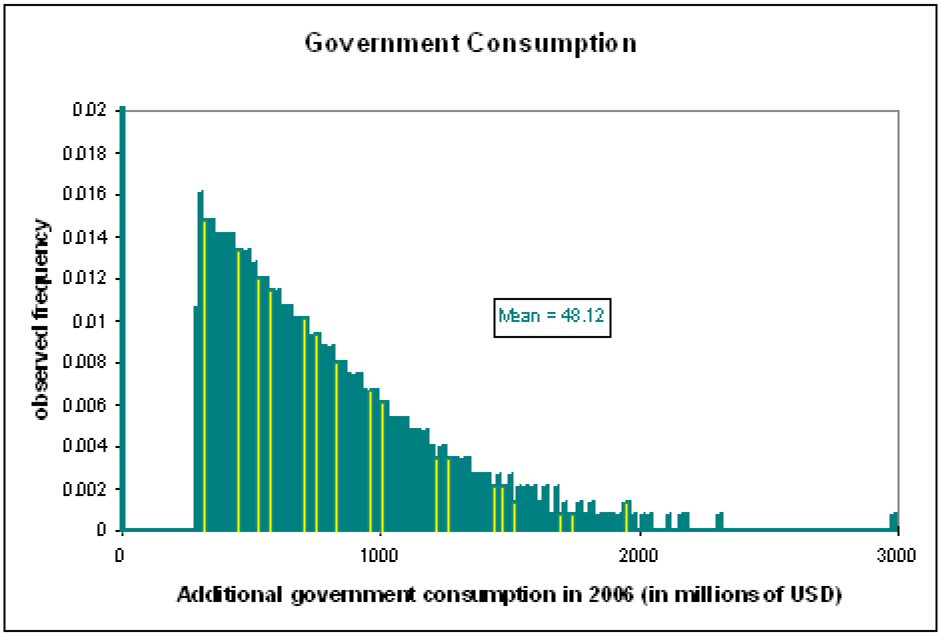


Figure 2.11 presents possible increases in government consumption in the year 2006 along with the associated frequencies of those values occurring. Figure 2.11 is magnified to highlight the tail of the distribution, that is, the infrequent but catastrophic events. This figure is important to planners because it describes the probabilistic worst case scenarios. The figure shows that the government has a low risk (0.1% chance) of needing to increase government consumption by as much as $3 billion.[11]

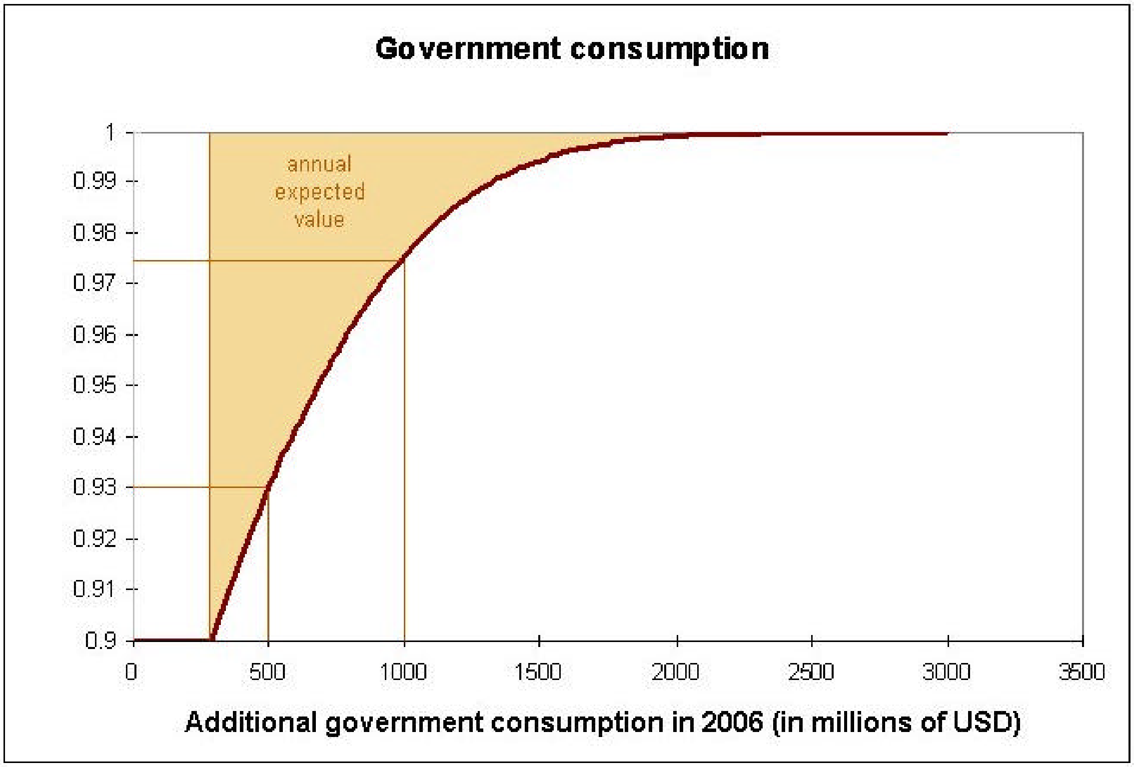
Running the simulations also calculates the expected value of the distribution. In this case, the annual expected value is $48 million, representing the average expected increase in government consumption in 2006. The expected value is calculated by taking the sum of all the possible events weighted by the probability of each event occurring in any given year. This mean is important. The government of Argentina should expect its consumption in 2006 to be $48 million greater than currently projected.

An alternative way to express the same probabilistic results is via a cumulative distribution function. Cumulative distributions represent the probability of events being less than or equal to any given value.[12] Figure 2.12 below shows the probabilities associated with additional government consumption requirements not exceeding any given level.

[11] The results in Figure 2.11 are driven by the input data on direct losses that only considers events above a certain "catastrophic" threshold (ones that occur less frequently than once every ten years). This omission explains the lack of values between the zero change mark and the tail of the distribution.

[12] The cumulative distribution is calculated by integrating the probability density function shown in Figure 2.11.

Figure 2.12: Probability of Additional Government Consumption in Argentina in 2006



The main benefit to expressing the results in cumulative form is that exceedence probabilities are easy to identify. One reads in Figure 2.12 that 93% of the time, changes in government consumption will not exceed $500 million. Conversely, 7% of the time additional government consumption will exceed $500 million. Similarly, one reads that 2.5% of the time additional consumption requirements will exceed $1000 million.

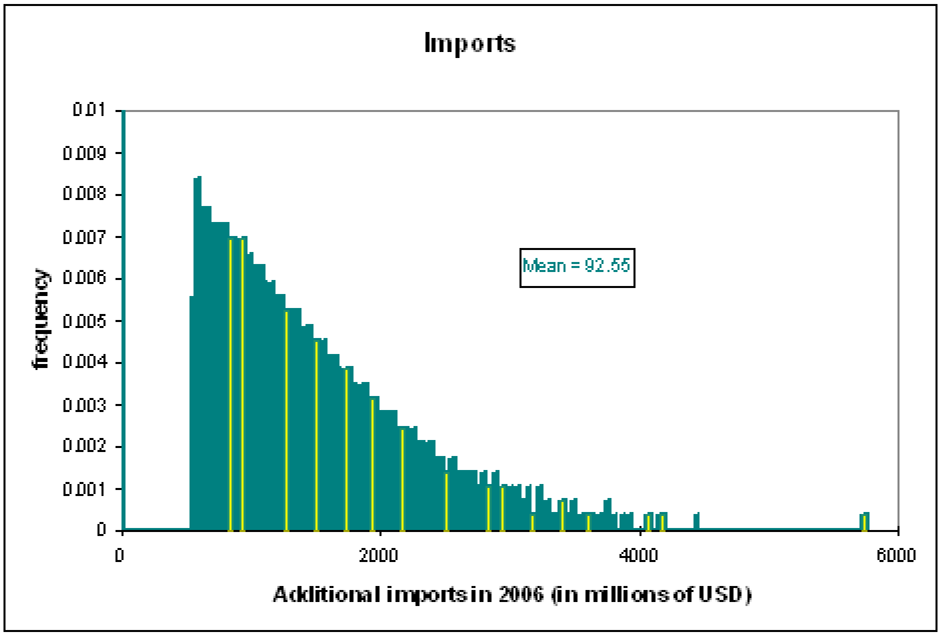
The cumulative form is also insightful because the annual expected value is mathematically equivalent to the area contained above the cumulative curve, shown shaded in Figure 2.12

Imports

Imports are a second critical variable impacted by natural catastrophes. Because floods damage productive capacity and reconstruction increases the demand for capital goods, it is common for catastrophes to be followed by an increase in imports. The level of this increase in imports is important to estimate.

Figure 2.13 shows the probability density function of increased imports for Argentina. The annual expected increase is $93 million for the sample year 2006.

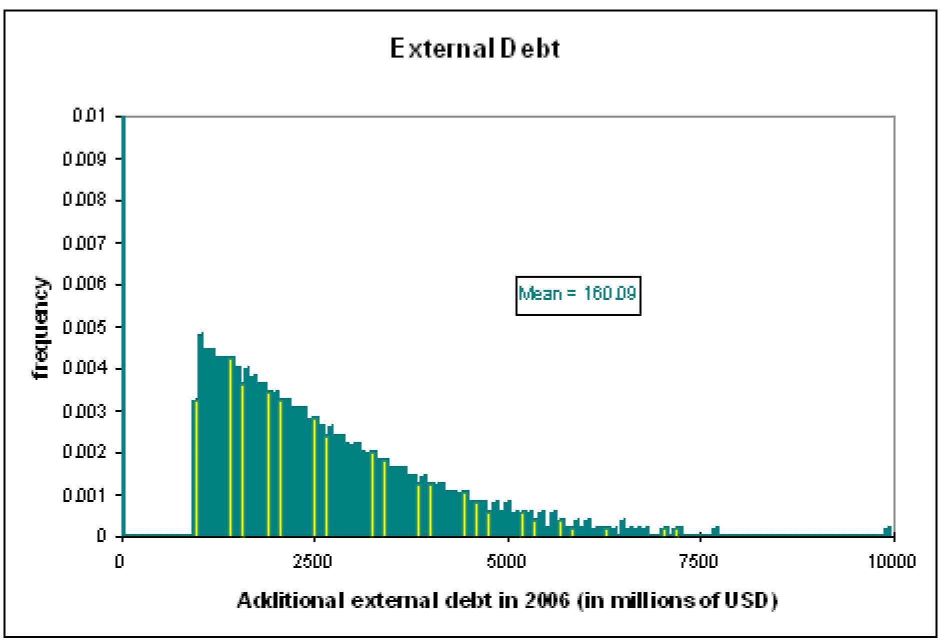
Figure 2.13: Projected Imports for Argentina in 2006



Natural catastrophes increase imports on average by $93 million

Holding domestic reserves of foreign currencies constant (as described in appendix E), the cost of the additional imports must come from an increase in external debt. This additional debt increases Argentina's annual debt service payments. If private consumption does not drop in post-event periods to pay the additional debt service, debt will continue to accumulate over time. Figure 2.14 demonstrates the accumulative effect of 7 years of catastrophe exposure on total external debt. The cumulative expected increase is $160 million by 2006.

Figure 2.14: External Debt Projections for Argentina in 2006

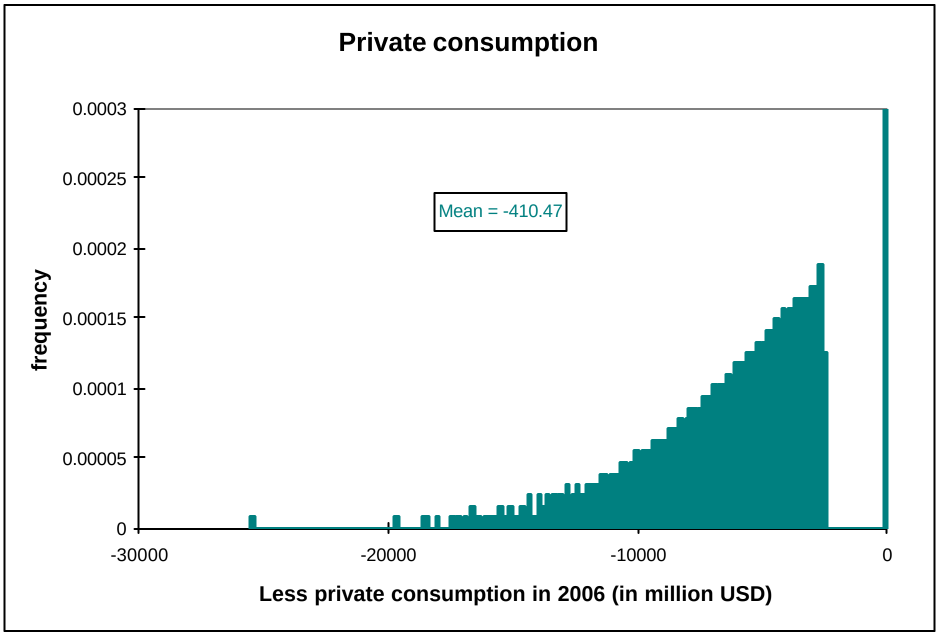


Expected increase in external debt projection by $160 million in 2006

Private consumption

Financing reconstruction investment must divert income from consumption to savings. Decreasing private consumption post-event frees up funds to be spent on reconstruction. Figure 2.15 demonstrates the impact on private consumption of incorporating catastrophe exposure into planning. The annual expected decrease in private consumption is $410 million in the sample year 2006.

Figure 2.15: Projections for Private Consumption in Argentina for 2006



On average, private consumption decreases in 2006 by $410 million

Conclusions for Argentina

The first case study identifies $320 million of annual expected loss to Argentina due to flood events. To achieve growth projections, Argentina must be able to mobilize the funds necessary for emergency relief and reconstruction investment. The study identifies two possible sources of these funds: tapping into foreign savings by increasing imports and/or decreasing private consumption. By stochastically integrating catastrophe exposure into a macroeconomic model for Argentina, the Argentina exercise projects for one sample year that government consumption is expected to increase by $48 million, imports increase by $93 million, external debt increase by $160 million, and private consumption decrease by $410 million. These expected adjustments to existing forecasts derive solely from accounting for catastrophe losses. Knowing the magnitude, probability, and range of these adjustments is important for planning.

2.5 Honduras: Necessity of Accessing External Funds

The second case study explores the impacts of catastrophes that may overwhelm a country's ability to absorb losses. This analysis considers the situation when private consumption and foreign savings are not reliable sources of post-disaster reconstruction and relief funds. It looks at a small country with relatively low domestic resources and high disaster exposure, Honduras. The modeling forecasts the impact to Honduras of an failure to access sufficient foreign assistance to meet reconstruction needs. As expected, both investment and production suffer. To frame the issue, Figure 2.16 and Table 2.4 shows the largest direct loss from natural catastrophes for each country: $2.4 billion in flood damage to Argentina and $1.9 billion in hurricane damage to Honduras. The direct losses are compared to chosen macroeconomic variables for each country, gross domestic product (GDP) and three indicators of potential domestic sources of reconstruction funds: annual tax revenue, gross domestic savings, and net domestic credit. Net domestic credit represents the credit available from the financial sector. In addition, the chart and graph provide additional data on per capita GDP and foreign aid as a percentage of GDP.

Both events described in Table 2.4 occurred in 1998. It is important to note that these events are less than 8 times larger than the probabilistic annual loss for Argentina and 39 times larger than the probabilistic annual loss for storm and flood events in Honduras. These numbers demonstrate the importance of knowing the range of probabilistic estimates that produce annual expected loss.

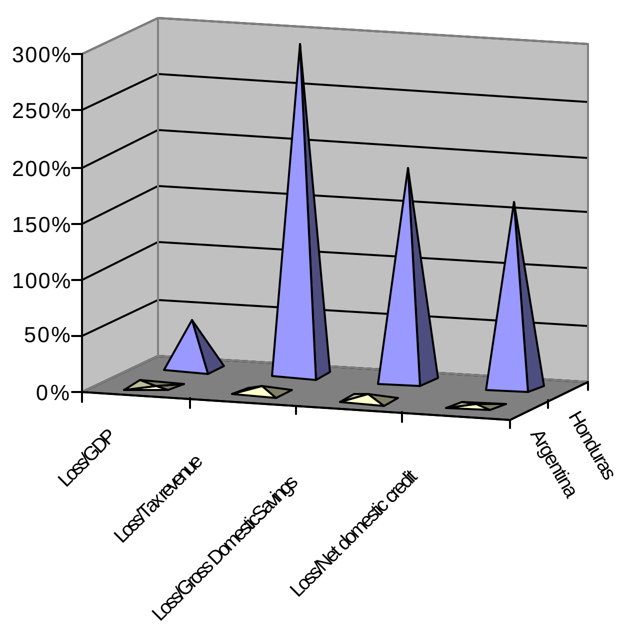
Table 2.4: Comparison of Key Macroeconomic Indicators to Largest Historical Losses from a Single Event in Argentina and Honduras

	Argentina	Honduras
GDP (millions)	293,005	4,725
GDP/percapita	8,214	790
Aid/GDP	0.03%	6.3%
Largest historical Loss (millions)*	2,432	1,951
Loss/capita	68.2	326.1
Loss/GDP	0.8%	41%
Loss/Tax revenue	6.7%	293%
Loss/Gross Domestic Savings	4.1%	189%
Loss/Net domestic credit	2.8%	166%

*Argentina: Floods 1998, Honduras: Hurricane Mitch 1998.

All values in 1997 USD. Sources: World Development Indicators 2000, IADB 2001, Munich Re 1998, ECLAC 2000.

Figure 2.16: Comparison of Key Macroeconomic Indicators to Largest Historical Losses from a Single Event in Argentina and Honduras



For Honduras, the size of an event like Hurricane Mitch overwhelms internal resourc es. Hurricane Mitch's direct damages are five times annual tax revenues. Clearly, disasters mean something different for Honduras than they do for Argentina. For this reason, the Honduras exercise approaches the modeling process from a different angle than the Argentina example.

The Honduras example uses the modeling process to illustrate what happens to a country when post-disaster reconstruction resources are limited. This involves two steps. First, the country's catastrophe exposure is stochastically integrated into the Honduras RMSM. As in the Argentina example, this process identifies emergency relief and reconstruction needs. Running simulations as described in the Argentine example, the first step estimates that planners in Honduras should expect to need $123 million annually in additional external funding to meet losses due to natural catastrophes.

The Honduras case, unlike that of Argentina, then assumes the private consumption cannot easily drop to free funds for reconstruction. Because nearly 66% of households in Honduras live below the poverty line (Government of Honduras 2000), there is little room for downward pressure on private consumption. If reducing private consumption is not an option to mobilize needed funds, then the financing for reconstruction, additional government expenditures, and increased imports must come from additional foreign savings.

The second step is to re-simulate the macroeconomic model under different scenarios to illustrate the impacts of a country's failure to access the needed additional external funds. Appendices D and F describe this process in detail. When simulating the model with limited access to foreign savings, private and government consumption requirements divert investment. Households spend a larger fraction of their income to stabilize consumption and the government spends more on relief. This process leads to chronic under-investment. The result is that future levels of GDP drop relative to the no-catastrophe case due to insufficient investment.

Figure 2.17 demonstrates the impact of incorporating catastrophe exposure into macroeconomic projections in Honduras as a function of the country's ability to mobilize external savings post-event.

Figure 2.17: Effect of Incorporating Catastrophe Exposure on GDP Projections

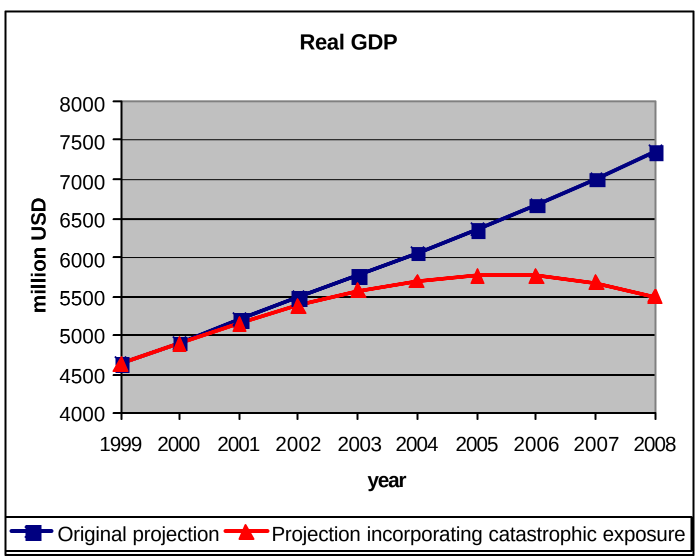


Figure 2.17 demonstrates that if access to foreign savings is limited in the post-event period, catastrophes could stagnate GDP for Honduras over the next 8 years. The first trajectory in Figure 2.17, marked with boxes, represents World Bank projections for expected annual growth rates of 5% to 6%. The second

growth trajectory, marked with triangles, incorporates the effects of catastrophic exposure assuming Honduras can not obtain sufficient external funds to finance post-disaster losses. T his new growth trajectory demonstrates that catastrophe exposure has the potential to impede future growth of the Honduran economy.

Conclusions for Honduras

In planning, it is important to understand the probable size of loss compared to resources available to meet reconstruction and relief needs. If catastrophe losses overwhelm Honduras' capacity to absorb losses, it must either obtain additional external savings or sacrifice future growth.

The Honduras exercise identifies that Honduras will need each year an expected $123 million of external funding above existing external funds projections to respond to catastrophic events. Incorporating annualized hazard exposure is sufficient, over time, to offset long-term growth for Honduras if sufficient additional external funding is not made available after catastrophic events.

2.6 Nicaragua: Impacts of Catastrophes on the Poor

The Nicaragua case explores an additional issue. As discussed in the introduction chapter, the impact of disasters on the poor is difficult to quantify. Because the poor are not well reflected in macroeconomic data, analysis of that data alone disguises the consequences of disasters on the poorest segments of society. With the Nicaragua country example, a technique was developed to better understand how disasters impact the poor.

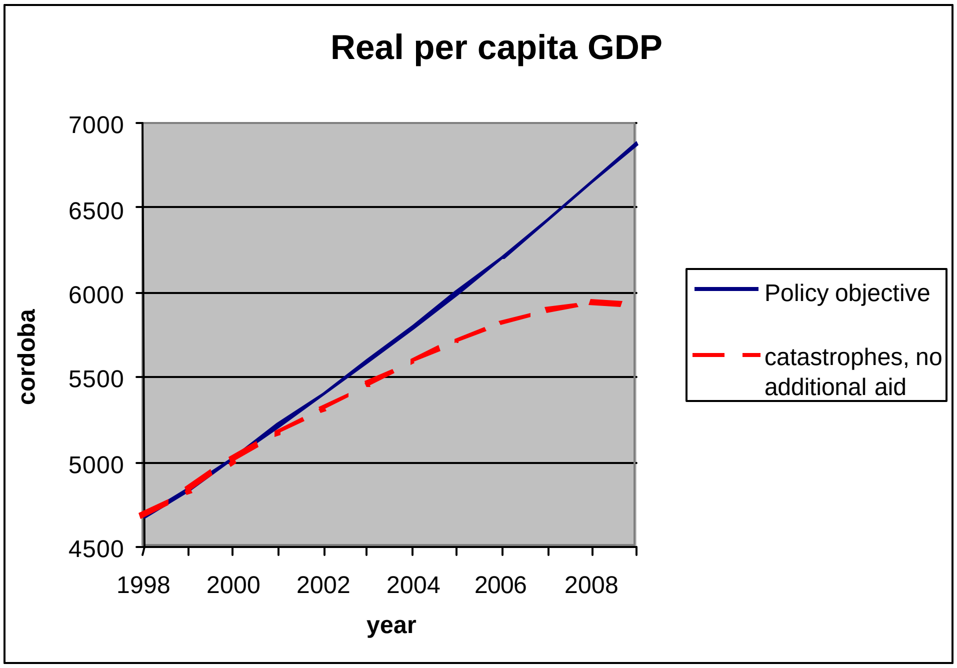
With Nicaragua, the process undertaken for Honduras is replicated. Like Honduras, Nicaragua currently depends on external funds to sustain infrastructure investment, including post-disaster reconstruction.[13]

The results of the first part of the analysis show that in Nicaragua the pairing of catastrophe exposure and low economic resilience can also undermine growth. High hazard risk and low economic resilience can flat-line projected growth in real per capita GDP, as shown in figure 2.18.[14]

[13] In Nicaragua foreign aid makes up 28.8% of GDP. (value in1999)

[14] Note that the values are expressed in local currency (cordobas) to align with poverty data also in (cordoba).

Figure 2.18: Impacts of Chronic Catastrophe Exposure on Real per Capita GDP



Poverty is a crucial issue in Nicaragua because approximately half of the population lives at or below the poverty line (Government of Nicaragua 2000).[15] The Nicaragua Living Standards Measurement Study Survey 1998 conducted by the World Bank, the United Nations Development Programme (UNDP) and the Government of Nicaragua estimated that poverty, as a fraction of the total population, has dropped from 50.3% in 1993 to 47.9% in 1998, representing 2.3 million people in 1998 (World Bank 2000b). Extreme poverty has dropped from 19.4% in 1993 to 17.3% in 1998, representing 830,000 people in 1998. Although the percentage of the population in poverty and extreme poverty has decreased, the absolute number of people in poverty and extreme poverty has increased.

One of the most important issues for the poor is the maintenance of a minimum level of income. Risk accounts for a large share of transient poverty by reducing the income of the poor below minimum levels (Sen 1999). Natural disasters impact the income of the poor in three specific ways. First, catastrophes impact their own-account food production and real labor income. For the very poor, both catastrophes and normal range variations in these two key variables can throw such families into absolute destitution (ADB 1999). Second, catastrophes can both directly and indirectly destroy assets of the poor. Catastrophes directly destroy homes, farmland, crops and other essential productive assets. Families with a stock of productive assets also suffer loss of income from normal range variation, but can protect themselves by drawing down savings or buffer stocks. In the event of a catastrophe, these are unlikely to be sufficient. In which case, real assets (including agricultural land and livestock) will be sold. This is the indirect impact of catastrophes on personal assets. This protects against absolute destitution, but at a heavy cost. Periodic depletion of savings due to natural disasters makes long-term accumulation difficult (Hoogeveen 2000). When assets are depleted, the household is thrown into poverty and left vulnerable to future normal range variations in income. Third, the poor have a large and important stake in public infrastructure projects (World Bank 2001). Rural transport, electrification, and irrigation projects, which have a proven track record in

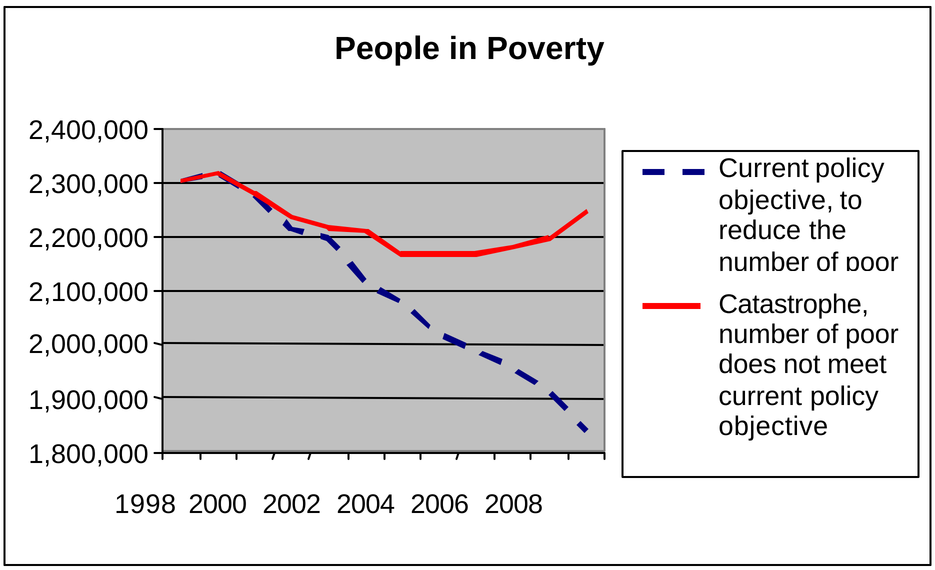
[15] There are many different ways to measure poverty. One measure is the number of people whose consumption falls beneath the poverty and extreme poverty lines. Approximately one-half of the population of Nicaragua is currently living in poverty and one-fifth is living in extreme poverty. Another measure of poverty is the depth of poverty, or the poverty gap: the amount of money needed to raise expenditures of the poor to the poverty line and of the extremely poor to the extreme poverty line, respectively. Currently the poverty gap is approximately 4 billion cordobas and the extreme poverty gap is approximately 2 billion cordobas.

poverty reduction, are damaged by catastrophes. Replacement is often delayed, and resources for reconstruction are diverted from other poverty-reducing development projects. Natural catastrophes attack the poor at three levels: they interrupt income, reduce personal assets, and destroy essential public infrastructure (World Bank 2000a).

To transfer from gross macroeconomic figures to poverty estimates requires that the analysis supplement RMSM with a household level model. The household model is based on the Nicaragua Living Standards Measurement Study Survey 1998 conducted by the World Bank, the United Nations Development Programme (UNDP) and the Government of Nicaragua.

The first step in modeling the effect of catastrophes on poverty is to measure the impacts that catastrophes would have if each person's share in both growth and catastrophe losses were directly proportional to their consumption[16]. Each person therefore loses an equal part of his or her income. The results shown in figures 2.19 and 2.20 are obtained by first estimating the macroeconomic impact of a natural catastrophe. This is done here by applying the changes in real per capita income calculated in RMSM to the poverty module. Appendix G describes in detail the methodology used to adjust poverty projections. Next, changes to real per capita income are calculated based on this estimate and incorporated into a poverty module. The module assumes that losses are proportional to consumption for each segment of the population. Figure 2.19 illustrates that catastrophes can slow or stall the reduction of poverty.

Figure 2.19: Projections of Number of People in Poverty in Nicaragua



Catastrophes can slow or stall the reduction of poverty

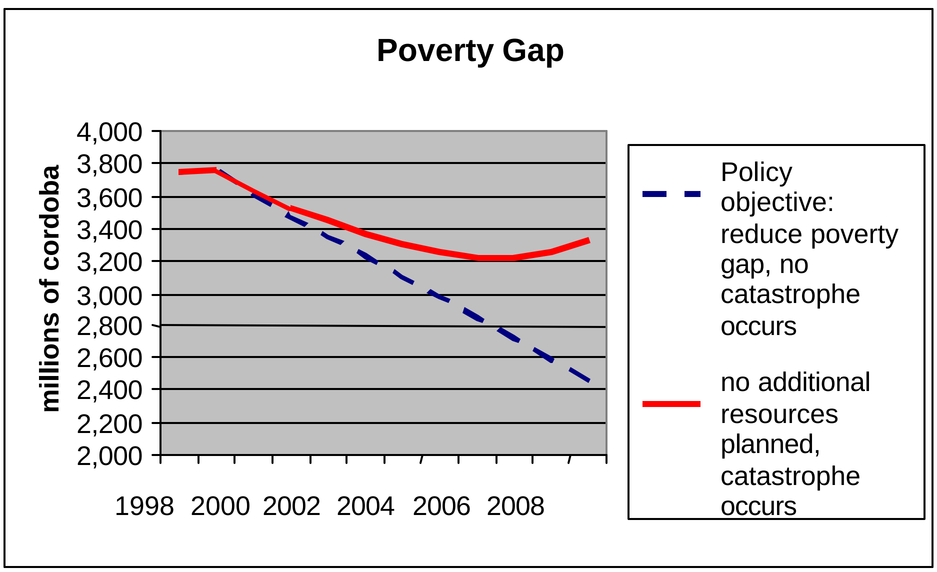
The dotted line in figure 2.19 shows the current policy objective for Nicaragua: to reduce the number of people in poverty. The dotted line indicates that, in the absence of a catastrophe, GDP growth alone reduces the number of people in poverty by 500,000 people by 2008. In the case of a catastrophe where a country does not obtain additional aid (shown by the solid line), the impact on poverty is substantial. For the decade following a 1998 catastrophe, the number of people living in poverty decreases only slightly. Towards the end of the projected period, the number of people in poverty begins to rise slightly.

[16] Consumption being a proxy for income used to determine poverty quintiles.

A major issue in this analysis is the incorporation of natural catastrophes into broad planning. To avoid the outcome described by the solid line in figure 2.19, the impacts of natural catastrophes on the poor would need to be considered. To meet poverty reduction objectives even when catastrophes occur, more assistance than is currently planned will be required. Considering catastrophe impacts and poverty in broad planning activities could help Nicaragua achieve its poverty reduction measures, even when a catastrophe occurs. If the impacts of natural catastrophes are not considered, when a catastrophe occurs, Nicaragua will not achieve its poverty reducing objectives.

Beyond the sheer numbers of those living in poverty, the poverty gap is also accentuated by catastrophes. The poverty gap is defined here as the amount of money needed to raise expenditures of the poor to the poverty line. Again, using an estimate of the macroeconomic impact of a natural catastrophe, figure 2.20 shows that catastrophes can accentuate the poverty gap. In the case where no catastrophe occurs, and the current policy objective is met (represented by the dotted line), the amount of cordobas needed to reduce the poverty gap declines from almost 3,800 million cordobas to just over 2,400 cordobas over a decade. This situation changes when catastrophe exposure is incorporated into macroeconomic projections. When the amount of aid for poverty reduction remains fixed and a catastrophe occurs (represented by the solid line), figure 2.20 shows that the amount of money needed to raise expenditures of the poor to the poverty line remains at approximately the same real level over a decade. Instead of reducing poverty and reducing the amount of money needed for poverty relief, in the case of a catastrophe the poverty gap does not close significantly.

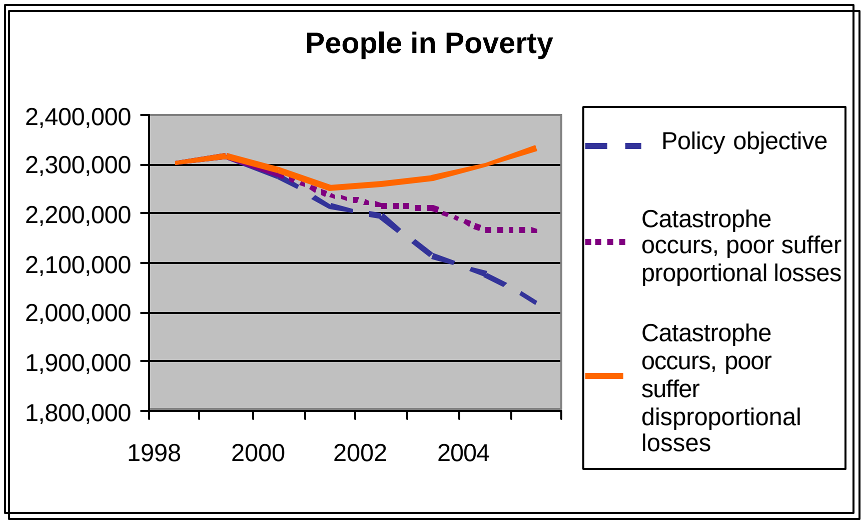
Figure 2.20: Projections of Funding Needed to Reduce the Poverty Gap in Nicaragua



Catastrophes can accentuate the poverty gap

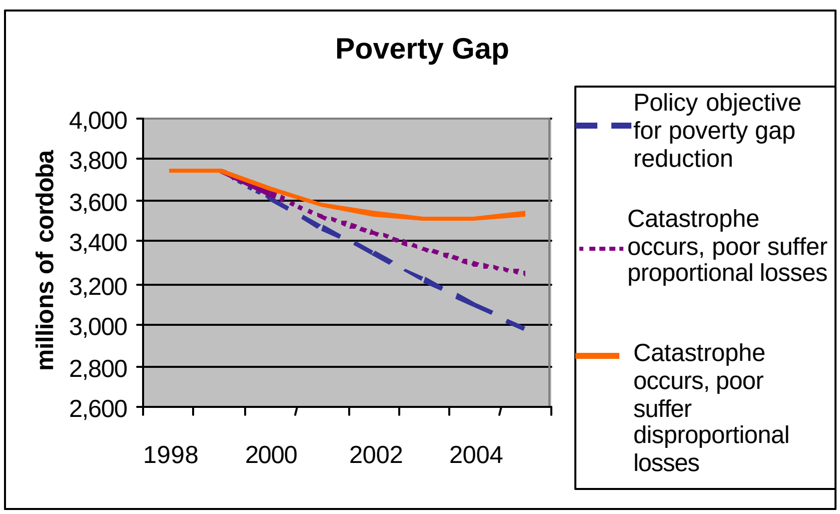
These results are based on the assumption that people proportionally shared the boon of economic growth, as well as the brunt of catastrophe losses. If the poor suffer from catastrophes in direct proportion to their consumption, catastrophes can slow poverty reduction measures. To the extent that the poor are disproportionately affected by catastrophes and no additional relief for catastrophe exposure is planned, the poverty impacts demonstrated above will be magnified, illustrated in figure 2.21. Doubling the fractional burden of natural catastrophes on the poor, the relative number of people in poverty increases, with an additional 150,000 people in poverty by 2005 (figure 2.21), and the poverty gap increases every year, with an additional gap of 300 million cordobas by 2005. The deterioration in absolute numbers of poor and the depth of poverty can come when the impacts of natural catastrophes on the poor are not considered in planning. In particular, poverty may be accentuated when critical infrastructure is not replaced following a disaster.

Figure 2.21: Projected Number of People in Poverty, Considering Disproportional Impacts on the Poor



The number of people in poverty increases if the poor suffer disproportionably from catastrophic events

Figure 2.22: Projected Funding Necessary to Reduce Poverty Gap, Considering Disproportional Impacts on the Poor



The effect on poverty of insufficient foreign aid after natural catastrophes is accentuated by disproportional impacts of catastrophes on the poor

The differences in the proportional and disproportional loss curves in figures 2.22 and 2.23 highlight the importance of correctly estimating the extent on nation-to-nation basis to which the poor may be disproportionately vulnerable to the impacts of natural catastrophes and/or disproportionately less able to cope.

Conclusions for Nicaragua

The integration of catastrophe losses, macroeconomic models, and living standard measurement surveys provides a helpful tool to disaggregate the impact of catastrophes on the poor. As Nicaragua shows, catastrophes can have a dramatic impact on increasing the number of poor, as well as the poverty gap of those already classified as poor. Using macroeconomic models can illuminate the plight of the poor from disasters.

2.7 Recommended Future Modeling Efforts

Time step

The most important limitation of the modeling described in the previous sections—and data-wise one of the strengths—is the discrete one-year time step. With such a time-step it is very difficult to consider delays of any other length. In dealing with the destruction and reconstruction of capital stock, and obtaining financing to do so, additional insight could be derived from studying the relative delays.

Sensitivity of results to imports parameter

The growth paths in the Honduras and Nicaragua case studies are very sensitive to the estimate of the extent to which reconstruction investment requires capital goods imports. By balance of payments consistency, the greater the need for imports, the greater the need for other capital inflows. If foreign financing is limited, export production is unable to increase, and the strategy of holding international reserves constant is maintained, then either other import categories or growth must suffer as a consequence. The sensitivity of the growth trajectory to this parameter signals a key area for future research.

Representing extreme events

Catastrophic shocks are characterized by both the mean and the extremes of the loss-frequency distribution, that is, by both the annualized expected loss and the maximum possible impacts of highly infrequent events. For Argentina, where the study identifies the probabilistic changes to macroeconomic variables, the model does justice to the extreme nature of the events. Extreme events translate to extreme costs to private consumption or external savings. In the Honduras and Nicaragua studies, however, the modeling only partially captures the distinction between ten years of successive minor losses and one year out of ten experiencing a major loss. In the CAT module, reconstruction resources are either available, at a given cost, or unavailable. In the real world, however, the issue of the availability of resources is rarely as clear-cut. The question may not be resource *availability*, but the marginal cost of each additional resource. The larger a catastrophic event, the higher the marginal cost of the last additional resource. So the occasional extreme event is definitely more detrimental, in cost alone, then a sequence of more manageable events.

2.8 Summary of Country Cases

The country cases demonstrate how to estimate the macroeconomic and poverty impacts of direct losses from natural disasters. These exercises isolate key variables, such as reconstruction investment, private consumption, capital goods imports or access to foreign savings, and demonstrate the consequences of the assumptions one makes about their behavior on the impact of natural catastrophes on macroeconomic projections.

The Argentina case, for example, identifies potential sources of post-disaster financing and displays probabilistic projections of the macroeconomic impacts of the diverted funds. The Argentina exercise assumes that growth objectives can be met. In addition, it assumes that government consumption and imports will rise post-disaster with a corresponding increase in foreign borrowing. The funds needed to pay reconstruction costs are diverted from private consumption. Of course, if one assumed that the government is willing to accept lower growth, then different tradeoffs could be evaluated. The modeling demonstrated in this chapter is a useful tool for evaluating different policy options and their costs.

The Honduras and Nicaragua cases make the assumption that access to post-disaster financing is limited. These exercises demonstrate the critical role that foreign assistance plays in financing post-disaster reconstruction and the continuation of growth objectives. The Nicaragua exercise extends the Honduras exercise by examining the impact of natural catastrophes and limited post-disaster financing on the poor. The results of the last exercise show that an inability to finance probabilistic annual losses to capital stock can stall or defeat poverty reduction measures.

Chapter 3.

Contribution of Country Cases to the Insurance Decision-Making Process

The traditional strategy for dealing with disasters has been the provision of post-disaster financial aid. In short, the international aid community has served as the de-facto insurer of last resort. However, the provision of post-disaster assistance creates disincentives for recipient countries to ensure the physical protection of their assets through disaster prevention and mitigation measures. Over recent years, development agencies have emphasized disaster risk reduction as an explicit policy tool for sustainable development. The United Nations declared the 1990's the International Decade for Natural Disaster Reduction (IDNDR) with a clear emphasis on reducing risk through mitigation. While the Decade contributed to raising worldwide awareness of the importance of disaster prevention and mitigation, mitigation still lags as a policy tool.

Disaster prevention and mitigation requires current expenditure of funds to reduce future risk. These expenditures compete for scarce resources with other policy objectives. In order to put in place formal incentives for mitigation the use of risk transfer instruments to finance post-disaster reconstruction of public assets has recently been proposed.[17] For example, recent report on risk management for the Caribbean noted that "risks can be better addressed via insurance and risk transfer mechanisms which provide the basis of financial protection and instilling strong incentives for vulnerability reduction" (Pollner 2000). Because the cost of insurance is linked to the risk it insures, the lower the risk, the lower the premium. The insurance industry provides incentives for the adoption of cost-effective risk-reduction measures by adjusting deductibles or coinsurance (the fraction of loss paid by the insurer). The involvement of the private sector brings additional expertise to the risk management process and creates a formal arrangement to carefully monitor the quality and extent of mitigation measures (Kunreuther/Roth 1998, Kreimer et al. 1999).

The reduction of disaster risk benefits both the developing countries that directly bear the losses from catastrophes and the international aid community whose mission is to assist the long-term development and reduction of poverty in these countries. For the incentive system provided by insurance to work, countries must insure their risks that rely on post-disaster assistance.

An additional benefit of risk transfer for the international development community is that risk transfer shifts the community's role as de-facto insurer to the private sector. The private sector has significant experience in identifying, reducing, and transferring catastrophe risk. By harnessing the private sector experience to cope with catastrophe risk, the international aid community frees itself and its resources to implement its broader agenda of development policies.

Insurance is only an effective tool to reduce risk if the party concerned is willing to pay for the insurance. In the case of catastrophes and developing countries, this party would be the affected poor countries that currently rely on post-disaster assistance. There is a cost in adopting risk transfer. For the poorest countries, post-disaster assistance is highly subsidized. Much of it is in the form of grants that need not be repaid. Even the loan portion of post-disaster finance comes at rates much lower than commercial rates (Klein 1994). Since 1980, the World Bank alone has provided well over $12 billion in post-disaster

[17] Risk transfer uses financial instruments that contractually shift risk from one party to another. For catastrophe risk, insurance and financial derivatives, like catastrophe bonds, are the two primary risk transfer tools. The range of the available tools is beyond the scope of this chapter, but recent research details these instruments. For simplicity purposes, all risk transfer tools will be grouped as "insurance" for this chapter.

assistance. By purchasing insurance, poor countries affected by catastrophes will pay the costs which are currently borne by the international aid community for post disaster finance.

However, catastrophe insurance is expensive. It is not uncommon for the premium to be several times larger than the actuarially-determined expected loss (Froot 1999a). While poorer countries still bear enormous risk from natural catastrophes, few incentives exist to substitute insurance for low-cost post-disaster assistance. The only logical reason to do so from the perspective of the poorer countries depends on the perception that foreign assistance may not be available in a timely manner for future catastrophe losses. If that perception exists, insurance may make sense for poorer countries despite the increased cost. This chapter explores these questions. In so doing, it relies on a number of insights gained from the country exercises.

3.1 Insurance as a Tradeoff

Our focus is the tradeoff in insuring public assets from the risk of catastrophe. As discussed in Chapter 2, the annual expected loss for Honduras and Nicaragua from storms is $56 million and $11 million, respectively. Losses from floods and storms could be as high as $4 billion and $788 million, respectively. These extreme losses have a very low probability of occurring. The variation of extreme losses from the annual expected loss is usually measured by the variance. It is the high variance of catastrophe risk that makes catastrophe insurance so expensive, but also so potentially valuable.

Purchasing insurance is a tradeoff. The money spent on the insurance premium diverts money away from other potential expenditures; it has an opportunity cost. On the other hand, if a major disaster strikes, the government may lack the resources to finance reconstruction. As Chapter 2 shows, the long-term economic impacts of direct losses can be dramatic. Buying insurance means lower current income but higher post-disaster income if a disaster hits. The demand for insurance is constrained by a country's willingness to accept the risk of future shocks.

The willingness to accept the risk of lower future income depends on the probabilistic size of the risk, the premium, and the cost of other alternatives to pay for the risk. For Honduras, insurance for flood and storm risk for all events that will occur less frequently than once every ten years will cost at least $100 million annually. Is the commitment to pay $100 million annually more or less valuable than the guarantee that Honduras will have the necessary resources to rebuild if a storm that strikes once every 500 years hits, knowing that the needed resources may be as high as $4 billion? The lost income from investing $100 million a year versus eliminating the risk of potential losses as high as $4 billion is the tradeoff.

Premium

An insurance company must be paid to accept risk. The payment made to an insurance company is called a premium. The higher the premium, the more future income will be lost from investments that could have been made with the funds diverted to pay the premium. The higher the premium, the greater the opportunity cost.

A wide range of factors impacts the premium charged for catastrophe risk. Generally, a premium is composed of three components: the expected loss of risk (actuarially fair premium), expense loading (covers the administrative expenses and profit of the insurer) and risk loading (risk premium). The risk-loading component is derived from the notion of required capital to support the risk underwritten. The variance of the insurer's loss distribution and the risk of ruin of the insurer from assuming particular risks underlie the calculation of risk loading (Tilley 1999). In the country examples, the probable capital stock losses for each country are expected loss calculations set for events that happen less frequently than once in ten years. As discussed earlier, the variance of extreme losses from the expected loss is important in determining the premium. As is common for catastrophe risk, the variance of the risk for Honduras and

Nicaragua is very high. To compensate for the high variance, the risk-loading component of premium for catastrophe risk is large. For catastrophe insurance, the risk premium may be many times higher than the pure premium. Consequently, catastrophe insurance is expensive. The high cost of the premium is a reflection of the large variance associated with catastrophe expected loss (Berliner 1982).

Opportunity cost: Incremental return on capital investment

There is an opportunity cost to paying an expensive catastrophe premium. In this analysis the opportunity cost is the incremental return on capital investment foregone due to insurance premium payment. If the premium for insurance is $1 million, paying the premium reduces future income that would have been earned if the money were invested: the incremental return on the additional invested funds. The incremental return on capital investment is a component of macroeconomic models like RMSM. Once the premium is known for catastrophe insurance, the opportunity cost of buying insurance can be calculated using the macroeconomic modeling methodology developed for this study and presented in the country cases.

Benefits of insurance for firms

This opportunity cost must be compared with the benefit of purchasing the insurance. The benefit of purchasing catastrophe insurance for public assets is virtually unexplored. Limited literature exists on the topic. The studies examining the purchase of catastrophe insurance primarily focus on the purchase of catastrophe reinsurance by insurance companies. Some insight can be gained by understanding why large non-governmental entities purchase catastrophe insurance. These firms also face an opportunity cost when they buy insurance. Firms have a real or perceived benefit for purchasing insurance.

The benefit of purchasing catastrophe insurance is linked to two financial characteristics of the purchaser: the risk of ruin to the firm and the need for liquidity if they suffer extreme losses from a catastrophe. The risk of ruin is a measure of the probability of insolvency of a firm if a disaster occurs (Kleindorfer 1999). This probability is a function of the firm's current financial position and the potential size of the loss. The larger the firm, and the smaller the potential loss to the firm's assets, the smaller is its risk of ruin. The smaller the risk of ruin, the less willing the firm is to incur the opportunity cost of purchasing insurance. The need for post-disaster liquidity is also important. The available funds to pay short-term obligations for a company are its liquidity position. In deciding to purchase catastrophe insurance, commercial firms weigh the opportunity cost associated with the premium versus the probabilistic risk of ruin (its solvency constraint) or to needs for immediately available funds after a disaster (its liquidity constraint) (Stone 1973). In economic terms, these latter two factors measure the firm's risk aversion. Generally, the higher a firm's risk aversion, the more likely it will purchase insurance. Said another way, the greater the risk of insolvency of a firm, or the more it needs short-term liquidity, the more likely a firm is to purchase insurance. Its decision process is directed at preserving its long–term survival as an ongoing business concern.

After a disaster, insurance companies will have a high demand for immediately available funds to pay claims. A disaster may not pose a risk of ruin for a company, but it may impair its ability to meet short-term cash obligations. Catastrophe insurance is a way for a company to make sure it has sufficient cash to meet short-term needs after a disaster (Gron 1999).

As a practical matter, the decision process for a firm in deciding to purchase insurance is made using information about the commercial firm that is similar to the data generated for Argentina, Honduras and Nicaragua. The firm first makes assumptions about its future economic performance and the assets required to meet those performance objectives. Generally, it will have a range of acceptable future growth objectives. The firm is concerned whether risk impacts its ability to meet those objectives. The firm needs to know the probable size of its stock losses from a disaster, the source and cost of funds to meet their reconstruction needs, and the implication of those losses on future growth, particularly if resources may not be easily accessed to meet post-disaster needs. An additional component of the decision process is that the firm sets a probability of ruin (or probability of liquidity shortfall) that it cannot tolerate. These become decision constraints. The firm will purchase insurance when the benefit of the insurance keeps the firm within its decision constraints.

Countries are not commercial firms. Governments are not the management of a commercial enterprise. Nevertheless, there are some similarities between the decision process of governments and commercial firms. As will be discussed later, these similarities may be particularly true for the governments of poorer countries. It clearly is not the case for the decision process about risk and governments in the developed world.

Benefits of insurance for governments

In the developed world, governments do not have a probability of ruin. Governments in advanced economies deal with their risk by relying on their own resources. Government retains all risk associated with its investments, including the risk of catastrophe loss. Consequently, governments do not shift their risks to third parties. They retain the risk and absorb it by adjusting their internal resources. "It is profitable for all concerned that risks should be shifted to the agency best able to bear them through its wealth and its ability to pool risks. The government, above all other economic agencies, fits this description" (Arrow 1992).

As demonstrated in the country studies, the governments in poorer countries do not often have the domestic resources to absorb catastrophe risk. To illustrate the distinctions of coping capacity as it relates to catastrophe risk, Table 3.1 compares of a series of economic indicators between Argentina, Honduras, Nicaragua and the United States. This table expands on the table in Chapter 2 that compared Argentina to Honduras. For each country, the largest historical direct losses[18] incurred by each country are compared to important economic indicators. By using the largest known historical loss, the table highlights the impact of an extreme event on the economic condition of the relevant countries. Table 3.1 compares the loss to a series of economic indicators that indicate capacity to finance post-disaster relief and reconstruction. The chosen economic indicators are loss per capita, loss compared to GDP, loss compared to tax revenue, loss compared to gross domestic savings, and loss compared to net domestic credit. In addition, as an indicator of existing reliance on external aid, aid received by each country as a percentage of GDP is also provided.

Table 3.1: Largest Historical Losses Due to Disasters Compared to Economic Indicators

	USA	Argentina	Honduras	Nicaragua
GDP (millions)	7,834,000	293,005	4,725	2,024
GDP/percapita	29,267	8,214	790	433
Aid/GDP	-	0.03%	6.3%	20.3%
Largest historical Loss (millions)*	45,181	2,432	1,951	2,318
Loss/capita	168.8	68.2	326.1	495.5
Loss/GDP	0.6%	0.8%	41%	115%
Loss/Tax revenue	2.9%	6.7%	293%	499%
Loss/Gross DomesticSavings	3.6%	4.1%	189%	4044%
Loss/Net domestic credit	0.7%	2.8%	166%	71%

*USA: Northridge Earthquake 1994, Argentina: Floods 1998, Honduras: Hurricane Mitch 1998, Nicaragua: Earthquake 1972
All values in 1997 USD. Sources: World Development Indicators 2000, IADB 2001, Munich Re 1998, ECLAC 2000.

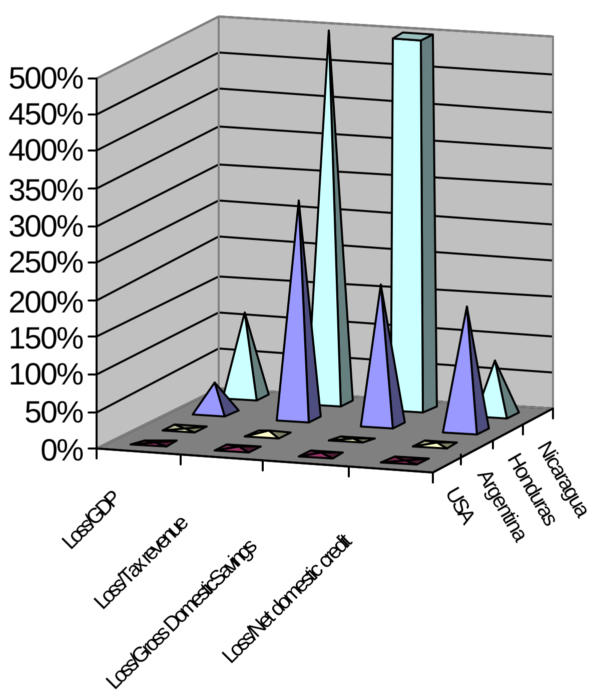
These countries provide a wide spectrum of economic strength: the United States with a GDP/capita of around $30,000 is a high income country, Argentina with about $8,200 is classified as an upper middle income economy, while Honduras and Nicaragua belong to the group of low income countries (World Bank

[18] USA: Northridge Earthquake 1994, Argentina: Floods 1998, Honduras: Hurricane Mitch 1998, Nicaragua: Earthquake 1972.

2000). Comparing the overall loss to internal resources, the inability of the poorer countries to internally spread the cost of loss is even more apparent. For example, if one compared the impact of the Northridge earthquake in the United States to Hurricane Mitch in Honduras, the ratios are revealing. Northridge represented less than 2.9% of tax revenue, 3.6% of gross domestic savings, and 0.7% of net domestic credit. There is little doubt that the country has the capacity to absorb this size loss. For Honduras, the direct loss from Hurricane Mitch represents 293% of tax revenue, 189% of gross domestic savings, and 166% of net domestic credit. These high figures occur despite the fact that the loss incurred by the United States is more than 23 times greater than the loss incurred by Honduras.

The mere calculation of per capita cost does not reflect the difficulty countries have of increasing internal tax revenue. Many countries have limited ability to spread the cost of risk internally through taxation (Rodrik 1998). Many countries rely on a system of indirect taxes, the increase of which has political implications for specific segments of society. For these countries, the budgetary adjustment process is difficult and politically costly (Lewis, Murdock 1999). As a result, the process of spreading even small dollar amounts of risk has high political costs (Meier 1995). In addition, shallow financial markets and weak financial systems limit the capacity to access internal or commercial external savings in times of catastrophes (Ferranti, Perry et al. 2000). So even if the cost of risk is modest in the hands of each taxpayer, the barriers to transferring the risk to each taxpayer is very high in many countries.

Figure 3.1: Largest Historical Loss Compared to Economic Indicators



Reliance on foreign savings

It is little wonder that Honduras and Nicaragua are dependent on foreign assistance to support their post-disaster rebuilding. These countries were highly dependent on aid to support their economic activity before the natural disasters occurred. For Honduras, before Mitch, aid represented 6.3% of GDP; aid rose to 17.3% of GDP in 1999 after Hurricane Mitch. The figure was 20.3% for Nicaragua (OECD 2001). As the case studies for Honduras and Nicaragua highlighted, both of these countries need to depend on accessing external savings, either in the form of external assistance or loans, to meet their growth objectives and deal with the risk of loss from natural catastrophes.

Risk aversion

What emerges is the question of risk aversion. It is not possible to evaluate the desirability of insurance without knowing about a county's risk aversion. In the case of the poorer countries, their risk aversion will be determined by their perception of the ongoing willingness of the international community to provide needed post-disaster assistance. This is the perception problem discussed earlier.

The obligation of the international community to provide low cost or free post-disaster savings is a controversial policy decision. On one side, the argument is framed in terms of the obligation of the international community to shift needed resources to the poorest countries. Aid is a wealth-shifting mechanism. It permits the risk of catastrophe loss to be shifted externally from a poor country to the international community. There is broad acceptance that catastrophe risk is one that can be shifted, and that the wealthier countries are willing to accept. The massive amounts of aid made available after some disasters is proof of the willingness to provide aid in the right circumstances. Based on a broad concept of worldwide solidarity, the movement of catastrophe risk from the poorer to the wealthier countries is the right moral policy. In addition, if the world community accepts that the risk from extreme weather events increases due to greenhouse gas emissions of the developed world, the equity of existing policy is even stronger.

There are severe disadvantages to this strategy. There is a well-established insurance literature on the consequences of failing to internalize the cost of risk (Epstein 1996, Priest 1996, Froot 1999). This literature takes the position that providing post-disaster assistance reduces the incentive for those exposed to risk to properly reduce their risk. As a consequence, the worldwide level of risk rises because of misplaced incentives (Epstein 1996). The only way to get the incentives right is to have those who incur the risk pay the price of their actions (Kunreuther, Roth 1998). Any other policy distorts the proper allocation of resources. This view echoes the risk reduction justification for action by the development community in dealing with catastrophe losses.

Other factors

There are other factors that may influence a country's willingness to pay the expense loading and risk premium. It may be that diverting funds to pay for a catastrophe loss may impact financial commitments made to international lending agencies. Having to renegotiate existing credit agreements has a cost, and that cost may be reduced by insurance. For countries that rely on external savings, their future economic growth is tied to a voluntary act by third parties. To the extent a country values sustainable growth based on accessing internal savings and modest external debt or aid, insurance provides an alternative source of guaranteed funding linked to internal resources. Insurance may be the justification to impose risk reduction measures that are not otherwise acceptable. Finally, insurance focuses attention on the ex ante nature of risk. Just as this report highlights the need to plan for catastrophe risk, insurance forces an evaluation of policy options ex ante. Absent the pressure of making an insurance decision, there is less need to rigorously evaluate the impact of risk.

The discussion about the allocation of catastrophe risk is more than theoretically interesting. Without some assumption regarding the role of external savings to assist developing countries, it is not possible to understand if insurance makes sense as a policy tool for poorer countries.

3.2 Modeling the Decision Process

Once decisions about tradeoffs are made, the modeling process used for the case studies can be adapted to optimize the decision process. The model permits the processing of options to weigh the benefits of different policy options. The model can help calculate the opportunity cost of paying a premium and the economic costs of relying on different resources. Comparing these variables with assumptions regarding the availability of external savings and growth objectives, a functional decision process can be framed. The decision-maker must decide what risk he or she is willing to take. Once the decision-maker has made that determination, the model can help identify the optimum decision based on the risk assumptions.

There has been only limited work exploring how to adapt models for these purposes (Freeman, Pflug 2001). As mentioned earlier, there is also literature on insuring catastrophe risk for municipalities and provincial governments (Kreimer 1999, Boswell, Deyle et al. 1999). The use of insurance for government risk in developing countries is ripe for additional theoretical and applied research.

In doing the three country studies, it is apparent that the modeling process permits a much wider application than simply providing projections that incorporate catastrophe risk. The model also can be adapted to understand the tradeoffs in policies developed to reduce or transfer risk. One specific application is framing the decision process regarding the use of insurance by poorer countries to hedge their risk of loss. While much needs to be explored regarding the risk aversion of these countries, modeling is essential to support the decision process.

Chapter 4.

Conclusions and Recommendations

4.1 Report Summary

This report developed a framework to analyze the economic impacts of natural disasters in developing countries. By incorporating future probabilistic exposure to disasters into macroeconomic projections on a country level, the research creates a planning tool that assesses the major tradeoffs for allocating a government's scarce resources. This model facilitates the analysis of policies designed to reduce the economic impacts of natural catastrophes and minimize the impact of catastrophes on the poor. The main achievement of this framework is that it lays a foundation on which to plan for natural disasters.

The Argentina example identified potential sources of post-disaster financing and projected the probabilistic macroeconomic impacts of the diverted funds. Knowing the magnitude, probability and range of the impacts of catastrophes on macroeconomic projections is valuable for planning for disasters.

The Honduras and Nicaragua examples considered cases in which access to post-disaster financing may be limited. These exercises demonstrated that an inability to finance probabilistic annual losses to capital stock can stagnate expected future economic performance. The analysis showed that in planning it is necessary to understand the probable size of loss in comparison to the available resources for coping with disasters.

The Nicaragua study went a step further to understand the impacts of catastrophes on the poor. Supplementing the CAT module with a household level model, the macroeconomic estimates of decreased economic growth were translated into poverty impacts. Two scenarios on proportional and disproportional impacts showed that an inability to reconstruct or provide relief post-catastrophe can stall poverty eradication efforts. Understanding disaster impacts on the poor is another important component of comprehending the full range of impacts and devising policies to cope with disasters.

Chapter 3 discussed how the country modeling can be used to assist policy makers to evaluate alternative funding sources for post-disaster reconstruction, like catastrophe insurance. It framed the decision process of poorer countries to use insurance to hedge their risk of loss. This chapter emphasized that it is crucial to understand the tradeoff of paying insurance premiums for safer, but lower income versus uninsured, more volatile income. The modeling in this report helps evaluate the tradeoff between enhancing and protecting economic performance.

By incorporating disasters as a component of macroeconomic projections for countries, effective planning options at the country and international level can be more fully explored. The framework presented in this report is a first attempt to incorporate probable future disaster losses into macroeconomic projections and outline the basic tradeoffs for policymaking.

4.2 Lessons Learned

Natural disasters can make a difference in the economic development of poor countries. The poor bear a heavy burden from natural catastrophes. As a consequence, natural disasters—like other events that impact development—should be accounted for in the planning process. Three central messages emerged in the preparation of this study. The first lesson learned is that planning for the impacts of catastrophes is possible. The second lesson is that the ability to finance losses following a catastrophe is crucial to recovery. Hence, planning for catastrophes is also essential. Finally, evaluating the potential benefits of risk transfer alternatives requires a formal model like the one prepared for and described in this study.

It is possible to plan for natural catastrophes.

During the past decade, scientific understanding of the causes and consequences of natural catastrophes has dramatically improved. Models to predict the frequency and severity of catastrophe events have been blended with sophisticated techniques to identify assets at risk (Walker 1997). In the developed world, the substantial catastrophe risk insurance market has driven catastrophe modeling (Swiss Re 1999).

The case studies illustrated how these probable losses can be incorporated into development planning. For example, in the Argentina example, the model used the estimate of direct damages to capital stock to derive an estimate of the flows required for emergency relief and reconstruction. The model generated probabilistic projections of the macroeconomic impacts of the diverted funds. In the Nicaragua example, the model provided insight into how disasters can impact the poor. The analysis supplemented the macroeconomic model (RMSM) with a household level model and displayed both proportional and then disproportional impacts of catastrophes on the poor.

The ability to finance losses following a catastrophe is critical to recovery.

The macroeconomic simulations in the case studies illustrated that the ability to immediately and fully replace lost capital stock plays a critical role in determining a country's recovery from the impacts of a disaster. The immediate availability of post-catastrophe resources affects how quickly a country can resume its growth path. For example, assuming that Argentina has sufficient resources to finance an estimated exposure loss, the negative consequences of this probabilistic event include increased government consumption and imports and decreased private consumption. Developing countries tend to rely heavily on external resources to finance catastrophe losses. With this dependence comes a risk that a country may not be able to secure the full amount necessary to replace lost capital stock, or may fail to secure the resources in a timely manner. The risk of this dependence is illustrated in scenarios in which Honduras secures full and partial funding. In the Honduras case, which is a small country with relatively low domestic resources and high disaster exposure, private consumption and foreign savings are not reliable sources of post-disaster reconstruction and relief funds. The model forecasted the impact to Honduras assuming no access to foreign assistance to meet reconstruction needs. As expected, both investment and production suffer. An inability to finance probabilistic annual losses to capital stock can cause expected future economic performance to stagnate. Without full and immediate replacement, the case of Honduras illustrated disasters can weaken economic growth. Further, the study of Nicaragua found that without full and immediate replacement resources, a natural catastrophe can suspend poverty reduction and other central development objectives for years following the event.

Evaluating the potential benefits of risk transfer alternatives requires a formal model.

Catastrophe insurance is virtually nonexistent in developing countries. Less than 1% of the losses from natural catastrophes are insured in the world's poorest countries. Several proposals exist to develop insurance as an alternative source to post-disaster financing for developing countries. However, insurance involves a tradeoff between opportunities for higher but uncertain income levels and lower but safe income. To value the tradeoff requires measuring the relative costs and benefits of accepting the risk. Valuing the insurance purchase tradeoff requires a formal model that estimates the impact of catastrophic events and reconstruction financing. The model developed for and described in this study is one such example.

4.3 Recommendations

The major policy recommendation that emerges from this study is that risk management must be a formal component of development planning for countries with high natural catastrophe exposure. Through planning, countries can reduce some of the negative impacts on development and improve the situation of the poor during and after crises. Such risk management involves three major steps: risk identification, reduction and financing. The recommendations of this report address each of the steps of the risk management process and are directed both at governments and development agencies.

First, countries must identify potential sources and assess potential costs of natural catastrophe risk. Second, countries must weigh the costs and benefits of mitigation and risk financing measures. Third, the international donor community should provide greater incentives for proactive risk management in countries affected by natural catastrophes.

Identify potential sources and assess potential costs of disaster risk

Countries must identify potential sources and assess potential costs of natural catastrophe risk. This risk must be taken into account when designing development strategies. For example, the potential effects of natural catastrophes should be included in infrastructure investment decisions, in Country Assistance Strategies (CAS) of the World Bank, and in the debt repayment projections at the core of Highly Indebted Poor Country (HIPC) proposals.

Risk can be determined by combining estimates of natural hazards with the underlying vulnerability. Two steps are necessary for risk assessment for an entire country. First, policy makers need an estimate of the potential direct loss (a stock variable) from catastrophe exposure. Potential direct loss can be assessed by combining hazard exposure with the physical vulnerability of a country's capital stock. Second, to account for the flow effects on the economy, this loss potential must be combined with the macroeconomic vulnerability of a country. For this purpose reliable and transparent modeling for catastrophes and their impacts is crucial.

Evaluate costs and benefits of mitigation and risk transfer measures

Risk identification provides the basis on which to evaluate cost-efficient mitigation and risk financing measures. As funds for development purposes are scarce the efficient allocation of resources and a comparison of costs and benefits is a critical issue. The evaluation of risk management measures is particularly important for two areas:

1. **Planning for infrastructure protection**. Public infrastructure provides the basis for economic activity and basic social goods, particularly for the poor. Countries need to understand the impacts of catastrophes on infrastructure. Planning for natural catastrophes must include measures for infrastructure protection in the future. This protection may come in the form of mitigation as well as measures to finance the reconstruction and restoration of public infrastructure.
2. **Planning for livelihoods of the poor.** Countries need to find ways to reduce the poverty-deepening impacts of disasters. Policies must be designed to address the most acute needs of the poor before and after catastrophes, and will include effective means for protecting livelihood and access to public infrastructure.

On the basis of risk identification, risk financing options comprising risk bearing and risk transfer for residual risk remaining after the implementation of mitigation measures can be evaluated. Risk transfer is expensive and involves a tradeoff between opportunities for higher but uncertain income levels and lower but safe income. Decision makers need to combine estimates of the costs and benefits of these options with the broader priorities determined for general policymaking. The international donor community should provide incentives for pro-active risk management behavior. The international donor community should also emphasize the development of comprehensive risk management approaches. In particular it should focus on the incentives and support necessary to foster risk identification, mitigation and risk transfer programs. A careful approach is needed providing more economic incentives to deal with risk while keeping the immediate emergency and reconstruction needs of developing countries and the poor in mind.

Appendix A

Estimating Catastrophe Exposure

Catastrophe exposure is calculated by combining natural hazard impacts with the distribution of a country's physical assets. Swiss Re publishes its catastrophe exposure assessment methodology.[19] Hazard models assess catastrophe exposure from geological phenomena, such as volcanoes and earthquakes, and meteorological phenomena, such as hurricanes and floods. Estimates of loss potential are derived from seismic and meteorological models employing extensive databases of historical catastrophic events and the economic losses they cause.

The flood risk assessment for Argentina is based on a Geographical Information Systems (GIS) scenario analysis[20] that incorporates historical flood surveys, river basin studies, and a statistical analysis of recent flood events. Extrapolating the results of the Great La Plata Basin analysis to a national level determines flood risk in Argentina.

For Honduras and Nicaragua, hazard analysis begins with an earthquake model to estimate the frequency of earthquakes of different magnitudes. The model distributes the impacts of historical earthquake point sources across a global grid. The model uses historical earthquake data from the Global Hypocenter Database of the United States Geological Survey Earth Science Information Center (USGS/ESIC)[21].

A second component is a tropical cyclone model that simulates all historical tropical cyclones on a global grid. The model relies on historical data from the National Hurricane Center[22] and wind model methodology by Ian Young and Greg Holland.[23] The model calculates cyclone risk due to wind damage. In areas like Honduras and Nicaragua where hurricane-induced flooding causes a large portion of losses, wind-related risk estimates are measured by a factor proportional to water-related risk.

Finally, catastrophe exposure is expressed in terms of dollar losses. To translate fractional asset losses to dollar losses requires an estimate of total capital stock in each country. For this task, the initial level of capital stock is estimated via three independent methods. The first estimate is the product of the World Bank's estimate of last year's output with extrapolated historical values for capital-output ratios taken from the Penn World Tables.[24] The second estimate uses the World Development Indicator data to accumulate depreciated historical series of real gross domestic fixed investment. The third estimate relies on third-party data. For Argentina third estimates were provided by the Centro de Estudios de Producción (CEP)[25] and the UN's Economic Commission for Latin America and the Caribbean (ECLAC)[26]. For Honduras the Inter-

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[19] Publications can be downloaded or ordered from their website, http://www.swissre.com.

[20] GIS is "a systematic means of geographically referencing a number of 'layers' of information to facilitate the overlaying, quantification, and synthesis of data." For more information about using GIS in natural hazard management, please refer to http://www.oas.org/usde/publications/Unit/oea66e/ch05.htm

[21] for more information see *http://mapping.usgs.gov/esic/esic.html*

[22] http://www.nhc.noaa.gov/

[23] Atlas of the Oceans: Wind and Wave Climate edited by Ian Young, School of Civil Engineering, Australian Defence Force Academy, Canberra, Australia and Greg Holland, Senior Principal Research Scientist and Leader of the Mesoscale Meteorology Research Group at the Bureau of Meteorology Research Centre, Melbourne, Australia.

[24] The Penn World Tables 5.6 by Alan Heston & Robert Summers, described in Alan Heston & Robert Summers, *The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988*. Quarterly Journal of Economics, May 1991, pp.327--368. or http://datacentre.chass.utoronto.ca/pwt/

[25] CEP: http://www.mecon.gov.ar/cep/default1.htm

[26] ECLAC: http://www.eclac.org/

American Development Bank's Economic and Social Data Base (ESDB) provides an alternative estimate, and the Nehru/Dhareshwar and King/Levine datasets estimate capital stock for Nicaragua.[27]

[27] Nehru, Vikram, and Ashok Dhareshwar. 1993. "A New Database on Physical Capital Stock: Sources, Methodology and Results." Rivista de Analisis Economico 8 (1): 37-59 and King, R. G., and Levine R., 1994, Capital Fundamentalism, Economic Development, and Economic Growth, Carnegie-Rochester Conference Series on Public Policy, Vol. 40.

Annex B

Fitting Probability Distribution Functions

IASA used Palisade Decision Tools' BestFit software program to determine the probability distributions and parameters that best fit Swiss Re's data points for catastrophe exposure in the case study countries. BestFit uses the method of least squares, meaning that the optimal fit is the one that minimizes the root-mean square error between the points and the theoretical function.

Argentina flood	Weibull(1.0122, 0.14753) Shift = -0.23611
Honduras earthquake	Pearson V(2.1796, 0.32510) Shift = -0.40966
Honduras storm and flood	Pearson V(2.0958, 2.0077) Shift = -2.7027
Nicaragua earthquake	Pearson V(2.1796, 0.32510) Shift = -0.40966
Nicaragua storm and flood	LogLogistic(-1.29777, 0.82627, 2.4315)

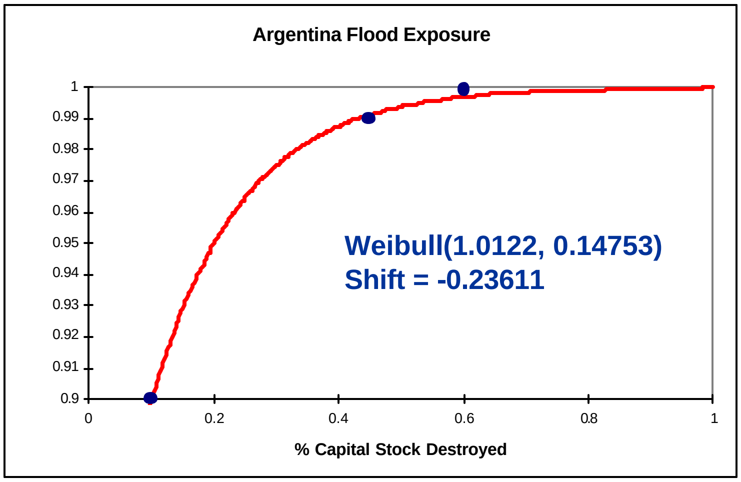
The functional form of the above distributions is as follows:

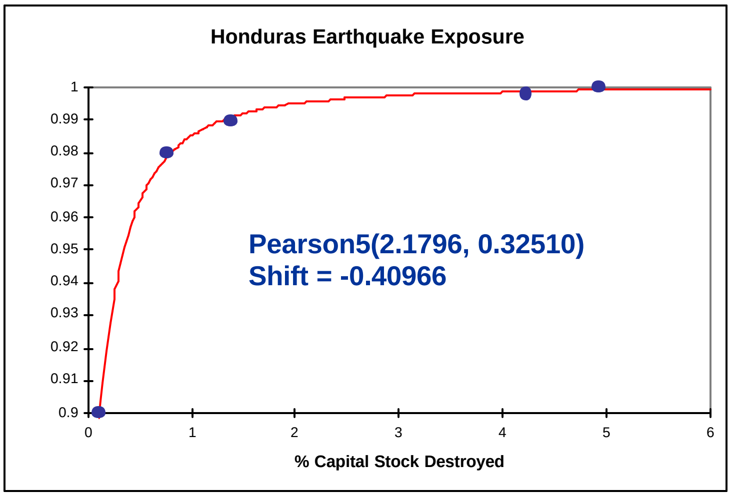
Weibull: $f(x;a,b) = abx^{(b-1)}e^{-ax^{(b-1)}}$ where a > 0 and ß≥ 1

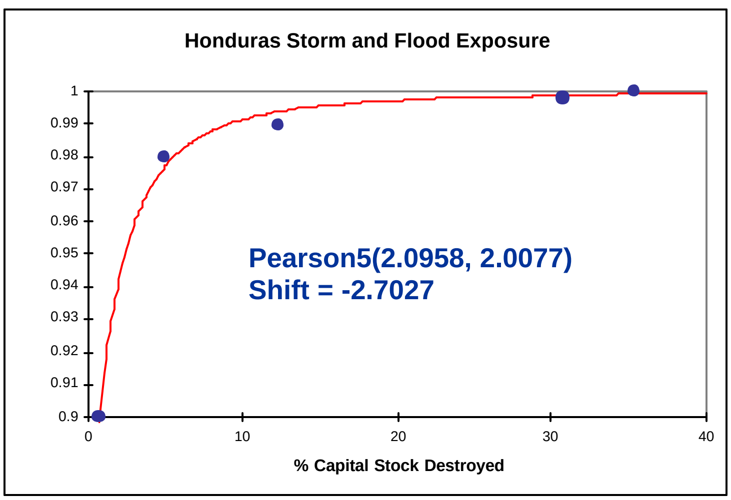
Pearson type V: $f(x;a,b) = \frac{1}{b^a \Gamma(a)} x^{-(a+1)} e^{-1/bx}$ (also known as Inverse Gamma)

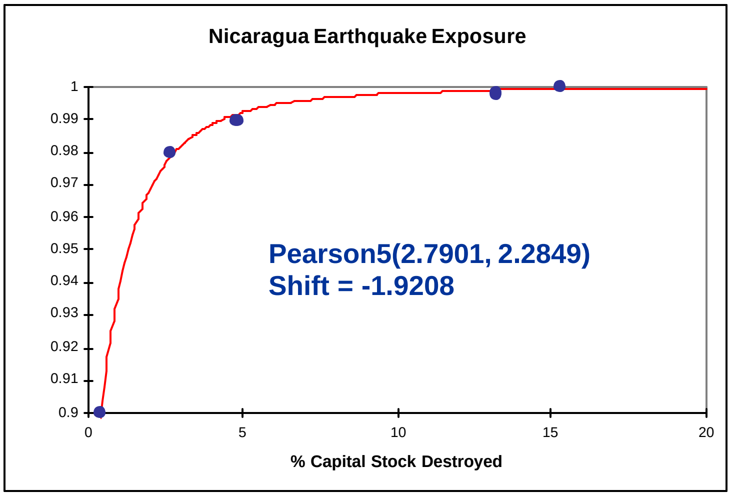
LogLogistic: $f(x;m,s) = \frac{1}{sx} f_{\log is}\left(\frac{\log(x)-m}{s}\right)$ where $f_{\log is}(z) = \frac{e^z}{\left(1+e^z\right)^2}$

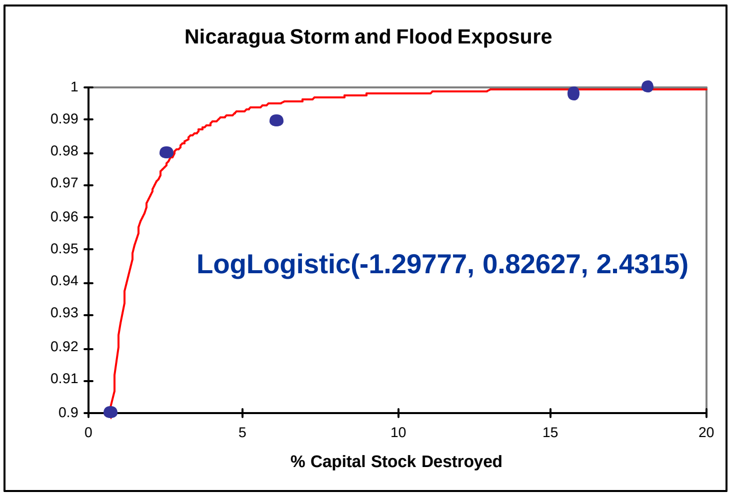
The quality of the fit can be seen by the following graphs of the data points and the best-fitting cumulative distribution functions. Note that all curves are lower-truncated at the 10-year loss.


Argentina Flood Exposure
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9
0
0.2
0.4
0.6
0.8
1
% Capital Stock Destroyed
Weibull(1.0122, 0.14753)
Shift = -0.23611


Honduras Earthquake Exposure
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9
0
1
2
3
4
5
6
% Capital Stock Destroyed
Pearson5(2.1796, 0.32510)
Shift = -0.40966


Honduras Storm and Flood Exposure
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9
0
10
20
30
40
% Capital Stock Destroyed
Pearson5(2.0958, 2.0077)
Shift = -2.7027





Truncating the theoretical curve at the 10-year event and using Monte-Carlo simulation yields the following summary statistics:

	% of capital stock destroyed
Argentina flood	0.025
Honduras storm & flood	0.42
Honduras earthquake	0.06
Nicaragua storm & flood	0.22
Nicaragua quake	0.20

Annex C

The Revised Minimum Standard Model (RMSM)

The Revised Minimum Standard Model (RMSM) is a flow-of-funds accounting model used by the World Bank to ensure consistency between the sources and uses of funds in a national accounting framework.

There are three important advantages to using RMSM. First, the model is designed to ensure internally consistent projections. Second, it presents results in a familiar and operationally-functional format. Third, although quality data tend to be difficult to obtain for developing economies, RMSM contains the most accurate, detailed, and current macroeconomic data available. The following subsections explain the structure of RMSM.

Consistency framework

RMSM is a consistency framework model that uses the flow-of-funds accounting methodology. It reconciles sources and uses of funds in a national accounting framework. RMSM provides arithmetic consistency; user judgment is needed to ensure that the results are economically plausible. Modeling with RMSM is intended to be an iterative process: users enter assumptions, run the model to observe the consequences of those assumptions, evaluate these consequences, modify their assumptions as necessary, and re-run the model. RMSM's projections are internally consistent: the expenditures of each sector equal its revenues and the outflows from each sector are the inflows into the other sectors.

Four sectors

The four sectors from and to which funds flow are: the public sector, the monetary sector, the foreign sector, and the private sector. The public sector usually represents the central government. In some cases—for example in the case of Nicaragua—where better data is available, the public sector is enlarged to a consolidated public sector that includes other levels of government and non-financial public enterprises. The monetary sector represents the central bank and deposit money banks. The foreign sector is the balance of payments viewed from outside. And, finally, the private sector represents all remaining entities, including non-monetary financial institutions. If the public sector refers exclusively to the central government, then the private sector also includes non-central government agencies and parastatal enterprises.

Nine core equations

Nine equations are at the core of RMSM. First is the GDP identity whereby output *ex post facto* equals total expenditures over all the sectors. This is followed by four budget constraints for each of the four sectors. These constraints dictate that the sources (revenues) available to the sector equal its uses (expenditures). Finally the model includes four financial asset market clearing relationships. These relationships define money demand, foreign credit, government borrowing from the private sector, and domestic monetary credit.

Three closures

To ensure that all of the above accounting identities hold, the model is structured around residual variables. The model first calculates all variables except for one in each identity. The remaining variable, the residual, is then determined by default. There are many possible choices of residual variables to satisfy all of the accounting identities. The creators of RMSM identified three different sets of residual variables that are particularly useful to World Bank staff. Each set of residuals is called a closure. The three closures are public closure, private closure, and policy closure. In private closure the residuals include private spending and private borrowing. In public closure the residuals include public spending and public borrowing. In each of these closures, foreign credit is determined by previously committed loans and new loans that fill the balance of payments requirement. The model assumes that these new loans, disbursed to the private sector in private closure and to the public sector in public closure, come from foreign commercial banks. In the third closure, policy closure, no new loans are available. Foreign credit is specified in advance and imports adjust to close the balance of payments. The user specifies government policies and private sector behavior rules and the model extrapolates real and nominal GDP.

The main purpose of the private and public closures is to analyze economic consistency between macroeconomic targets (such as GDP growth, inflation, foreign reserves, and exchange rates) and expected fiscal policies (such as revenue, current and capital expenditure and its sources of finance). In addition, RMSM users evaluate the sustainability of the balance of payments by analyzing the patterns in the exposure indicators, such as foreign debt to GDP and total debt service as a ratio to exports. Finally, users investigate the sustainability of fiscal policies by evaluating the outcomes of, for example, government debt to GDP and interest payments on debt as a function of tax revenues. The purpose of the policy closure is to quantify the consequences of deviating from the base case scenario generated in the private or public closure.

Two approaches to the CAT module

Incorporating catastrophes into development planning depends on the assumptions one makes about a country's ability to absorb the impact of the events. If one assumes that it is possible for a country to divert enough consumption and access sufficient foreign savings to cover the costs of relief and reconstruction post-event, then the modeling can be used to demonstrate probabilistically the macroeconomic impacts of the diverted funds. If private consumption and foreign savings are not reliable sources of post-disaster reconstruction and relief, the model can be used to forecast macroeconomic impacts as a function of the country's ability to access foreign funds.

For the first approach, RMSM can be run in either private or public closure (the authors chose private). The second approach, on the other hand, requires that RMSM be run in policy closure.

Annex D

Overview of the CAT Module

The following table summarizes the different forms of the CAT module designed for RMSM.

Table D-1: Synopsis of CAT modules

	Argentina	Honduras	Nicaragua
Objective	demonstrate probabilistically the macroeconomic impacts of funds diverted for post-event reconstruction and relief	forecast macroeconomic impacts of catastrophes as a function of the country's ability to access foreign funds	forecast macroeconomic impacts of catastrophes as a function of the country's ability to access foreign funds; project poverty implications
Model closure	private	policy	
Real GDP growth	exogenously specified	endogenous	
Reconstruction investment	government undertakes reconstruction investment for infrastructure private sector undertakes reconstruction investment for private capital		
Foreign savings	supplied as necessary	limited	
Government consumption	constant except for year of catastrophe		
Private consumption	endogenously determined	constant	
Production function	ICOR	Cobb-Douglas	
Treatment of capital	capital stock implicit	capital stock calculated	
Treatment of labor	labor implicit	effective labor force decreases in year of event	
Imports	Adjusted upwards post-catastrophe in year of event		
Exports	constant	decrease post- catastrophe proportional to drop in output	
Poverty implications	implicit		explicit

Table D-1 demonstrates the impact of assumptions about the availability of financing post-disaster on the choice of modeling approach. The rest of this section describes the elements of the table.

Country able to access post-disaster financing

Assuming that Argentina wants to meet its growth objectives, the CAT module "shares out" resources required for post-disaster reconstruction investment over possible sources. These sources can be either in the form of private or public domestic savings or "foreign savings" (i.e., foreign capital inflows). If available foreign savings are insufficient to meet balance of payments constraints, additional savings can be accessed. The availability of foreign savings is first calculated on the basis of the supply of various forms of external finance identified in advance. The difference between investment and total savings then comes in the form of additional "gap-fill" foreign borrowing. Appendix E details how the CAT module works for Argentina.

Country unable to access post-disaster financing

If a country is unable to divert enough consumption or access sufficient foreign savings to cover the costs of relief and reconstruction post-event, there will be long-term growth impacts. To evaluate these impacts, the catastrophe module needs a production function that explicitly recognizes the role of capital stock in growth. The CAT module uses a Cobb-Douglas production function with capital and labor inputs.

The CAT module used for Honduras and Nicaragua measures the impact of catastrophes on growth, *given that consumption must stay at base-case levels*. In the CAT module, when a catastrophe occurs, capital stock and effective labor force drop. Government consumption rises in the year of an event by a fraction of the value of capital stock destroyed due to emergency response programs. Exports drop in proportion to their share in output and the drop in output. The module then calculates the amount of additional external savings necessary to resume the pre-catastrophe growth trajectory, given the assumption that neither the private sector nor the public sector will be able to significantly reduce consumption post-catastrophe to mobilize funds for reconstruction investment. To the extent that this additional external savings is available, the economy resumes its growth trajectory in the following period. Long-term effects on the national level are restricted to those attributable to the additional external debt. If the additional external savings are limited, however, long-term effects follow. These effects are due to a perpetual shortfall in output (and, in particular, export production) relative to the base case, a permanent relative increase in some categories of imports countered by a relative decrease in other imports, and permanently reduced savings in both the private and public sectors. Appendix F details the CAT operation for Honduras and Nicaragua.

Poverty

The third disaster study demonstrates the poverty implications of macroeconomic impacts of natural catastrophes. The catastrophe module used in the first half of the Nicaragua modeling is structurally identical to the Honduras module. The Nicaragua exercise first generates a modified projection of real per capita GDP by simulating catastrophic shocks through RMSM. It then passes these estimates into the household-level model and recalculates poverty statistics. These statistics are expressed in terms of both the number of people beneath the poverty and extreme poverty lines and the depth of poverty, or the poverty gap.

The Nicaragua example first measures the impacts that catastrophes would have if each person's share in both growth and catastrophe losses were to be directly proportional to their consumption.[28] To the extent that the poor are disproportionately affected by catastrophes, the Nicaragua example then demonstrates that the poverty impacts will be magnified. Appendix G describes in detail the poverty modeling for Nicaragua.

[28] Consumption being a proxy for income used to determine poverty quintiles.

Annex E

Implementing the Catastrophe Module for Argentina

Investment

Based on the assumption that catastrophic events do not lead to structural economic change, the amount of reconstruction investment necessary to restore output to its pre-catastrophe level is simply the amount of capital destroyed.

The module then calculates the total investment necessary to meet planned GDP growth target. In RMSM, GDP growth is taken as a target and required investment is calculated using an assumed incremental capital-output ratio (ICOR),[29] where:

$$ICOR = \frac{\text{investment}}{\Delta\text{GDP}}$$

ICOR can be interpreted as the amount of new capital necessary to generate an additional unit of GDP. The amount of investment required to meet the target growth rate between the current period and the next period is then the product of the ICOR and that growth rate.

After the catastrophe, the targeted change in GDP can be attained only by increasing investment over base case levels by reconstruction investment. The CAT module accounts for this reconstruction investment by making an upward adjustment to the baseline ICOR. The catastrophe-adjusted ICOR is of the form:

$$ICOR' = ICOR + \frac{\text{reconstruction investment}}{\Delta\text{GDP}}$$

Total investment required to meet the targeted growth trajectory is the product of the catastrophe-adjusted ICOR and base case targeted GDP growth. Note that the upward adjustment to ICOR does not reflect structural change in the economy, change in the aggregate production function, or change in the nature of capital; it is just a computational accounting tool to capture reconstruction investment.

The CAT module then allocates reconstruction investment between public and private sectors. The module assumes that the government takes on the reconstruction of infrastructure stock and that the private sector takes on the reconstruction of non-infrastructure capital stock. The authors assume that infrastructure makes up 30% of capital stock in Argentina over the period of the simulation. The module adjusts government investment to account for its reconstruction investment by increasing the ratio of government investment to GDP. The new catastrophe-adjusted ratio is the old ratio plus the ratio of reconstruction investment to GDP times the fraction of reconstruction investment taken on by the public sector. Private investment, calculated as the difference between total investment and public investment, then adjusts automatically. Implicitly the CAT module assumes that infrastructure and non-infrastructure capital stock are equally vulnerable to catastrophic events.

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[29] The ICOR formulation represents a production function in which the change in output is exclusively a function of the change in capital stock.

Resources for investment

The next step is to allocate resources to finance reconstruction investment. Reconstruction investment must be financed either by lower domestic consumption or increased foreign borrowing. Consider the national income accounting identity, where *GDP* is output, *C* is private consumption, *Ip* is private investment, *Ig* is government investment, *G* is government consumption and *RB* is the resource balance (exports minus imports):

$$GDP = C + I_p + I_g + G + RB$$

Using prime notation to denote the post-catastrophe situation,

$$I'_p + I'_g = I_p + I_g + \text{reconstruction investment}$$

After the catastrophe, assuming GDP to be unchanged (i.e., that the goal is to get back to the pre-event situation),

$$GDP = C' + I_p + I_g + \text{reconstruction investment} + G' + RB'$$

Subtracting this from the original expression and rearranging,

$$\text{reconstruction investment} = (C - C') + (G - G') - (RB' - RB)$$

The first two terms together represent foregone domestic consumption and the last term represents added foreign borrowing. The greater the reliance on foreign borrowing, the more modest the required domestic consumption cuts. The CAT module proceeds by adjusting government consumption and the resource balance, with adjustments in private consumption being calculated as a residual.

Foreign savings

Because of immediate reconstruction, the GDP growth trajectory is unaffected by catastrophic events. The CAT module for Argentina therefore assumes that export production is also unaffected. Food imports, however, rise in proportion to the magnitude of the event in order to replace domestic food production lost due to the event or foregone during the reconstruction period. In addition, capital goods imports rise post-catastrophe as reconstruction investment requires additional capital goods imports. The CAT module assumes that Argentina will be able to supply only 80% of reconstruction capital goods domestically, acquiring 20% from abroad. Capital goods imports therefore increase post catastrophe in RMSM both because additional investment increases these imports and because the composition of the additional investment has shifted towards foreign goods. Through the national income accounting identity, this increase in imports dampens the downward shock to domestic consumption.

Because the CAT module assumes that 1) foreign exchange reserve coverage stays constant and 2) catastrophes do not affect the decisions of monetary authorities to change money supply, the cost of the increase in imports must come in the form of additional foreign inflows. These "gap-fill" loans[30] that will need to be paid back in future periods. The catastrophe module distributes the gap-fill loan between the private and public sectors (instead of allocating the entirety to the private sector as is traditionally the case in private closure) as a function of the reconstruction investment undertaken by each sector.

Consumption

The CAT module increases government consumption in the year of an event in proportion to the magnitude of the event to represent emergency relief expenditures. The authors furthermore propose that following a natural catastrophe a government has limited ability or desire to lay off people to cut back consumption. The domestic consumption cuts necessary to finance reconstruction investment and the additional government expenditures therefore fall entirely upon the private sector. In the CAT module for Argentina the authors assume that emergency relief costs amount to 10% of the value of the capital stock destroyed.

[30] For these loans a 9.5% interest rate, 10-year maturity, no grace period for private borrowers and one year grace period for the government is assumed.

Annex F

Implementing the Catastrophe Module for Honduras and Nicaragua

Output

In contrast to the Argentina report, the Honduras and Nicaragua reports focus away from the identification of the resources needed to achieve a given growth target and towards the evaluation of the impacts on growth of failing to mobilize those resources. In order to shift this focus, the analysis requires an explicit recognition of not only current investment but also past accumulated investment, that is, of capital stock. The first task of the CAT module is therefore to replace the ICOR production function with a Cobb-Douglas with capital stock and effective labor inputs, of the form:

$$GDP = AK^{a}L^{(1-a)}$$

where K represents capital stock, L represents effective labor force, A is an efficiency parameter and α represents the production elasticity of capital stock.

The CAT module first generates base case capital stock and labor force time series. For the capital stock time series the authors obtained data (using historical values for capital-output ratios and current output or accumulating depreciated historical series of real gross domestic fixed investment) for the initial level of capital stock. Future capital stock values equal the previous period's capital stock plus the previous period's gross domestic fixed investment (that it, real investment less change in stocks) less depreciation. The authors assumed 7% depreciation for the purposes of the Honduras and Nicaragua reports. For the labor force time series the CAT modules estimates the percentage of the population in the labor force. It multiplies this parameter by the population time series extrapolated in the PIT worksheet. The authors assumed a fixed 50% labor force participation rate for both Honduras and Nicaragua. Note that a possible extension of the modeling effort could involve adjusting labor force participation when catastrophes occur.

Next the CAT module estimates the production elasticities of the Cobb-Douglas production function. For the Honduras and Nicaragua models, the authors assumed constant returns to scale and equal marginal factor productivity across labor and capital. The elasticity for capital and labor is then each factor's share in production. The authors set elasticities for both factors to 0.5 in the Honduras and Nicaragua models.

The following step is to calibrate the growth coefficient of the Cobb-Douglas function given the time series for capital and labor, the elasticities of each factor, and the desired growth trajectory specified in RMSM using the desired growth rates.

The module receives a catastrophe shock input as a time series of fraction of capital stock destroyed. It recalculates capital stock figures increasing capital stock with catastrophe-adjusted values of real gross domestic fixed investment and reducing capital stock not only by depreciation but also by capital stock destroyed in the current period by catastrophic events. It adjusts the effective labor force reduced by the fraction of labor force affected by the catastrophe. The authors assumed that for every percentage of capital stock destroyed, the effective labor force was reduced by a tenth of a percent in the year of the event.

Finally the module recalculates real GDP using the base-case elasticities, base-case growth coefficient, and catastrophe-adjusted levels of capital and labor. Note that real GDP will drop relative to the base case in the year of a catastrophic event and will remain low in future periods if gross domestic fixed investment in the year of the event fails to rise enough to counterbalance the loss in capital stock.

Exports

In the CAT module for Honduras and Nicaragua, export volumes decrease as a function of the share of exports in production. In RMSM export volumes are commodity-specific. To model the effect of catastrophes on exports, the module first converts the export volume for each commodity from constant USD to constant local currency. It then calculates a time series of the ratio of the export volume of each commodity to real GDP at market prices (also measured in local currency). The user should paste-value these ratios into a separate location. Then the isolated ratios and the new catastrophe-adjusted values for real GDP determine the catastrophe-adjusted export volumes in local currency for each commodity. The module converts the volumes back to real USD and feeds them back to the TRA worksheet. In the case of Nicaragua, the authors repeated this process for coffee, shrimp, meat, sugar, and "other" imports.

Imports

In contrast to the CAT module for Argentina, not only does reconstruction investment require additional capital goods imports, but food imports also rise post-catastrophe in proportion to the magnitude of the event to replace lost domestic food production (Argentina does not currently import food). The authors assume that food imports rise by 1% for every 10% downwards shock in capital stock. The CAT module processes capital goods imports identically in the Argentina and Honduras and Nicaragua modules, except that the percentage of reconstruction investment that requires the capital be imported from abroad is increased to 30% of total reconstruction investment.

Foreign savings

As in the module for Argentina, the CAT module for Honduras and Nicaragua assumes that 1) foreign exchange reserve coverage stays constant and 2) catastrophes do not affect the decisions of monetary authorities to change money supply. In the cases of Honduras and Nicaragua, however, additional foreign inflows may not be available to finance the lower export earnings and higher import expenditures. To the extent that these flows are unavailable, the balance of payments constraint drives a decrease in imports of other consumer goods.

To determine additional external savings, the CAT module first back-tracks through the gap-fill loan equations to determine how much gap-fill loan would be needed in order for the country to resume its targeted growth trajectory in the period following a catastrophic event. The module first calculates necessary additional investment from the Cobb-Douglas function, then, given the other elements in the SNA identity, the necessary increase in imports, determining the necessary change in other consumer goods from the balance of payments identity, the necessary additional capital flows, and finally the necessary additional external savings to achieve those flows.

The catastrophe module takes the fraction of the necessary additional external savings actually obtained as an input. The product of these two determines the additional external savings received. The CAT module then distributes these additional savings between the private and public sectors (instead of allocating the entirety to the private sector as is traditionally the case in private closure) as a function of the reconstruction investment undertaken by each sector. The authors assume that the additional external savings available come at highly-concessional IDA rates.

Private consumption

In the private sector, the propensity to consume wage and transfer income rises as wage and transfer incomes fall in order to maintain consumption at pre-catastrophe levels. The catastrophe module implements this assumption by first separating disposable income due to interest income from disposable income due to wage and transfer income. It then calculates and fixes the base-case time series of net disposable wage and transfer income and the ratio of private consumption to net disposable income, that is, the propensity to consume wage and transfer income. The catastrophe-adjusted ratio is then the sum of the original ratio and an adjustment factor. The adjustment factor is calculated by multiplying the original ratio by the percentage change in net disposable income relative to the base case (that is, by dividing the difference between the old and new values by the new value). Catastrophe-adjusted private consumption is then the product of the catastrophe-adjusted net disposable income and the catastrophe-adjusted propensity to consume wage and transfer income. Private consumption, thus formulated, remains constant despite changes in wage and transfer income. Note that this formulation highlights the necessary reduction in domestic savings necessary to stabilize consumption.

Public consumption

In the CAT module for Honduras and Nicaragua, government consumption is stabilized in the same way to private consumption, with the exception that it increases in the year of the event due to emergency response expenditures. The assumption is that work programs are used to rebuild damaged infrastructure and are therefore counted as reconstruction investment. In addition, income support for those unable to work comes in the form of transfers between sectors and therefore does not affect public consumption figures.

Specifically, the CAT module calculates and fixes the base-case time series of government consumption. The catastrophe-adjusted ratio of government consumption to real GDP is the sum of the original ratio found in the Assumptions (ASU) worksheet and an adjustment factor. The adjustment factor is calculated by multiplying the original ratio by the percentage change in real GDP relative to the base case. Catastrophe-adjusted government consumption is then the product of the catastrophe-adjusted real GDP and the catastrophe-adjusted ratio of government consumption to real GDP, plus any additional consumption spent on emergency response in the year of a catastrophic event. The authors assume that emergency response will cost 10% of the value of capital stock destroyed due to the event.

Investment

As in the CAT module for Argentina, the government undertakes reconstruction investment of infrastructure while the private sector undertakes reconstruction investment of non-infrastructure capital stock. The module increases public investment by its share of reconstruction investment by increasing the ratio of government investment to GDP by the ratio of reconstruction investment to GDP times the fraction of reconstruction investment taken on by the public sector. Again the CAT module assumes that infrastructure and non-infrastructure stock are equally vulnerable to catastrophic events.

Annex G

Implementing the Poverty Module for Nicaragua

The poverty modeling in this report is based on the household survey data in the Nicaragua Living Standards Measurement Study Survey 1998 conducted by the World Bank, the United Nations Development Programme (UNDP) and the Government of Nicaragua.

The survey collects data from over 4000 households. Along with each household is a measure of the probability of selecting that household from the population, that is, the representativeness of that household. The per capita data, multiplied by the number of members in the given household and the household representativeness approximates national-level data.

The most common measure of poverty is in terms of the number of people beneath the poverty and extreme poverty lines. In Nicaragua, the poverty line is established at the average level of total expenditures (4,259 cordobas per person per year) of families whose food expenditures (2,246 cordobas per person per year) provide them with just the calories needed to avoid the negative effects of malnutrition. The extreme poverty line is set at the level of food expenditures needed to avoid malnutrition. Someone at the extreme poverty line therefore could either spend their entire income on food, and consume the minimum amount of calories, or spend on a combination of food, shelter, clothing, etc. and suffer from malnutrition. In addition, another equally important measure of poverty is the depth of poverty, or the poverty gap: the amount of money needed to raise expenditures of the poor to the poverty line and of the extremely poor to the extreme poverty line, respectively.

The main input to the CAT modeling work is annual per capita consumption adjusted for regional price differentials for each of the surveyed households. Other inputs include projections of the population growth rates of the different quintiles (assumed in this first run to be equal across quintiles) and the elasticity of consumption with respect to income (assumed to be 1 because regressions on the data did not yield statistically significant results). The final input is the output from the RMSM model: projections of real catastrophe-adjusted growth rates (also assumed in the initial runs to be equal across quintiles).

The poverty model then uses the real catastrophe-adjusted growth rates to project annual per capita consumption and test by the cutoff figures given above whether the members of each household qualify as poor or extremely poor. The representative population of each household grows along with the quintile-specific growth rates.

The changes in poverty, extreme poverty, in the poverty gap, and in the extreme poverty gaps are then contrasted relative to a base line in which RMSM-generated improvements in per capita GDP are equally distributed among the population as a function of current consumption levels.

To model the disproportional impacts, the same process is repeated, with the exception that the poverty model now doubles for the lowest three quintiles the catastrophe adjustment to real growth rates calculated in RMSM.

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