Natural Disaster Risk Management and Financing Disaster Losses in Developing Countries

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Summary of the dissertation

Natural Disaster Risk Management and Financing Disaster Losses in Developing Countries

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The dissertation analyzes the significant economic impacts natural disasters may exert on developing countries and the viability of ex-ante disaster management, termed risk management, undertaken by national governments in reducing those impacts. In particular, the economic viability of risk transfer by national governments of disaster risk to its infrastructure is discussed and analyzed by means of a modelling approach. Risk transfer has become a policy issue and forms an important component of disaster management strategies particularly in Latin America and the Caribbean. However, currently risk transfer instruments are not used frequently by national governments due to their assumption of disaster risk. Economic theory suggests that governments can assume risk if they are able to share or pool it without major difficulties. For disaster risk, this applies generally to the more developed countries. On the contrary, developing countries are often not able to finance disaster losses, relief and reconstruction by their own means. The international donor community in its role as "reinsurer of last resort" is assisting in such cases. Even then, however, some losses will remain unfinanced and a financing gap - an inability to finance the losses fully - will occur, which creates significant developmental losses, if e.g. important infrastructure elements like roads and bridges cannot be repaired and put into use again. Consequently, risk transfer instruments may help in providing financing for those losses.

In order to study these issues and compare the costs with the benefits of risk management measures, a stochastic simulation approach is developed. The modelling combines probabilistic information on the direct losses due to natural disasters with a macroeconomic projections model. Outputs are macroeconomic flow impacts such as impacts on GDP. While the direct losses give account of the magnitudes of potential catastrophes, the macroeconomic losses represent the full consequences that catastrophes may cause to an economy. In order to analyze the costs and benefits due to undertaking of risk management measures, a Cost-Benefit Analysis approach is employed. Risk is accounted for by using the mean-variance method that basically relies on the mean and variance weighted by a parameter representing the decision-maker's preference to risk.

The main objective of the thesis is to establish a platform to provide information on the costs due to disasters and the costs and benefits of disaster risk management with the focus on ex-ante risk financing measures by means of risk transfer (particularly insurance and reinsurance) by governments in developing countries. The final objective is to provide insight into the specific conditions where risk financing may constitute an option that provides net benefits and increases social welfare.

Two case studies are conducted on countries with different exposures to disaster risk and different economic vulnerabilities: Honduras, a low income country subject to severe disaster risk, and Argentina, an upper middle income country with moderate exposure to natural disasters. A number of insights are derived from the case studies: disasters can cause large economic impacts and hamper socioeconomic development in some developing countries considerably. The losses as e.g. measured by GDP can be substantial depending on the degree of the hazard, the vulnerability and the elements at risk. Finally, risk transfer can be a viable risk management tool to decrease the risk to an economy as it stabilizes the financing flows and reduces financing gaps post-disaster. In total, such risk transfer arrangements may contribute to decreasing economic volatility resulting in more robust development in developing economies.

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I GENERAL PART

1 INTRODUCTION

1.1 Background and problem statement

Natural disasters constitute a severe problem, particularly for a number of developing countries[1] where they repeatedly cause a high number of fatalities, affect a large portion of the population, and incur substantial social, economic and long-term developmental losses.

A natural disaster event is commonly defined as an extreme event triggered by geophysical causes affecting an exposed and vulnerable society in such a way that society's coping capacity is exceeded and outside assistance is needed.

There were about sixty million casualties during the 20th century due to natural disasters. In the 1990s, the annual human toll approximated 79,000 casualties on average. Most of the fatalities occurred in the developing countries. Economic losses amounted to 61 billion USD in the annual average of which 18% were insured. While the major part of the absolute losses occurred in the developed world, the losses in relative terms were substantially larger in developing countries. Measured as a fraction of GDP, during the period 1980-1999 losses in the least developed countries amounted to 13.3% compared to only 2.5% in the developed world (CRED 2002; Munich Re 2000: 19-25).

In a joint statement by the International Federation of the Red Cross and Red Crescent Societies (IFRC), the largest emergency relief organization, and the World Bank, the largest development-sponsoring organization, concern about the challenges posed by natural disasters to developing countries and the poor was expressed as follows:

> Reducing disaster vulnerability in developing countries may very well be the most critical challenge facing development in the new millennium. Rapid population growth, urbanization, environmental degradation, and global climate change are all contributing to an increase in the frequency and magnitude of disasters. And their most deadly impact is on the lives and living environment of the poor (Wolfensohn and Cherpitel 2002).

This statement calls for an increase in efforts to engage in disaster management in order to reduce the impacts of disaster events. Disaster management aims to reduce the impacts and losses before, during, and after events. Efforts in this field have historically focused on the time period during or immediately after catastrophes (relief period) and the longer time horizon following relief activities (reconstruction period), which can be described as an *ex-post approach*. Following the recognition that a mere focus on after-the-fact approaches is unsustainable in the long run, the paradigm has

[1] The term developing countries in this thesis is meant to comprise the emerging countries as well.

recently been shifting towards more emphasis on measures taken before events, referred to as an *ex-ante approach*. Awareness for this has been created particularly by the International Decade of Natural Disaster Reduction (IDNDR) declared by the United Nations in the 1990s. Today, efforts in this field generally aim at a more comprehensive approach involving a combination of measures taken before actual disaster events (ex-ante) and measures during and after disasters (ex-post) as e.g. explained in a disaster management action plan proposed by the Inter-American Development Bank (IDB 2000).

1.2 Scope and main objectives

This thesis is concerned with the viability of ex-ante disaster management, termed *risk management,* to reduce the large impacts of disasters on developing countries, in particular on their economies. Risk management comprises three elements:

- risk identification and assessment of potential impacts,
- mitigation, the reduction of risks by e.g. building dams, improving early warning systems or preparing people for possible events, and
- risk financing, the arrangement of financing prior to actual events so that in case of an event, sufficient financing will come forward.

Risk management can and should be undertaken by a variety of actors such as individuals, communities, businesses or local and national governments. The thesis focuses on risk management by national governments which are often the main actors in this field in developing countries. Risk management of natural disasters in developing countries is currently broadening the focus; so far mainly mitigation activities have been undertaken whereby the number of casualties was successfully reduced. However, economic losses and impacts have remained high and constitute a large developmental burden. This places considerable pressure on governments having to bear a large part of these losses due to their role as "insurers of last resort" for the private sector and particularly the poor, and due to the losses to their own public assets (e.g. infrastructure, schools and hospitals).

The common approach to loss financing by governments is to assume these losses; however, typically developing countries cannot finance these losses fully by their own means. Generally, the international donor community helps with financing and is considered a "reinsurer of last resort." Even so, parts of damaged assets remain unreplaced due to a lack of reconstruction financing causing significant longer-term effects and costs.

A theoretical underpinning to this strategy of assuming the losses is provided by the risk-neutrality theorem of Arrow and Lind (1970), which holds that generally governments can behave risk-neutrally and are able to assume risk relatively effortlessly. Two reasons are discussed: The one is the risk spreading ability of governments which implies that they can spread risk due to their ability to raise taxes and borrow post-disaster. Thus, even large losses spread over the whole population will cause only a negligible loss of income for the individual. And second, governments have the ability to pool a large number of risks. This pool in effect, consists of a large number of public assets in various regions of the country; thus the government's risk portfolio is diversified as a disaster affecting one region will not affect all other regions alike and simultaneously. However, for a number of developing countries recurrently subject to large natural disasters, the Arrow-Lind theorem has to be debated as risk spreading and pooling may not always be feasible. Consequently, in these cases aversion to risk-taking should be the proper preference to risk.

If risk aversion prevails, there will be additional incentives for efforts to decrease risk, and ex-ante financing options can be investigated that usually have higher (annual) costs than ex-post sources. In the wake of the changing paradigm of disaster management, risk transfer has recently moved into the spotlight advanced by multilateral finance institutions like the World Bank and the Inter-American Development Bank which are concerned with the increased financing necessary for disaster-affected countries, particularly in the Latin American and Caribbean region.

One particular option under discussion is risk transfer of public assets by governments, i.e. shifting the obligation to finance losses in exchange for a premium payment. Public assets are owned by governments, and thus constitute their own risk and are highly significant for development. Consequently large effects occur when these assets are lost and rebuilding is delayed.

However, risk transfer arrangements usually have relatively high costs. Premia costs are normally higher than the costs due to the own assumption of risk. In addition, these financial costs create developmental opportunity costs as the budget resources spent on risk transfer instruments have to be diverted from other important sectors such as education, development of infrastructure, and poverty alleviation in general. On the other hand, risk transfer provides stability by indemnifying against disaster losses. In contrast to relying on ex-post financing, the risk of incurring an inability of financing losses, termed *financing gap*, in case of an event is lower. Thus, undertaking risk transfer has to be seen as a trade-off between stability and growth. In order to analyze the desirability of risk transfer and this trade-off properly, it is crucial to know the costs and benefits.

The main objective of this thesis is to establish a platform to provide such information necessary for analyzing the trade-offs involved, namely on the costs due to disasters and the costs and benefits of disaster risk management. The primary focus is on determining the types and magnitudes of the costs and benefits of ex-ante risk financing by means of risk transfer (particularly reinsurance) of infrastructure by governments in developing countries. The final objective is to provide insight into the specific conditions where risk transfer may constitute an option that provides net benefit and increases social welfare.

This thesis concentrates on sudden-onset events such as storms, flooding, and earthquakes. A natural disaster will thus be defined as an event concentrated in time and space whose occurrence is triggered by natural causes. In addition, the focus is on the economic costs, particularly the macroeconomic costs. Other impacts such as the loss of life and measures to reduce those impacts are only marginally discussed. The public sector/government is regarded as the risk management actor. Though the private sector plays only a small role in this analysis, the impacts on this sector are of importance for the modelling approach.

1.3 Methodological approach

To arrive at these objectives, a macroeconomic modelling framework was developed. The RMSM-X model of the World Bank, which is regularly used for macroeconomic projections in World Bank client countries, was extended by a catastrophe module in order to account for the macroeconomic impacts of natural disasters (based on IIASA research as described in Freeman et al. (2002a). In addition, a risk transfer module was developed that allows to study the costs and benefits of governments undertaking a variety of risk transfer strategies for public assets in order to reduce their loss exposure.

The model employs a stochastic simulation approach utilizing the Monte-Carlo method to generate random catastrophe shocks to the economy. Input data for the Monte-Carlo simulation are loss-frequency distribution curves derived from data on potential catastrophe events obtained from Swiss Reinsurance Company. Risk as represented by these stochastic shocks is modeled as a function of the natural hazards, the elements exposed and the vulnerability of the elements.

This thesis limits the discussion to economic vulnerability, which was measured as the ability to undertake reconstruction for damaged assets. Economic vulnerability is to a large degree determined by the structure of an economy (e.g. commodity-based versus high-technology), the prevailing economic conditions (e.g. degree of inflation, economic recession) and the general stage of technical, scientific, and economic development (Benson and Clay 2000:11). Here, economic vulnerability is defined as the inability or lack of domestic and foreign savings for financing reconstruction investment and post-disaster relief.

In order to come to a conclusion about the social desirability of certain risk transfer strategies, a Cost-Benefit Analysis (CBA) approach was used and modified for the specific purpose. The CBA approach measures the net benefits due to these strategies and uses GDP and the induced change as the main welfare indicator.

The modelling framework was applied to two case studies in Latin America with different exposure to hazards and different economic conditions: Honduras and Argentina.

1.4 Scientific contribution

In addition to developing a methodology to address and provide insight into these policy-relevant issues, this thesis aims to help fill the following major research gaps:

1. The inadequate representation of macroeconomic consequences of disasters.
2. Lack in modelling of costs and benefits of disaster risk management, particularly risk transfer. Additionally, no representation of the effects due to the purchase of risk transfer options by sovereign entities existed for public assets.
3. In-depth analysis of risk aversion.
4. Gaps in the economic assessment of costs and benefits.

Modelling of macroeconomic consequences of disasters

No functional and prospective macroeconomic model existed for the analysis of the economic consequences of natural disasters for developing countries in an ex-ante manner. A wealth of information exists on the direct impacts to stock (Swiss Re, Munich Re, EM-DAT databases). Modelling approaches have analyzed the indirect impacts on a regional basis. The aggregate, macroeconomic consequences on the other hand were only assessed post-event by using statistical information or case studies (Otero and Marti 1995; ECLAC 1999; Benson 1997a,b,c; Benson and Clay 1998, 2001). The only modelling approach (Albala-Bertrand 1993) is a very rudimentary approach that does not use ex-ante information; furthermore, assumptions used for the modelling derived from statistical analysis conflict with other research.

The approach developed in this thesis uses and extends an approach developed at the International Institute for Applied Systems Analysis (IIASA) as summarized in Freeman et al. (2002a).[2] This approach allows to assess the macroeconomic impacts of disasters on developing countries in an ex-ante manner. The IIASA modelling approach was further extended. The main addition was the dynamic representation of economic vulnerability. While in the original approach the availability of post-event financing was mainly determined by the availability of foreign financing for which supply-side constraints (0%, 50%, 100% available) were assumed, the current approach represents economic vulnerability dynamically and in more detail by examining the availability from the demand side as well, i.e. the government. The availability is finally summarized in the "financing gap" indicator that shows the amount of financing shortfall to be expected for representative events in given years.[3] The private sector was extended as well, but remains rudimentary and is not the main focus of this thesis.

Modelling of costs and benefits of disaster risk management, particularly risk transfer

The most applicable research on the modelling of government risk management and risk transfer focuses on optimal insurance strategies and investment decisionmaking in the context of natural disaster risk and the government budget decision (Croson and Richter 1999; Ermoliev at al. 2000; Amendola et al. 2000; Freeman 2000a; Freeman and Pflug 2003). Additionally, Pollner et al. (2001) outline in detail the costs of different risk transfer strategies for specific countries and separately discuss the benefits. Generally, this line of research allows the analysis of different risk management options, but due to the lack of macroeconomic detail it cannot capture the macroeconomic opportunity costs involved in undertaking risk management, i.e. diverting budget funds from consumption and investment, and the transfer of risk to the foreign sector.

[2] This was done under the leadership of Paul Freeman with the team consisting of Leslie Martin, Koko Warner and the author in collaboration with World Bank and Swiss Re. Additionally, Tanja Ermolieva, Landis McKellar and Georg Pflug contributed to this research project.

[3] The dynamic and demand-side representation of vulnerability was to a major extent developed by the author for recent work on a set of case studies on the comparison of different ex-ante risk financing instruments as well as mitigation (Mechler and Pflug 2002; Freeman et al. 2002b).

Analysis of risk aversion
The issue of risk aversion has been analyzed previously by OAS (1991) and more recently by Freeman (2000a). Both sources contend that under certain conditions, a risk averse attitude should be adopted by governments facing natural disaster risk. However, the more specific conditions when risk aversion should prevail are not discussed. This thesis will examine these conditions in more detail. As well, it considers the implications of risk aversion for prescriptions about decision-making.

Economic evaluation of costs and benefits
As far as theoretical approaches are concerned, there is a large literature on Cost-Benefit Analysis and how to deal with risk. However, in general it is maintained that in the standard case, risk should not influence government decision-making. As a consequence, natural disaster risk is not accounted for on a regular basis when assessing new investments. Natural disaster risk management options are not assessed by CBA and in the cases when it is done, natural disaster risk is usually included via sensitivity analysis or average values only. Kramer (in OAS 1991, Kramer 1995) is the exception and proposes a risk-averse attitude in decision-making and provides a case study on including risk and risk aversion more fully when undertaking CBA of projects. The Kramer approach is adopted and translated from the project-specific microeconomic level to the aggregate macroeconomic level.

When CBA applications in the context of disaster risks are considered, there are only a few examples concerning the project level, and more aggregate analyses are generally lacking. As well, risk transfer has not been analyzed by CBA. Risk in applications (with the exception of Kramer) is dealt with in a risk-neutral fashion and accounted for by sensitivity only or by average values. Consequently, gaps are filled in this thesis, as CBA has not been done for the assessment of natural disaster risk transfer as well as employing a macroeconomic perspective.

1.5 Outline of thesis

This thesis consists of three major parts (fig. 1):

- Part I consists of an analysis of the major issues concerning natural disasters, developing countries, risk aversion, risk management and risk transfer.
- Part II develops the modelling approach for the assessment of the costs of natural disasters and the costs and benefits of disaster risk management.
- Part III consists of the case studies for Honduras and Argentina and the overall results.

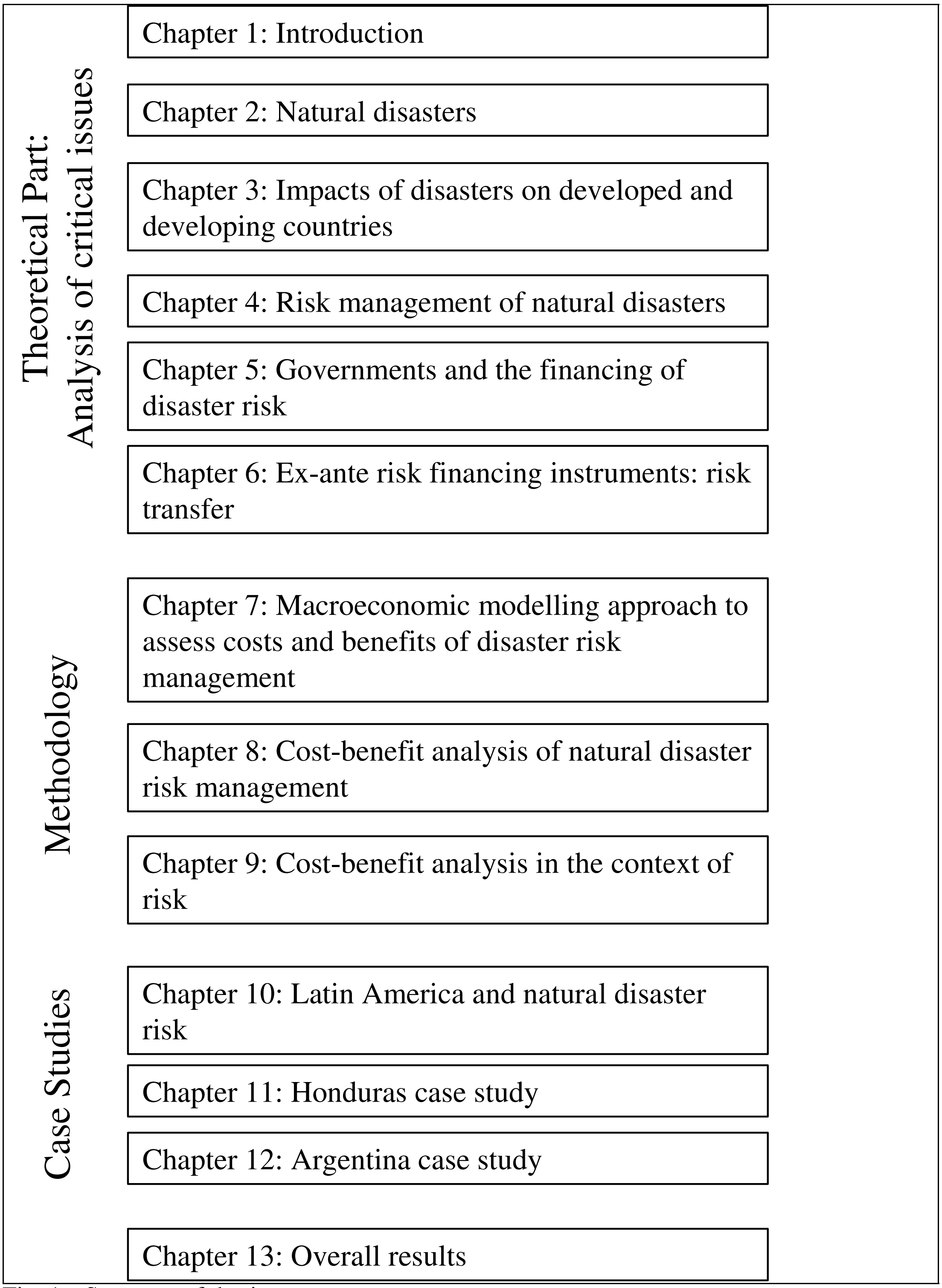

Fig. 1: Structure of thesis

Part I discusses the general issues related to natural disasters, developing countries and risk management, and the rationale and efficiency of financing natural disaster risk with a particular focus on risk to public infrastructure in developing countries. As of today, this risk has rarely been transferred by these countries. This thesis first examines the implicit and explicit assumptions driving this behavior and consequently outlines the issues involved.

Chapter 2 introduces the general context of disaster risk as it relates to developing countries. The risk potential due to natural disasters with current as well as future driving forces will be analyzed. **Chapter 3** describes the differential impacts on developed and developing countries. **Chapter 4** delineates essential components of comprehensive disaster management and of a risk management system that consists of risk identification, risk assessment and risk control. Risk control will further be subdivided into risk reduction and risk financing measures. In **chapter 5** current (ex-post) strategies to finance disaster losses and the shortcomings of this approach are examined. Countries and regions that are particularly at risk and thus in need of a risk management approach will be identified. **Chapter 6** focuses on ex-ante risk financing instruments. First, it discusses several ex-ante instruments and then focuses in detail on insurance and reinsurance, and finally outlines the risk transfer strategies that will be analyzed in this thesis.

Based on the issues analyzed in **part I**, in **part II** a modelling approach is developed in order to assess the costs of natural disasters and the costs and benefits of natural disaster risk management.

Chapter 7 discusses the relevant literature on the modelling of the economic impacts of natural disasters and explains the development of the modelling approach. This approach uses input data on direct economic losses and incorporates this direct loss exposure into a macroeconomic model in order to calculate macroeconomic costs as outcomes. For this purpose, a standard macroeconomic model was modified in such a way as to appropriately represent natural disaster effects. Furthermore, the representation of the purchase of reinsurance for infrastructure against natural disaster risk as well as the associated costs and benefits will be discussed in this chapter.

Chapters 8 and 9 describe how Cost-Benefit analysis can be used for the assessment of the costs and benefits of natural disaster management estimated with the macroeconomic model. First, CBA and its applicability to natural disaster management will be discussed. In CBA, different decision methods are traditionally used to assess the costs and benefits. It is necessary to discuss the applicability of these methods and to modify them. Furthermore, the assumption that governments or government institutions should act risk-neutrally when taking investment decisions (decisions pertaining to risk reduction or risk transfer measures are interpreted as such) needs to be tested. This assumption is equivalent to partly ignoring risk in the investment decision. This assumption is problematic for several developing countries subject to high natural disaster risk. Causes for and implications of relaxing this assumption will be discussed. Additionally, the explicit integration of risk into CBA methods will be put forward and a procedure proposed.

In **part III**, in order to test the working hypotheses and to assess the costs and benefits of risk management, in particular risk transfer, the methodology will be applied to two case study countries in Latin America (Honduras and Argentina). **Chapter 10** shortly discusses the general situation in the Latin America and Caribbean region. **Chapters 11 and 12** analyze the impacts of catastrophes in Honduras and Argentina and evaluate the efficiency of undertaking risk transfer for natural disaster risk. Honduras and Argentina exhibit different socioeconomic characteristics and vary substantially in their exposure to natural hazards thus covering a wide range of country-specific attributes. Finally, **chapter 13** summarizes the major results and insights from this thesis and concludes.

2 NATURAL DISASTERS

This introductory chapter gives a general overview of the situation regarding natural disasters, defines important terms and assesses factors determining natural disaster risk and possible increases. Section 2.1 introduces and defines natural disasters and resulting risk. 2.2 outlines the determining factors of disaster risk, and 2.3 presents some statistics on the occurrence and impacts of disasters and examines driving forces associated with current and predicted future increases in natural disaster risk.

2.1 Definition of natural disasters and potential impacts

A natural disaster event is commonly defined as the impact of an extreme natural event on an exposed, vulnerable society (ADPC 2000a: 1). If impacts exceed an affected region's coping capacity thereby necessitating interregional or international help, a large disaster is said to have occurred (e.g. Munich Re 2002: 15).[4] The following criteria can be used to define a large disaster (Smith 1996: 29):

- More than 100 casualties, or
- economic damage in excess of 1% gross national product (GNP), or
- more than 1% of an impacted country's population harmed.

Disasters cause humanitarian, economic, and ecological impacts (fig. 2).

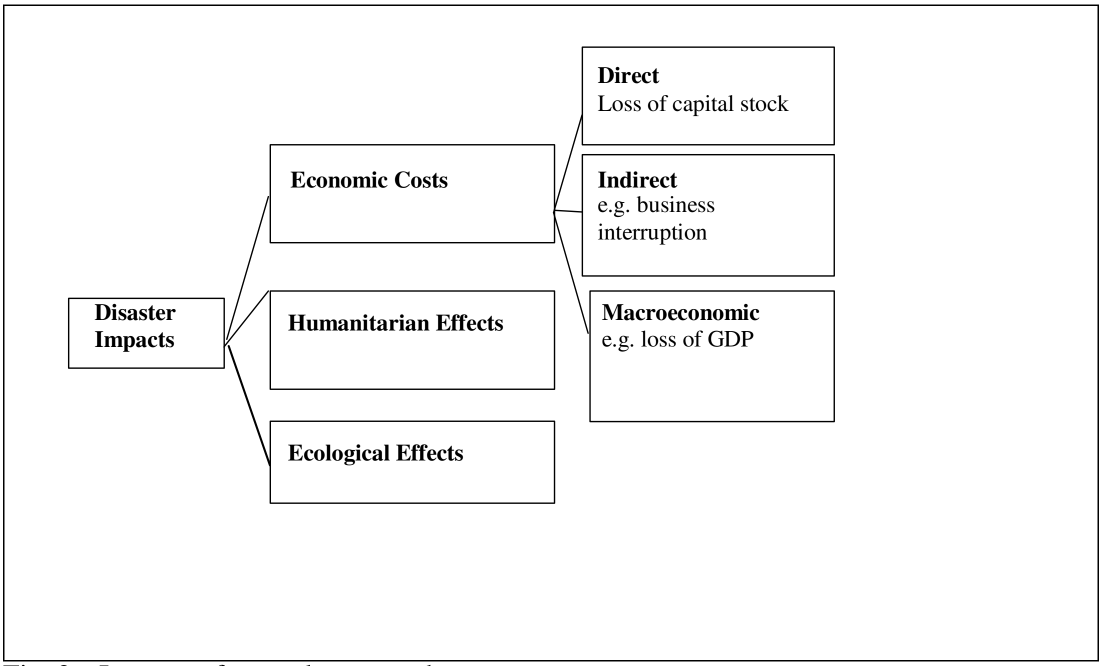

Fig. 2: Impacts of natural catastrophes

[4] In this thesis, the terms impacts, effects and damages are used as general termini to denote the harm disasters may cause. The terms costs and losses referring to the economic impacts are used synonymously. Sometimes, a distinction is drawn between costs and losses where costs refer to the economic impacts, and losses to the reimbursement payments by insurers and governments (CACND 1999: 5).

Humanitarian effects include the loss of life, people affected and psychological post-disaster effects; *ecological* effects comprise the loss of arable land, forests and damages to ecosystems. *Economic* effects due to disasters are usually grouped into three categories: direct, indirect, and macroeconomic (also called secondary) effects. These effects fall into stock and flow effects: Direct losses describe the physical impacts on infrastructure (transport, energy, water), buildings, machinery and agricultural assets. They are roughly equal to stock impacts. These can be caused by the disaster itself or via follow-on physical destruction, e.g. through fire. Resulting from these direct stock losses are impacts on the flow of goods and services: Indirect losses occur as a consequence of physical destruction on firms and households, e.g. business interruption and wages lost.

The macroeconomic impacts comprise the aggregate impacts on economic variables like gross domestic product (GDP), consumption and inflation due to the effects of disasters, as well as due to the reallocation of government resources to relief and reconstruction efforts. As the macroeconomic effects reflect indirect effects as well as the relief and restoration effort, these effects cannot simply be added up without causing duplication (Otero and Marti 1995: 16-18). This thesis will restrict the analysis to the economic effects for the following reasons:

- Although the loss of life and the immediate threat to life is without doubt the most important impact category, it will not be monetarized and analyzed in the present approach. Putting monetary values on lives is fraught with moral and methodological difficulties (such as intercountry comparisons).[5] In the context presented here saving human lives and suffering should be the paramount issue of policy-making, and cost-efficiency considerations should be restricted to the reduction of other non-humanitarian impacts.
- Ecological effects are often measured by the change in quality of non-use values. Questionnaires are used to elicit values of consumers for these services. For the evaluation of risk transfer options, these effects are not of importance.
- The input data on the direct losses of disasters obtained from Swiss Re focus on the economic losses to public and private capital stock.

Furthermore, this thesis mainly restricts the analysis to the costs that are potentially incurred by the federal government and cause disruption to financial and development planning, and furthermore focuses on the macroeconomic costs.

The probability of impacts or losses occurring is commonly referred to as risk. Natural disaster risk can be defined as the following.

> The exposure or the chance of loss (of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard for a given area and reference period. It may be expressed mathematically as the probability that a hazard impact will occur multiplied by the consequences of that impact (ADPC 2000a: 1).

Risk can be characterized by a probability distribution of the losses. Thus, risk is a function of probability and losses:

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[5] There is a large literature on imputing values for human life and problems of these methods (e.g. see Green 1992).

Risk = probability * losses.

Sometimes, particularly in financial applications, risk is defined as the variability around the mean and measured by variance or standard deviation. This will be discussed later in this thesis. Natural disaster risk has special characteristics. Probability distributions representing disaster risk are of the *fat tail* kind, i.e. events are low-frequency high-consequence events. Natural disaster risk is also a *pure, downside risk* that entails only opportunities to lose vs. the more general kind of *speculative risk (*encountered e.g. in stock market transactions) that involves chances to win and lose and is a driving force behind these transactions.

2.2 Determinants of natural disasters

A natural hazard is the necessary condition for the occurrence of a disaster. However only when hazards intersect with exposed, vulnerable elements at risk will a disaster occur and cause humanitarian, economic and ecological effects. Natural hazards thus are triggering disaster events. But, it is the elements at risk and their degree of vulnerability inherent in a social system that will define the final consequences. Thus natural disaster risk can be said to be defined by three factors: hazard, elements at risk, and vulnerability (Burby 1991: 137; Swiss Re 2000: 17) (figure 3).[6]

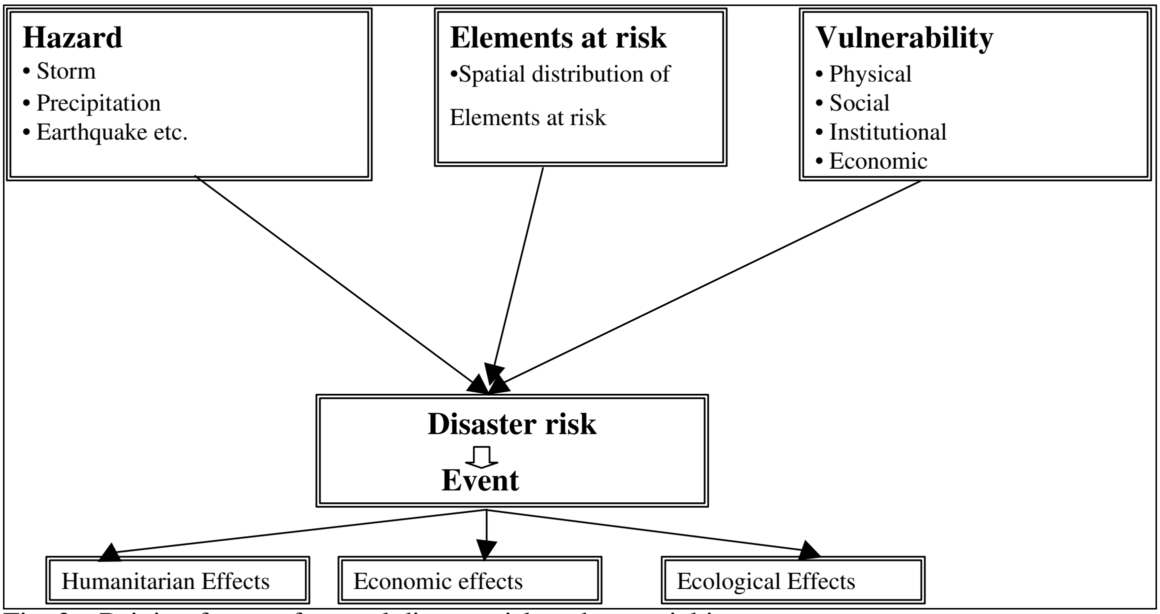

Fig. 3: Driving forces of natural disaster risk and potential impacts
Source: Modified and extended based on Lass et al. 1998: 9.

These three components are the driving forces determining probability and losses. Thus, the above equation on risk can be reformulated as follows, where probability is a function of hazard and the potential loss a function of vulnerability and elements at risk:

Risk = probability (hazard)* losses (vulnerability, elements at risk).

[6] Sometimes elements at risk are included in the vulnerability component and risk is defined by hazard and vulnerability only (e.g. ECLAC 2000: 6).

Extreme natural events like storms, rainfall or earthquakes constitute the hazard. Elements in harm's way may be affected in case of an event; these may be physical structures such as roads or buildings, people or more broadly society. Vulnerability denotes the degree to which the elements at risk might be affected by a specific level of hazard. Vulnerability can be analyzed with respect to a variety of dimensions such as physical, social, economic or institutional. The main focus of this thesis will be on the economic dimension of vulnerability which will be analyzed in detail in the following. Hazard, elements at risk and vulnerability combined constitute natural disaster risk.

2.2.1 Hazard

Natural disasters can be defined according to the underlying hazard. Table 1 lists the different kinds of disasters events (Eikenberg 1998: 3-4).

Table 1: Classification of extreme events

Sudden-onset events

Extreme geotectonic events:

- earthquakes,
- seaquakes,
- volcanic eruptions,
- slow mass movements (avalanche, lahar).

Extreme climatic conditions:

- floods triggered by extreme precipitation,
- storms and extreme precipitation triggered by atmospheric low pressure conditions: gales in moderate latitudes, and cyclones in tropics (hurricanes and typhoons),
- hail, cold spells and heat waves.

Slow-onset events

- droughts causing famines,
- desertification.

There are sudden-onset events such as extreme geotectonic events: earthquakes, volcanic eruptions, slow mass movements; and extreme weather events such as tropical cyclones, floods and winterstorms.

Slow-onset natural disasters are either of a periodically recurrent or permanent nature. These are droughts and desertification. Sudden-onset events cannot be modified at all (tropical cyclone) or merely to a lesser degree (floods). However, the probability of occurrence (e.g. influenced by climate change) may be anthropogenically influenced. Slow-onset events are usually significantly impacted by human behavioral patterns and there is some time for warning in advance. E.g. famines caused by droughts are an example as they are often largely a consequence of distribution bottlenecks and mismanagement in the affected regions. For these reasons famines are often treated in a different fashion than other natural disasters, and disaster management options vary from those for sudden-onset events (Sen 1999). This thesis will concentrate on the sudden-onset events. A natural disaster will thus be defined as an event concentrated in time and space whose occurrence is triggered by natural causes. The work follows Smith's definition of hazards:

> Extreme geophysical events [...] characterised by concentrated releases of energy or materials, which pose a largely unexpected threat to human life and can cause significant damage to goods and the environment (Smith 1996: 16).

The extent of damage of the event, however, is subject to societal intervention and will be determined by the exposed elements at risk and inherent vulnerability (Smith 1996: 16).

2.2.2 Elements at risk

The second component in the risk assessment is to determine the *elements at risk*. This may relate to persons, buildings structures, infrastructure (e.g. water and sewer facilities, roads and bridges) or agricultural assets in harm's way which can be impacted in case of a disaster event (ADPC 2000a: 2). In this thesis, the focus is on the impacts on physical elements, and capital stock, in particular infrastructure will be examined. Theoretically, it would be desirable to establish an inventory with the types, numbers, values, usage and spatial distribution of the exposed elements at risk. Especially, the spatial distribution determining how exposed these elements are to the relevant natural hazards, is of importance. In practice, collecting an inventory often proves very difficult and expensive due to the heterogeneity and sheer number of the examined elements; as a consequence such inventories often do not exist. It is particularly burdensome to develop inventories for infrastructure as these are often complex network structures with several subcomponents which have been built incrementally over time and thus information on these components differs (Burby 1991: 137). As will be explained later, in the case study on Honduras, an inventory of exposed public assets was available and used. For the other case study on Argentina, an aggregate value derived from a top-down approach was used.

2.2.3 Vulnerability

Vulnerability refers to the susceptibility of the exposed elements to incur damages. Vulnerability can be defined as follows:

> The extent to which a community, structure, service, or geographic area is likely to be damaged or disrupted by the impact of a particular disaster hazard, on account of their nature, construction, and proximity to hazardous terrain or a disaster prone area (ADPC 2000).

There are different dimensions of vulnerability (ADPC 2000b: 8):[7]

- Physical vulnerability: this relates to the susceptibility to damage of engineering structures such as houses, dams or roads.
- Social vulnerability: the ability to cope with impacts on the individual level.
- Institutional vulnerability: referring to the existence and robustness of institutions to deal with and respond to natural disaster.
- Economic vulnerability: the economic or financial capacity to finance losses and return to a previously planned activity path. This may relate to private individuals

[7] Sometimes vulnerability is referred to as susceptibility or as the inverse of resilience, or just set equal to risk as e.g. done in the climate change research community.

as well as companies and the asset base and arrangements, or to governments that often bear a large share of a country's risk and losses.

This thesis will limit the discussion to physical and economic vulnerability. Physical vulnerability will be examined with respect to capital stock and infrastructure. This will determine the probability of capital stock to incur direct losses. Such information on the vulnerability of aggregate capital stock in the case study countries was received from Swiss Re. Economic vulnerability will be determined to assess the consequences and the ability of the government and the private sector to finance incurred direct losses. Economic vulnerability is to a large degree determined by the structure of an economy (e.g. commodity-based versus high-technology), the prevailing economic conditions (e.g. degree of inflation, economic recession) and the general stage of technical, scientific, and economic development (Benson and Clay 2000: 11). Economic vulnerability can be measured by a set or a composite index of indicators such as the degree of export dependence, lack of diversification, export concentration, export volatility, share of modern services and products in GDP, trade openness or often simply GDP (Briguglio 1995: 1619; Commonwealth Secretariat 2000: 3). As will be discussed later, the focus in this thesis is on vulnerability in relation to the ability to restore capital stock, including public assets such as infrastructure lost in a disaster and the provision of relief to the affected private sector by the government. Vulnerability is thus defined as the lack of domestic and foreign savings for financing reconstruction investment and relief post-disaster.

2.3 Statistics on disasters

2.3.1 Largest historical events

The largest disasters in terms of human casualties ever were the floods in 1887 in the Henan region in China that cost about 900,000 lives; in European latitudes several centuries ago, the "Grosse Manndränke" at the North Sea in Germany in 1362 killed about 100,000 people. In the 20th century the worst events of this magnitude were a cyclone in 1970 in Bangladesh that killed 300,000 people, and an earthquake in the Tangshan region in China that caused 290,000 casualties. These events are not automatically the largest instances in terms of economic and insured losses. In terms of economic loss, the Kobe earthquake 1995 ("Great Hanshin Earthquake") in Japan caused economic losses in excess of 100 billion USD while killing 6,300 people and the Northridge earthquake in California in 1994 that caused 44 billion USD damage while causing 60 fatalities. In terms of insured damages, the Northridge event was also the second largest loss, with Hurricane Andrew in 1992 in Florida being the worst at about 17 billion USD. In Europe, the largest economic losses so far were the winter storms of 1990 with a loss of 15 billion USD and an insured one of 10 billion and -for this region- a high number of casualties of 230 people (Munich Re 1998).[8]

When looking back at the 20th century, an increasing incidence of natural disaster events can be noted (fig. 4). While there were about 10 disaster events per year in the

[8] It is expected that the summer floods of 2002 in continental Europe surpassed the losses from the winter storms of 1990. However, final values had not been made available at the time of writing of this study.

beginning of the century, now about 300 hundred events are registered on average each year. It has to be noted, however, that the population exposed and overall welfare increased as well over this period which increased the risk widely.[9]

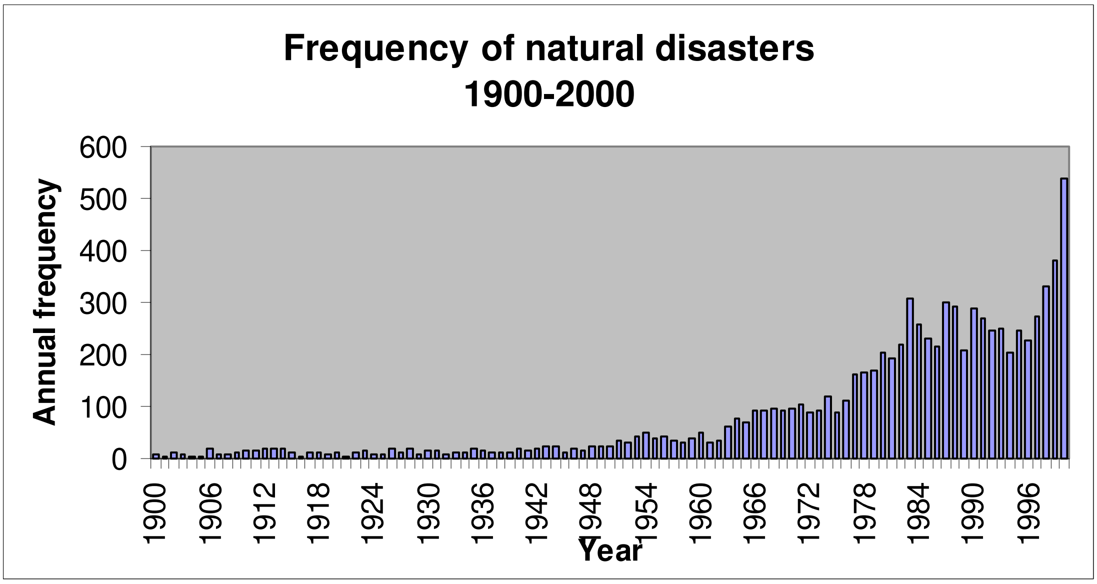

Fig. 4: Annual frequency of natural disasters on a global scale from 1900 to 2000
Data source: EM-DAT 2002.

About sixty million casualties occurred during the 20th century. The casualties in absolute terms have been decreasing in the last years, but the number remains high: In the last ten years alone, over 750,000 people died due to natural disasters (figure 5).

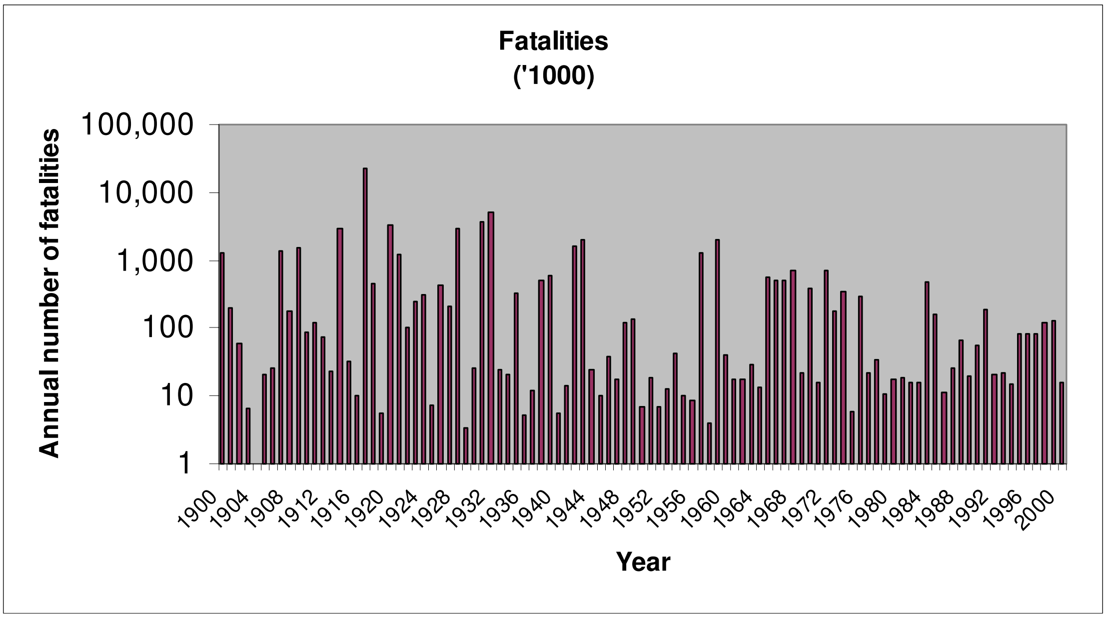

Fig. 5: Annual number of casualties due to natural disasters from 1900 to 2000
Data source: EM-DAT 2001.

Economic and insured (i.e. the insured part of the economic damages) damages have increased at an even faster rate than has the number of events. Comparing the 1990s

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[9] Also, due to improved information technologies more disasters are recorded today.

to the 1960s on a global level, there has been an increase of about 220% in the number of events while economic damages increased by 750% and insured damages by 1,510% (Munich Re 2000: 19).

Table 2: Trends in largest natural disasters 1950-1999 (1999 billion USD)

	1950s	1960s	1970s	1980s	1990s	**Factor 90s-60s**
Incidence	20	27	47	63	87	**3.2**
Economic damages (billion USD)	39.6	71.1	127.8	198.6	608.5	**8.6**
Insured damages (billion USD)	-	6.8	11.7	24.7	109.3	**16.1**

Source: Munich Re 2000: 19**.**

2.3.2 Interrelations between elements at risk, vulnerability, and hazard

Increases in welfare mainly in developed countries entail an increase in property and assets at risk and play an important part in the rise of losses. This can be discerned when analyzing the development in losses in the 1980s and 1990s in Germany. While the number of events only rose by about 10% during this period, there was an increase in economic losses by about 190% and in insured losses by 280% (Münchener Rückversicherung 1999: 6).

However, the increase in welfare can only partially explain these trends. As fig. 6 shows, the increase of damages as a percentage of GDP[10] which, though less severe than the increase in frequency, is still significant. There are other factors contributing to these trends that need to be discussed.

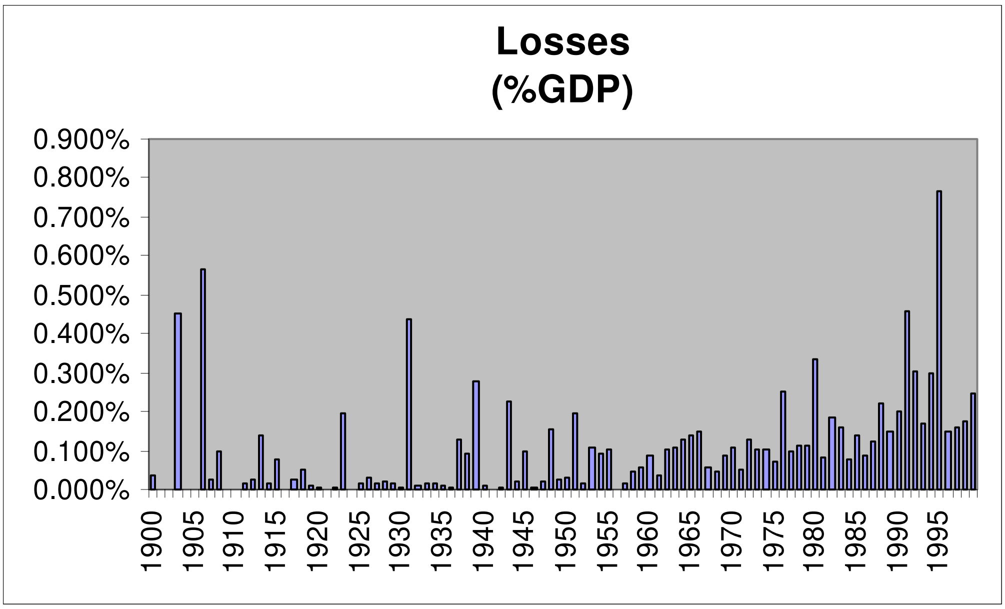

Fig. 6: Annual losses due to natural disasters as percentage of world GDP in 20th century
Data source: EM-DAT 2002.

[10] Equivalent to the rise of average per capita damages measured in average GDP.

On a global level, **population growth** is high and almost exclusively occurring in the less developed world due to factors like low education levels (a determinant of high fertility rates), underdeveloped social security systems and social desegregation. There are also **migratory trends** from rural to urban areas. As a great number of large cities are located close to the sea, there is **increased exposure to coastal natural hazards**. In general, urban infrastructure is overstressed, urban and rural (loss of workforce) poverty are increased, and an **overuse of the environment** ensues, resulting again in an increase of vulnerability in various dimensions (Smith1996: 42-43).

Though coastal areas only constitute a fraction of total landmass of the earth, they are densely populated, as they grant easy access to the sea, often exhibit fertile soil, and are suited for the development of large cities. In 1999 about 3 billion people lived in coastal areas, about half of the total global population. Of the 15 largest urban settlements 13 are in coastal areas where population increase is about double the average.

Fig. 7 illustrates the areas thought to be at major risk in the year 2100. In particular densely populated coastal areas (US American East Coast, North sea coast, Southeast Asia) are severely at risk. Cities such as Tokio, Shanghai, Lagos, Hong Kong and Hamburg are at high risk. On the other hand, the costs of flood protection are extremely high. For example, the costs of installing flood protection structures in the Netherlands alone for a sea level rise of 50 cm are estimated at 3.5 trillion USD (IFRC 1999: 11).

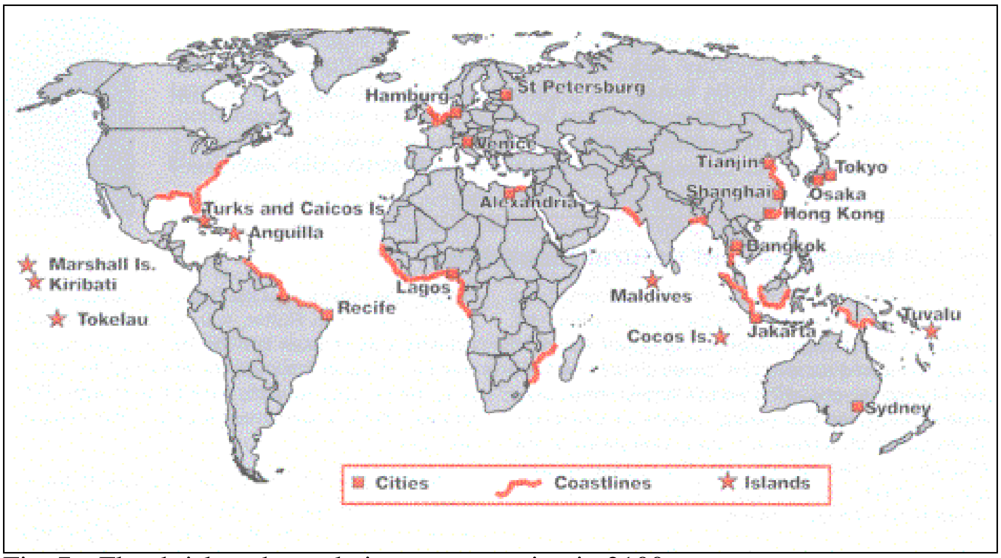

Fig. 7: Flood risk and population concentration in 2100
Source: IFRC 1999: 18.

The **increase in complexity** in modern industrial societies, the increase in division of labor, and reliance on modern technologies have brought about an increased vulnerability to exceptional events. There has also been a decrease in redundancy of systems. Thus the loss of a single subsystem can significantly interrupt the flow of the overall system. An example may be the loss of electricity transmission lines due to extreme cold spells, as experienced in Eastern Canada in 2000 causing large losses (Swiss Re 1999).

Migration to cities increases vulnerability. This holds particularly true for the large urban conglomerates with more than 1 million inhabitants. Between 200 and 300 cities of this size exist today, the majority (20 of the largest 30) are located in developing countries. This trend is predicted to continue (Smith 1996: 43).

This increases vulnerability and risk in the following manner: **Urbanization** concentrates man and capital on scarce land. Often the highest migration rates occur among the rural poor, who set up squatter housings in unsuited and dangerous areas or already declared problem zones. New risks are created and old ones are exacerbated. In this fashion, the earthquake in Guatemala City in 1976 has become known as the "class-quake," seeking the large majority of the 23,000 dead it caused among the poor that lived in insufficient squatter settlements and were hit by mud lahars (IFRC 1999: 19). Another consequence of urbanization is that the maintenance and construction of new urban infrastructure cannot keep up with the high pace of urbanization, leading to gradual decay and again increased vulnerability.

With a high degree of probability, emissions of long-lived greenhouse gases into the atmosphere are predicted to lead to a significant **anthropogenic influence on the climate**; repercussions of the climate effect with the oceanic circulation and the dynamic of the polar ice-masses are to be expected. By 2100 global temperatures are expected to increase in the range of 1.4 to 5.8°C and the sea level is expected to rise about 9-88 cm. The predicted rise in sea level is on the one hand a consequence of the fact that water generally expands as temperature rises and on the other hand a result of the melting of ice and snow, in particular the polar ice caps. In the course of the 20th century, sea level rise during tide amounted to 10 to 20 cm. Already today, changes in precipitation patterns in some regions have been detected. There is recent evidence of a correlation between the anthropogenic greenhouse effect and the El-Nino phenomenon and the increase in hurricane frequency in the western Atlantic ocean (IPCC 2001: 1-18). However, the types and magnitudes of the effects resulting from the predicted change in climate, vegetation zones as well as the expected sea level rise and increase in weather extremes are largely unknown.

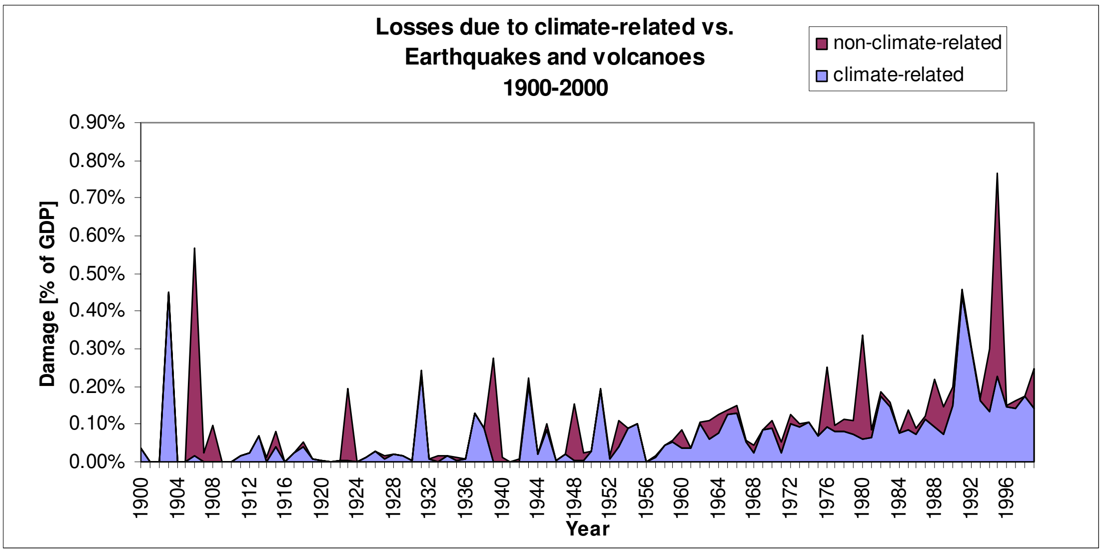

Fig. 8: Losses due to climate related events seem to be increasing whereas the losses due to other events stay approximately constant in relation to GDP.
Data sources: EM-DAT 2002

Excessive use of natural resources caused by unsustainable agriculture and ensuing soil erosion and deforestation increase the risk of natural disasters. For example, the loss of natural vegetation in particular in forests leads to decreased water absorption capacity of soils hereby increasing the risk of floods and lahars. The Yangtse floods of 1998 in China, which caused a death toll of 3,000, were at least made more devastating by these factors. More than 80% of the forest area of the Yangtse river basin has been clearcut in the last few years. In Central America, lahars and mud avalanches in the wake of Hurricane Mitch in 1998 buried thousands of people settling on exposed hillsides (IFRC 1999: 21).

These global change impacts have spatial as well as temporal dimensions. The negative consequences today affect mostly developing countries. In the future it is to be expected that impacts in these regions will worsen and also affect the developed countries more severely when the capacity for coping with such impacts is exceeded.

3 IMPACTS OF DISASTERS ON DEVELOPED AND DEVELOPING COUNTRIES

This chapter will discuss the differential impacts of disasters on developed and developing countries and focus specifically on the economic impacts that are of relevance for this thesis. Section 3.1 outlines the differences in impacts and provides some statistical information, section 3.2 discusses the empirical evidence on the direct and indirect economic impacts of disasters and 3.3 focuses in detail on the macroeconomic effects and summarizes the evidence on these effects.

3.1 Differential impacts of disasters

The impacts of natural disasters on society and the environment are substantially larger in less developed countries. This is explained by the typically higher degree of vulnerability in developing countries. Factors contributing to increased vulnerability in developing countries are high rates of poverty, high unemployment, distributional inequalities, socioeconomic exclusion of the poor from basic services, strong population growth, and lack of strong national and local institutions for dealing with natural disasters (Smith 1996: 42-46; ECLAC and IDB 2000: 1; UNISDR 2002: 4ff.; Anderson 2000: 45; Vatsa and Krimgold 2000: 135).

There is awareness today that disasters in developing countries should not be analyzed in isolation but should rather be seen as "only a more acute, more extreme form of the general chronic daily suffering of many of the people" (Cannon 1994: 16). The processes that drive vulnerability are considered largely the same (but not identical) to those that determine differences in income and social status. The concept of vulnerability is thus regarded a tool for translating known everyday socioeconomic and political processes into an analysis of who and what is at risk in the context of natural hazards. However, vulnerability is not the same as individual or aggregate poverty. As discussed above vulnerability is multidimensional and depends, for example, also on the institutional context (e.g. existence and effectiveness of disaster management authorities) and other factors such as preparedness for disasters (Cannon 1994: 17-27).

Nevertheless, the poor are particularly at risk as they lack the capacities to cope with shocks, have limited access to essential services, and often live on marginal, unsafe land. Repeated occurrence of disasters may lead to a "vicious circle of disasters" (ECLAC 2000: 1) and chronic poverty: Poverty increases vulnerability which decreases the ability to recover after disasters, thus perpetuating poverty.

The increased vulnerability and consequently higher impacts in developing countries can be gathered by analyzing statistics by Munich Re that list events and costs for four different groups of countries differentiated by GNP per capita in 1998 for 9,270 large natural disasters between 1985 and 2000 (table 3 and fig. 9)

Table 3: Impacts of major disasters on countries differentiated by income groups[11]

Countries with per capita income in 1998 of (USD ppp)	**Number of loss events: 9,270**	**Fatalities: 586,900**	**Economic losses: US$ 984bn**	**Insured losses: US$ 178bn**	**Losses/ GDP**
>9,361	45%	4%	57%	92%	2.5%
3,031-9,360	11%	11%	8%	4%	2.7%
761-3,030	21%	13%	9%	1%	5.0%
<760	21%	65%	24%	2%	13.3%
Not assignable	2%	1%	2%	1%	-

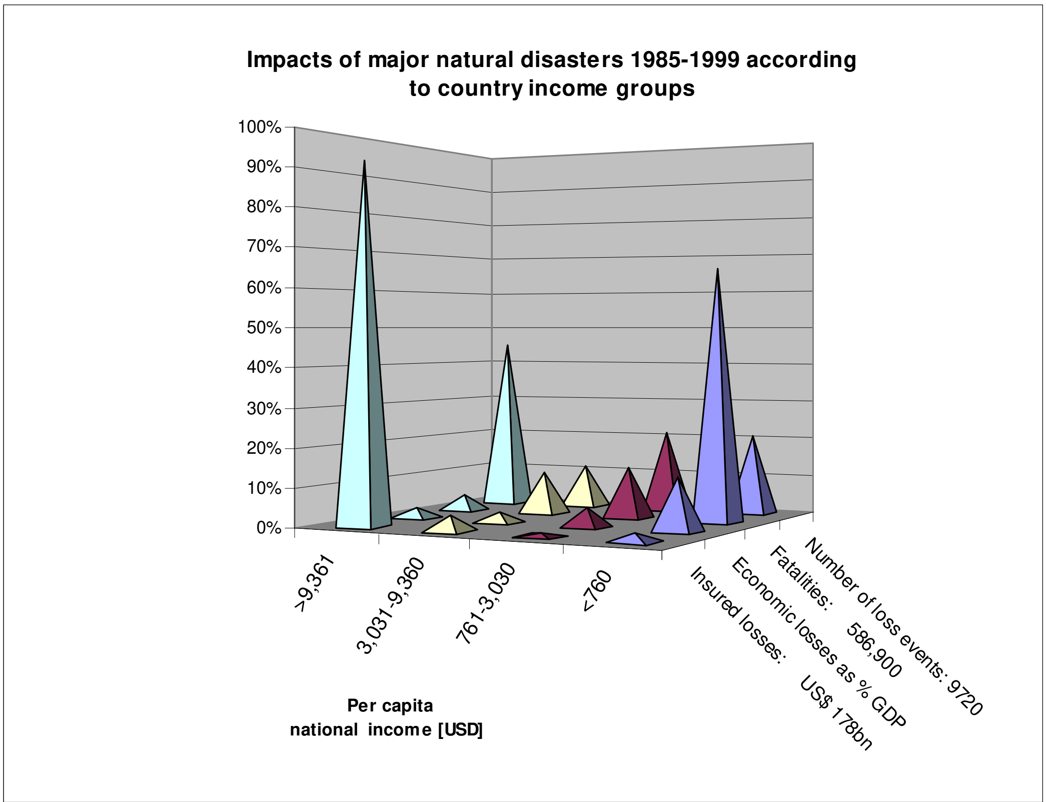

Fig. 9: Impacts of major disasters on countries differentiated by income groups
Source: Munich Re 2000: 24-25.

The majority of these events (45%) occurred in the highest income group (per capita income in 1998 higher than 9361 USD), with 11% happening in the per capita income group of 3,031 to 9360 USD, 21% in the income group of 761 to 3,030 USD, and 21% in the lowest income group with average income lower than 760 USD.[12] If vulnerability had been approximately equal across income groups, the shares of these country income groups in impacts in terms of fatalities, and economic and insured losses should be roughly comparable to their share in the number of events. This is not the case.

[11] Note: Number of losses contain vulnerability already as the definition of disasters relates to large disasters not hazards (see chapter 2).
[12] 2% were not assignable.

3.1.1 Humanitarian impacts

The highest number of fatalities (65%) was borne by the lowest income group. Risk of loss of life due to natural disasters is thus clearly much higher in less-developed countries. Looking more closely at concrete events and countries in Asia, table 4 shows how economic development as measured by average country income impinges upon vulnerability to typhoon risk for three Asian countries: Japan, the Philippines and Bangladesh.

Table 4: GDP and Vulnerability

Country – respective income group	*GDP/ capita [USD]*	*Population [millions]*	*Number of typhoons*	*Fatalities*	*Fatalities/ event*
Japan - high income	38,160	126	13	352	27
Philippines - lower middle income	1,200	74	39	6,835	175
Bangladesh - low income	360	124	14	151,045	10,788

Sources: Smith 1996: 37; World Bank 2001a.

All of these countries have experienced a substantial number of typhoons from 1980 to 1994 with Bangladesh having had the most with 39 events. When breaking casualties down per event, impacts differ widely. In Japan 27 people were killed on average per event, in the Philippines 175 and in Bangladesh more than 10,000 (Smith 1996: 37). While the degree of hazard and population exposed to the natural hazard typhoon may differ, the wide range in the order of magnitudes of the people killed suggests that there is close correlation between economic development and vulnerability. On the other hand, it should also be stressed that economic development alone is not the panacea to reduce vulnerability and potential disaster impacts. Development rather needs to proceed in a sustainable way covering a series of issues like equal income distribution, the development of strong institutions and concern for environmental regards.

3.1.2 Economic impacts

In the statistical information from Munich Re, economic losses in the lowest income group were slightly higher than should be expected from the number of events. In the countries with the highest income, economic losses were highest due to the high concentrations of value. Insured losses were also highest there, constituting about 90% of total global insured losses. In the other countries the share in insured losses is much smaller, being negligible in the poorest countries. In these countries, therefore, insured losses have to be borne by the victims and, as is often the case, if the victims are unable to do so, the government has to assist.

Of greater significance, however, is to compare the economic losses to GDP. The poorest countries exhibit a higher ratio in this regard, with total losses over this period averaging 13.3% of GDP while the richest countries had a ratio that was still high at 2.5%. This exemplifies that the impacts for poor developing countries as measured against economic development are larger than for more developed economies. However, these statistics on the economic losses do not reveal the actual impacts of disasters on society and the economy. This is rather determined by the inherent economic vulnerability and needs detailed and dynamic representation. The loss data from this database focus on the direct stock losses, not the consecutive impacts. How to estimate those and their magnitudes will be a main topic of this thesis.

3.2 Literature review on direct and indirect economic costs of natural disasters

In this section and in section 3.3, the literature on the evidence found on the direct, indirect and macroeconomic costs will be discussed. This discussion thus refers to the ex-post assessment of the economic impacts of disasters. Modelling methods to estimate and assess these impacts in advance will be discussed in the chapter dealing with the modelling approach developed in chapter 7. The evidence presented here will also serve as an input to this modelling.

3.2.1 Direct losses

Often, disaster losses are expressed as *direct losses*. The statistics presented above on the economic losses relate to the direct losses. A large amount of work and research has been conducted on these direct losses. Direct losses are estimated post-event by local, national, or multinational institutions and insurance companies. The four main sources for this information are Swiss Re, Munich Re, the EM-DAT database from the Centre for the Epidemiology of Disasters (CRED) of the University Catholique de Louvain in Brussels, and the reports by the Economic Commission for Latin America and the Caribbean (ECLAC). Swiss Re and Munich Re annually publish data on the worldwide direct economic and insured losses. EM-DAT compiles information on events, fatalities, people affected, and the losses on a worldwide basis dating back to 1900.[13] This information is valuable and a good basis for analysis. However, it does not describe the full costs of natural disasters to an economy that are better expressed by the flow indirect and macroeconomic effects. Another important source for this information for Latin America is ECLAC. Since 1972, ECLAC has been estimating the impacts in Latin America and the Caribbean post-event and been conducting a large number of case studies.

3.2.2 Indirect losses

Indirect losses are harder to identify and measure. For these no standard assessment framework exists (CACND 1999: 47), which renders estimates from different sources hard to compare. The CACND manual on assessing costs due to natural disasters aimed to correct this and made recommendations on how to derive loss estimates. In general, indirect losses are measured by conducting business and household surveys (generating primary data) or using secondary statistics on insurance claims, disaster relief spending, or emergency loans (CACND 1999: 15). For developing countries, the main source again is ECLAC.

Generally, large indirect costs are found. E.g. business interruption losses from the Northridge earthquake amounted to 6.5 billion USD and from the Kobe earthquake to an enormous sum of 100 billion USD (CACND 1999: 35). Evidence suggests that the proportion of indirect impacts to direct impacts increases with the magnitude of the event (CACND 1999: 18).

[13] This information is available on line: www.munichre.com, www.swissre.com, www.cred.be/emdat.

It is interesting to note that in the context of the empirical studies on the economic costs on developed countries, often a distinction is drawn between direct and indirect impacts only, whereas macroeconomic effects are not discussed; consequently, the spatial scope of these analyses is regional rather than national in nature (e.g. CACND 1999). Cochrane (1992) sheds some light on this. While he does not differentiate between indirect and macroeconomic effects, but uses them synonymously to refer to what in this thesis is related to as indirect effects, he lists two reasons why there are no aggregate economic impacts:

> [...] The economy is more resilient than most economists like to believe, and the effects of disasters are shifted to other regions or to another time period (possibly to other generations) (Cochrane 1992: 103).

Even in the two events for which he finds aggregate impacts, the Dust bowl period of the 1930s in the USA, and the Managua earthquake in Nicaragua in 1972, he sees the stock market crash in the USA and the political revolution in Nicaragua as more important influences. He asserts that the underlying strength of an economy is the main factor determining whether an economy will exhibit effects. He discusses for example the impacts of the Loma Prieta/Northridge Earthquake in the USA. The Loma Prieta event alone (5 billion to 10 billion USD direct losses in 1994)[14] represented less than 1% of the affected region's capital stock, which is less than the annual depreciation or less than capital loss resulting from a 0.1 percentage point change in the long-run rate of interest (Cochrane 1992: 107).

While the studies on the economic impacts of disasters in developed countries generally do not find and discuss aggregate, macroeconomic impacts, a series of studies focusing on developing countries finds significant short- and longer-term macroeconomic impacts.

3.3 Literature review on macroeconomic effects

A smaller, but growing amount of research has been conducted on the *macroeconomic* costs. The main bulk of this body of research focuses on developing countries, assessing the impacts post-event using statistics on actual, historical events. The main empirical studies on the macroeconomic effects are Benson (1997 a,b,c), Benson and Clay (1998, 2001), ECLAC [several studies e.g. 1982, 1985, 1988, 1999, 2002; Otero and Marti (1995)], Albala-Bertrand (1993), Murlidharan (2001), Crowards (1999), Charveriat (2000). The empirical research literature generally finds significant short- to medium-term macroeconomic effects and considers natural disasters a barrier for longer-term development. The only dissenting view is Albala-Bertrand (1993) (table 5).

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[14] Total direct and indirect losses are estimated at 44 billion USD (Munich Re: 1998).

Table 5: Empirical work on macroeconomic effects of disasters

Study	*Data*	*Findings on macroeconomic effects*
Dacy and Kunreuther (1969)	▪ Several disasters in the USA, Netherlands and Yugoslavia (1953-1964) ▪ Focus on earthquake in Anchorage, Alaska (1964) ▪ Short- to long-term, regional scope	▪ Tax revenue decreased ▪ Demand for goods and prices did not change significantly
Albala-Bertrand (1993)	▪ 28 disasters in 26 countries, mainly developing countries (1960-1979). ▪ Short- and medium-term (1-3 years) ▪ Longer- term	▪ GDP fell only in 25% of cases in year of event, in rest of cases no decrease in GDP growth rate, increase even. However, effect rather ambiguous when analyzing data more closely: in year after disaster GDP fell in 54% of cases ▪ Rate of inflation not significantly affected ▪ Public deficit increase small or negligible ▪ Trade deficit worsened ▪ Sharp increase in capital inflows and transfers ▪ Disasters "a problem *of* development, but essentially not a problem *for* development"
ECLAC (several, e.g. 1982, 1985, 1988, 1999, 2002) ECLAC and IDB (2000) Otero and Marti (1995)	▪ Countries in Latin America and Carribean since 1972 ▪ Short- to medium-term (up to 5 years) and long- term	▪ GDP fell ▪ Tax revenue fell ▪ Fiscal deficit increased as spending for relief and reconstruction increased ▪ Trade deficit worsened, as reduction of exports and increase of imports ▪ Substantial long-term negative impacts ▪ Disasters "a problem *of* development, and *for* development"
Benson (1997 a,b,c) Benson and Clay (1998, 2000, 2001)	▪ Fiji (1971-1994), Viet Nam (1971-1994), Philippines (1970-1995), Dominica (1978-1999) ▪ Rather short-term focus (1 year)	▪ Severe negative economic impacts ▪ Increase of imports ▪ Agriculture hit most strongly ▪ Exacerbation of inequalities and reinforcement of poverty ▪ Found it difficult to isolate disaster impacts on economic variables from other impacts
Crowards 1999	▪ 22 hurricane events in borrowing member countries of Caribbean Development Bank	▪ GDP growth slowed on average by 3% post-event, but rebounded the following year due to increase in investment ▪ Large variations around average ▪ Rise in external debt
Charveriat 2000	▪ 35 catastrophes in 20 Latin American and Caribbean countries 1980-1996 ▪ Medium-term (3 years)	▪ Real GDP decreased in the year of the disaster, then increased as investment rose
Murlidharan and Shah 2001	▪ 52 catastrophes in 32 developed and developing countries ▪ Short- medium- and long-term	▪ Catastrophes affected short term growth very significantly, and longer-term growth significantly ▪ Negative impacts on external debt, budget deficit, inflation

Dacy and Kunreuther (1969) mainly examined industrialized countries and found that tax revenue decreased while demand and prices did not change considerably.

ECLAC has been conducting numerous case studies on disaster impacts in Latin American countries since 1972. Based on this experience they have developed a manual for the quick identification and assessment of the direct, indirect, and macroeconomic impacts to be carried out shortly after the occurrence of an event to identify necessary rehabilitation and reconstruction measures and needed international aid. Otero and Marti (1995) summarized results and generally found serious shorter-term impacts as national income decreases, an increase in the fiscal deficit as tax revenue falls, and an increase in the trade deficit as exports fall and imports increase. Substantial longer term impacts on development prospects, perpetual external and fiscal imbalances due to increased debt service payments post-disaster and spending requirements, and negative effects on income distribution were also found (ECLAC and IDB 2000: 16; Otero and Marti 1995: 28ff.)**.** To give an example, more than twenty years after the Managua earthquake, part of destroyed urban structures have still not been rebuilt (Otero and Marti 1995: 28). Reasons for this are discussed in the following quote:

> The predominance of cumulative negative effects as a result of disasters is explained by the fact that the countries affected in the region [i.e. the Latin America and Caribbean region] never manage to obtain all the resources needed to completely replace the assets lost, much less to rebuild them with significant improvements where risk reduction is concerned. If this is true for the region as a whole, it is more so for the smaller, less diversified economies which as a result are more vulnerable, because in these cases reconstruction processes take long periods in which the reduction of activities and production (indirect and secondary consequences) are not compensated for with the increase in replacement activity (ECLAC and IDB 2000: 13).

However, they also assert that it is difficult to measure impacts of disasters in the long term because there is a complex interaction between the impacts due to a particular disaster event and prevailing economic conditions as well as the relations to the international community. They hold that the significance of the impact depends on the size of the disasters, the size of the economy and the prevailing economic conditions (Otero and Marti 1995: 32).

Benson (1997 a,b,c) and Benson and Clay (1998, 2000, 2001) produced a number of case studies on Fiji, Vietnam, the Philippines, and Dominica. The timeframe of this analysis was mainly short-term, i.e. the period up to one year after a disaster. They detected severe negative economic impacts, with agriculture being hit most strongly, an exacerbation of inequalities, and reinforcement of poverty. However, they also found it difficult to isolate disaster impacts on economic variables from other impacts:

Murlidharan and Shah (2001) by means of a regression analysis analyzed a large data set of 52 catastrophes in 32 developed and developing countries with the same time-horizon approach as Albala-Bertrand: in the short-term (year before event compared to year of event). They found catastrophes for all country income groups to affect short-term growth very significantly. In the medium-term (average of two preceding years compared to average of event and two following years), the effect on growth was still significant. As time passes, they found the impact on economic growth to subside. They also found associations between disasters and the growth of external debt, the budget deficit and inflation (2001: 18-19).

Crowards (1999 in Charveriat 2000: 19) examined the impacts of 22 hurricane events in borrowing member countries of the Caribbean Development Bank and found that GDP growth slowed by 3% on average post-event, but rebounded due to the increase in investment the following year. He also found large variations around averages.[15]

Charveriat (2000: 16ff.) for most cases in her disaster sample found a typical pattern of GDP with a decrease in the year of an event and a recuperation in the following two years due to high investment into fixed capital. She detected the scale of short-term impacts to depend on the loss-to-GDP-ratio and whether the event was localized or country-wide. For high-loss-to-GDP ratios and country-wide events she found larger impacts. She identified as another crucial variable economic vulnerability, as defined by the size of the economy, the degree of diversification and the size of the informal and agricultural sectors. For example, there were severe impacts of disasters for the smaller undiversified Caribbean island economies. Also she lists the case of the earthquake of 1987 in Ecuador that damaged the most important oil pipeline of the country which caused a large loss of earnings from oil exports. She discusses the following crucial variables affecting the scale of aggregate effects: structure of the economy and general conditions prevailing, the size of economy, the degree of diversification and the speed of assistance of the international community.

In contrast to the above studies, Albala-Bertrand (1993) comes to different conclusions and finds himself partially in opposition to accepted views when analyzing impacts mainly on developing countries. He first statistically analyzed part of the ECLAC data set and found that natural disasters do not negatively affect GDP, public deficit and inflation in the short to medium term. His findings on the trade deficit are in accordance with ECLAC and other research. These findings he explains with a sharp increase in capital inflows and transfers (private and public donations). He holds that natural disasters do not lower GDP growth rates and "if anything, they might improve them" (1993: 207). However, this statement is not fully tenable when analyzing his statistics more closely. He compared 28 disasters in 26 countries, mainly developing countries between 1960 to 1979, with a short– and medium-term focus (1-3 years). In 7 out of the 28 cases the GDP growth rate slowed in the year of the event compared to the year before and in only one case it became negative. However, 16 of the 28 events in his sample happened in the second half of the year. Accordingly, when comparing the year of the event and the year following it, GDP in the year after the event declined in 15 cases. Also, when comparing the average of the year of the event and the two years succeeding it with the average of the two years before the event, the effect is ambiguous as average GDP went up 15 times and down 12 times.

Albala-Bertrand also examined longer-term effects for a number of developed and developing countries and found no significant long-term effects in developed countries; he came to the conclusion that in developing countries aggregate effects fade away after two years, but that some negative effects on income distribution and

[15] This study could not be obtained and the discussion had to rely on Charveriat (2000) as a secondary source.

equality persist. In total Albala-Bertrand occupies a dissenting position and considers disasters "a problem *of* development, but essentially not a problem *for* development." (Albala-Bertrand 19993: 202). According to his analysis, while the number of deaths and people affected, and the extent of economic losses are determined by the current state of a country's development, disasters do not normally hinder long-term development, with the sole exception being widespread droughts.

However, ECLAC finds three assumptions used by Albala-Bertrand in his argumentation on the inexistence of long-term development impacts of disasters particularly problematic (ECLAC 2002: 373-374). Concerning the assumption about GDP and inflation not being impacted adversely, ECLAC has shown contradicting examples as discussed. Albala-Bertrand also posits that direct disaster damages are frequently overstated for political and technical reasons; ECLAC maintains that there are many examples were damages were underestimated due to electoral reasons, when vulnerable social sectors were affected or when strict fiscal discipline had to be maintained. ECLAC also disagrees with Albala-Bertrand's assertion that disaster events are scarce and occur only occasionally, and rather posits that they happen more often, an observation which can clearly be corroborated for Latin America (see also fig. 45 in ch. 10). In conclusion, contrary to Albala-Bertrand, ECLAC considers disasters to be a problem *for* development, the existing gaps between expected and actual economic growth may become larger, *and of* development, disaster impacts are determined by vulnerability, which is affected by the state of socioeconomic development.

When treating Albala-Bertrand as the dissenting view, empirical effects on macroeconomic variables found can be summarized by the following:

- No significant macroeconomic impacts are found for developed countries. In developed countries, the literature focuses generally on the direct and indirect impacts and on the regional economies.
- In developing countries, GDP falls in the year of the event or the year after, but rebounds in successive years due to increased investment and capital inflows.
- The public deficit increases due to increased spending needs and decreased tax revenue.
- The trade balance worsens, as less exports are undertaken and more imports are demanded. Also, a worsening of the trade deficit is usually reported, as imports rise (need for additional goods) and exports fall (destruction of goods produced and productive capital stock) post-catastrophe.
- Significant longer-term impacts are to be expected depending on the size of event, economic vulnerability, and prevailing economic and socio-political conditions.
- The inflow of external aid and capital is decisive for the speed of economic recovery.

However, rather than establishing some general laws on the economic impacts of natural disasters, it is more interesting and fruitful to analyze the factors influencing the impacts of disasters on the economy and its recovery. In the empirical analyses, these factors are heavily dependent on the general economic situation and cannot be isolated in a *ceteris paribus* manner. The macroeconomic modelling approach that will be developed in this thesis in part II serves the purpose of isolating the major variables and their effects on the economy post-catastrophe. This thesis will analyze in more detail economic vulnerability and its causes for developing countries, and focuses on natural disaster risk borne by governments in developing countries and the risk management options available for governments to reduce their exposure to risk.

4 RISK MANAGEMENT OF NATURAL DISASTERS

After the discussion of the general issues related to natural disasters with particular reference to developing countries, this chapter deals with approaches to manage and decrease disaster risk and impacts. It introduces the elements of disaster and risk management and puts the analysis of this study on risk transfer for public infrastructure into a larger perspective. Risk transfer will be analyzed in detail in chapter 6. Section 4.1 discusses disaster management, 4.2 current shifts in the approaches to disaster management occurring, 4.3 explains risk management and its elements, and 4.4 discusses the developmental dimensions of disaster management.

4.1 Natural Disaster Management

Disaster management encompasses a variety of measures taken before, during and after disasters; it denotes the management of disaster risks as well as the consequences of disasters (ADPC 2000a: 2). Risk management can and should be undertaken by a variety of actors such as individuals, communities, businesses or local and national governments. The thesis focuses on risk management by national governments which are often the main actors in this field in developing countries (see e.g. CGCED 2002: 8). Three phases can be distinguished: The pre-disaster phase, the disaster phase and the post-disaster phase. Accordingly, efforts to deal with disaster risk and the impacts can be separated into the categories risk management (ex-ante), relief (during) and rehabilitation and reconstruction (ex-post). Table 6 gives an overview over the elements of disaster management (based on IDB 2000: 13).

Table 6: Important elements of natural disaster management

Pre-disaster phase: Risk Management			**During disasters**	**After disasters**
Risk Identification and Assessment	**Risk reduction: Mitigation**	**Risk financing**	**Rescue and Relief**	**Rehabilitation and reconstruction**
Hazard identification and assessment	Physical and structural mitigation works	Risk transfer (by means of (re-) insurance) for public infra-structure and private assets	Humanitarian assistance	Reconstruction of damaged buildings
Vulnerability assessment	Land-use planning and building codes	Alternative risk transfer	Clean-up, temporary repair and restoration of services	Reconstruction of damaged critical infrastructure and private capital
Risk assessment (function of hazard and vulnerability)	Economic incentives for active risk management	National and local calamity funds	Damage assessment	Macroeconomic and budget management

Pre-disaster phase: Risk Management			During disasters	After disasters
Risk Identification and Assessment	**Risk reduction: Mitigation**	**Risk financing**	**Rescue and Relief**	**Rehabilitation and reconstruction**
	Education, training and awareness		Mobilization of financial resources (public/multi-lateral), insurance	Revitalization of affected economic sectors, incorporation of disaster mitigation components in reconstruction activities
	Early warning systems, communication systems			
	Contingency planning, networks for emergency response			
	Shelter facilities, evacuation plans			

Source: Modified based on IDB 2000:13.

Risk management analyzes risk exposure ex-ante and aims at reducing risk and potential losses before events. There are three areas that can be distinguished: Risk identification and assessment where risk exposure and potential impacts are assessed, risk mitigation that is concerned with risk reduction and risk financing dealing with the ex-ante financing of risk.

During events, rescue and relief efforts are undertaken. People are rescued, humanitarian assistance is provided to those affected, temporary clean-up and repair measures is conducted and financial resources for financing the losses and reconstruction are mobilized.

After events, rehabilitation and reconstruction are started. Houses are rebuilt, critical infrastructure and other capital stock are reconstructed. Budget and macroeconomic management is done so that the fiscal situation and economic situation are impaired to the least extent possible and affected economic sectors are revitalized. The reconstruction efforts should incorporate disaster mitigation components, so that risk in the newly rebuilt structures is kept as low as possible.

4.2 Shifts in approaches to natural disaster management

Traditionally the main effort in this field has been on ex-post approaches, but currently a shift in paradigm is being advocated towards more emphasis on ex-ante risk management measures. There is a growing awareness that disasters are not mere "acts of God" beyond human influence. It is acknowledged that disaster impacts can be reduced by modifying hazard and vulnerability ex-ante instead of relying on aid ex-post. The current attitude in this field is well described in the following quote:

> International aid and development funding agencies, besides sharing consternation at delays, disruptions, and increased costs, have the strong view that wisely planned hazard and vulnerability reduction efforts and funding before a catastrophe pay excellent

dividends in reducing economic impacts. Mitigation expenditures are a very small fraction of the funds spent on reconstruction in the aftermath of catastrophes (Pollner 2000: 44)

One point emphasized particularly in the 1990s during the process of the International Decade for Natural Disaster Reduction (IDNDR) of the UN was a gradual shift of emphasis from ex-post response and relief to ex-ante mitigation focusing on preventive measures against natural disasters. While granting assistance to disaster stricken countries is an important obligation of the international donor community, there are several drawbacks to this strategy for financing natural disaster losses (Cuny 1983: 89 ff). Potentially, there are adverse impacts on existing coping mechanism based on self-reliance. Aid interferes with existing societal coping mechanisms and may reduce the efficiency of those. As well, donor assistance may obscure existing strains on the social and political system and hinder appropriate adjustments and reforms. And, unrealistic expectations that high level of relief donations can be supplied to all in need and continued for long may be fostered.

Another ongoing shift of emphasis is the awareness that vulnerability needs to be targeted in addition to the natural hazards. Traditionally the focus has been on physical hazard modification, but lately the modification of vulnerability has been receiving more attention (Quarantelli 1991: 98).

Furthermore, what is of major importance for this thesis, there is growing interest in making more use of risk financing mechanisms in risk management. Risk financing by governments by means of e.g. insurance especially for developing countries has only lately moved to a more prominent place and is seen as a (partial) alternative to risk assumption and ex-post loss financing. As in these countries domestic loss financing resources are usually quickly exhausted, and financial sector and insurance markets are characteristically underdeveloped, the main sources of financing have to be provided by international donors in the form of foreign disaster aid and lending.

This thesis focuses on risk management, in particular on risk financing measures. For this reason, the major elements of risk management are discussed below in more detail. In addition, chapter 6 will discuss risk financing options while concentrating on risk transfer.

4.3 Natural disaster risk management

Risk management in general can be characterized the following:

> Risk management is the systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring risk. For any organization, whether a large corporation, a government agency, or a family farm, risk management is, or should be, an integral part of good management. [...]. It is a continous, adaptive process that needs to be integrated into all relevant aspects of the decision-making procedures of the organization (Hardaker et al. 1997: 12).

The application of risk management approaches to natural disasters denotes a planned and structured approach to dealing with natural hazard risk *before* the actual occurrence of events.

> Risk Management means reducing the threats to life and property (and the environment) posed by known hazards, whilst simultaneously accepting unmanageable risks and maximising any associated benefits (Smith 1996: 54).

Risk management involves identifying the major threats and implementing measures to reduce those, but also accepting limits to the risk reduction potential and determining acceptable risk levels which leads to the question of risk bearing and the associated costs (Gilbert and Kreimer 1999: 35).

Risk Management may be conducted by individuals, private and public entities. This study deals with public risk management strategies undertaken by governments or government institutions with a focus on developing economies.

There are four sequential steps that are or should be taken for the management of risks: first the identification of possible risks that are of significance in a particular region; then the risks need to be assessed which entails determining potential impacts; third, risk control measures need to be planned consisting of risk reduction and risk financing options (Kreimer and Arnold 2000: 4). And fourth, an important element of a risk management process is or should be the analysis of costs and benefits of the risk control measures. Cost-efficiency should be an important consideration as risk management is generally undertaken in the context of scarce resources. Thus it is crucial to optimally allocate available resources for reducing risk (fig. 10). Undertaking risk management has to be understood as a continuous cycle with potential for perpetual improvement.

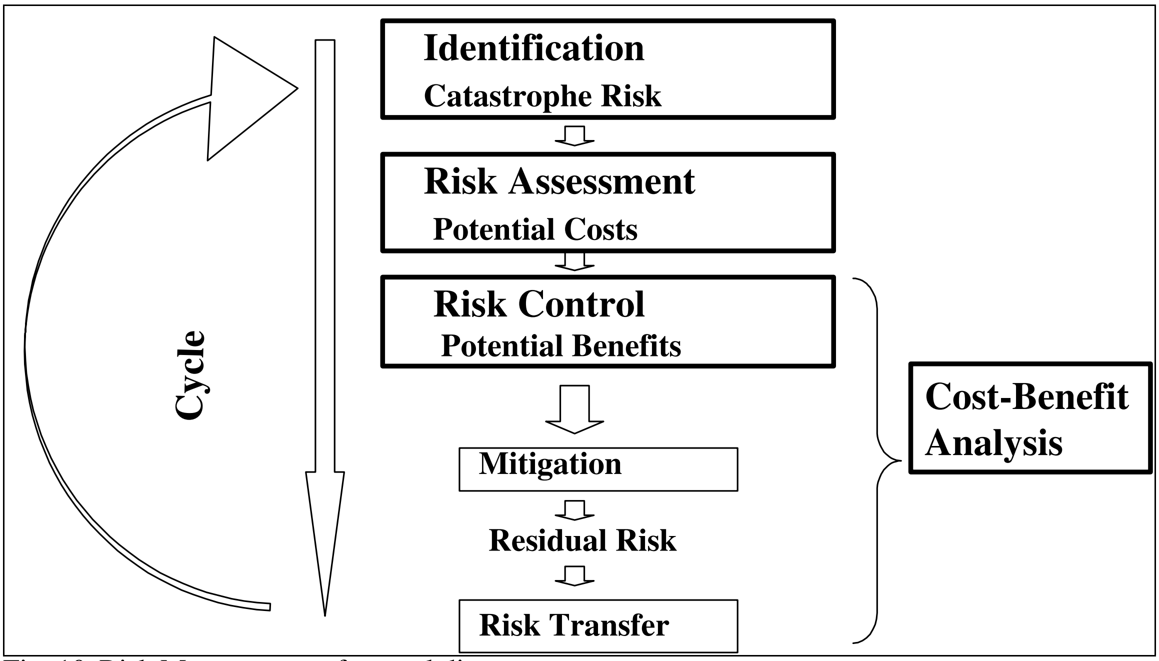

Fig. 10: Risk Management of natural disasters

4.3.1 Risk Identification and Assessment

In a first step risk needs to be identified and potential effects and losses assessed and where possible probabilities attached to these outcomes. As explained above, natural disaster risk is determined by the natural hazard and the vulnerability of a community or society in which these events occur (Smith 1996: 25-26); these two determinants need to be assessed and combined for a risk assessment.

Vulnerability can refer to the physical vulnerability of structures and production systems and the extent to which these will be damaged and interrupted. Also, it may denote a society's socioeconomic susceptibility to adverse influences and the existing coping mechanisms (ADPC 2000a: 1).

Hazard assessment involves creating hazard maps that show expected peak intensities for an event (like for Earthquakes) or the frequency of occurrence (like for floodmaps) in a given area. Historical events provide the main basis for this assessment. Often models generating hazard scenarios like the tracks of hurricanes are employed. Vulnerability assessment evaluates the elements (like structures, infrastructure and institutions)[16] that may potentially be struck by hazards. Bringing hazard and vulnerability assessment together allows the creation of damage functions and probability curves that measure the likelihood of losses (Kreimer et al. 1999: 9).

Such loss estimates provide a valuable basis for decision-makers: Investors and insurance companies can examine their risk exposure. Governments or public institutions can use these estimates to plan risk mitigation or risk transfer measures, plan response requirements post-event or employ it for general developmental planning purposes.

Crucial is also to determine who bears which losses. Governments usually are responsible for dealing with the following losses:

- Losses of public assets and infrastructure,
- Losses to private entities due to the failure of insurance markets to provide cover,
- Risk to the poor when they lack the capacity to deal with losses themselves.

This will further be discussed in chapter 5.

4.3.2 Mitigation

Risk mitigation (also termed reduction or prevention)[17] is concerned with reducing risk due to disasters. As risk is determined by the natural hazard as well as by the existing social and economic vulnerability, there are two areas for addressing risk: one area is to modify the intensity, frequency or location of a given hazard by building dams against floods, reinforcing existing structural engineering measures or using hazard-resistant design. The other area is to modify vulnerability by educating people, devising land-use measures that decrease environmental degradation (Kreimer and Munasinghe 1991: 4), installing early-warning systems like radar or by decreasing vulnerability of the population at risk or in economic sectors. A more general vulnerability reduction measure is to improve living standards which will usually improve the capacity to cope with disaster risks. To date, the focus in mitigation approaches has traditionally been on physical and structural measures to modify the hazard (Smith 1996: 73).

Two basic approaches can be used: avoidance of disasters which falls in the realm of land use and development planning and e.g. bans settling in hazard-prone areas, and resistance which is focused on increasing the capacity to withstand hazards by building safer structures. Whereas these approaches should be taken into account for

[16] The effect on human beings can also be evaluated, but will not be discussed here due to the ethical issues involved. Safety of human lives should receive priority in risk management.

[17] Mitigation, reduction and prevention are often used synonymously. Often mitigation is preferred as it denotes that disaster risk cannot be prevented fully. The term mitigation will be used in the following.

new settlements, existing structures are more problematic due to difficulties and costs for relocation and reinforcement (Kreimer et al. 1999: 17).

4.3.3 Risk financing

Risk can only be reduced to a certain degree due to physical or financial restrictions or due to the fact that the costs of reducing risk may outweigh the benefits. If, after possible risk reduction measures have been taken, the remaining risk level and potential costs are considerable, ex-ante risk financing options have to be evaluated. The ex-ante risk financing strategy consists in arranging the financing of risk prior to actual events so that in case of an event, sufficient financing will come forward. Thus ex-ante risk financing stands in contrast to the assumption of risk and reliance on ex-post loss financing sources such as budgetary resources and donor assistance and lending. The dominant risk financing instrument used is risk transfer by means of insurance or reinsurance. Other options and more detail will be discussed further below.

Risk financing and mitigation measures are closely linked: Incentives for mitigation are directly related to insurance and reinsurance schemes and premiums and the perception of being bailed out post-disaster by the government. A two-track approach is currently advocated to link these activities (Kreimer et al. 1999: 22 ff.).

4.4 Risk management as an integral part of comprehensive disaster management

A decisive step is to link the different risk reduction and risk transfer activities with the other elements of disaster management so that a comprehensive framework for tackling natural disaster risk and disaster impacts results. In numerous regions of the world disasters constitute a recurrent problem. In fact disasters are often accepted as a normal part of life (Smith 1996: 25). Thus, disaster management should be part of normal developmental planning processes with an understanding of the full economic and social short-and long-term consequences of disasters (Gilbert and Kreimer 1999: 31).

> […] Experience has shown that effective natural disaster management has to be part of the development planning and budgeting of countries at risk. From an emergency reconstruction perspective, many in the [World] Bank and among borrowers still see disaster management as traditionally being outside the normal business of development, as if it were an exceptional activity brought on by exceptional circumstances. It is indeed ironic that such "exceptional" activities are carried on almost regularly, year after year, in the most disaster-prone countries (Gilbert and Kreimer 1999: 37).

In general, the conviction is that natural disaster management has to be an integral part of a larger approach to development that embraces the principles of sustainable development and combines a prudent management of natural resources and hazards while fostering coping capacities (Mileti 1999: 2). The final aim of disaster management is to make development more „disaster-proof" (Wolfensohn and Cherpitel 2002).

5 GOVERNMENTS AND THE FINANCING OF DISASTER RISK

As outlined in chapter 4, risk management measures planned before actual disaster events comprise measures to mitigate risk as well as measures to finance risk. Mitigation options to reduce risk should be analyzed first and implemented as much as feasible (regarding cost-efficiency). When risk cannot be reduced efficiently anymore, risk financing measures should be taken into account. This thesis concentrates on the latter risk financing measures and will analyze those options in detail in theory and as relating to practical application.

As outlined, there are basically two ways for financing the costs of natural disasters for governments:

- assumption of risk and ex-post loss financing,
- ex-ante risk financing, especially risk transfer to private sector by means of insurance or reinsurance.

From a theoretical standpoint, engaging in one of these options depends on the preference towards risk, i.e. how much importance a particular risk represents. If risk is considered unimportant, the preference of risk is termed risk-neutrality. Risk-neutral governments can afford to assume the risk and will be able to finance the losses themselves, while risk-averse countries (should) evaluate the ex-ante financing of risk. After explaining a government's exposure to risk in 5.1, the theoretical underpinnings of risk aversion will be analyzed in 5.2, implications for some developing countries discussed in 5.3, statistics on loss financing by governments, and related issues will be examined subsequently in 5.4.

5.1 Governments and disaster risk

From an economic perspective, governments are exposed to natural disaster risk and potential losses due to their two main functions: the allocation of goods and services (security, education, clean environment and the distribution of income (Peffekoven 1992: 487 ff.).

The need for government intervention in the economy can be derived from the two fundamental theorems of welfare economics. The first theorem postulates that under certain conditions a competitive market economy without government intervention results in a pareto-efficient outcome, the second that an equitable pareto-efficient market outcome can be reached by a redistribution of initial endowments. The rationale for government intervention thus comes from a violation of these two theorems. Violations of the first theorem are the cases of complete market failure with public goods and partial market failure such as the existence of externalities, non-competitive markets and imperfect information. Governments have to allocate or regulate the allocation of those goods. Violations of the second theorem occur due to the inability to redistribute initial endowments (Devarajan and Hammer 1997: 7). This calls for redistribution by governments which is done by progressive taxation or transfer payments.

This leads to three sources of government risk that can be distinguished: First, governments allocate funds to the provision of public goods[18] and services - which due to their technical characteristics are not provided by the market. Public economic infrastructure is a major example. Thus, in the presence of natural disaster risk, governments are exposed to the risk of losing public infrastructure.

Second, in the case of partial market failure, governments also provide those goods and services. Natural disaster insurance is one example. Thus, governments assume natural disaster risk to which the private sector is exposed. Governments are often called "insurers of last resort" and "the most effective insurance instrument of society" (Priest 1996: 225). This takes the fact into account that governments are often the final entity that private households and firms turn to in case of need.

Third, governments redistribute income to those members of society that are in need of help. Thus, after disasters, the poor as well as those that are in danger of slipping into poverty need government relief payment to be able to sustain a basic standard of living. This is even more the case for developing countries with low per capita income and/or large proportions of the population in poverty.

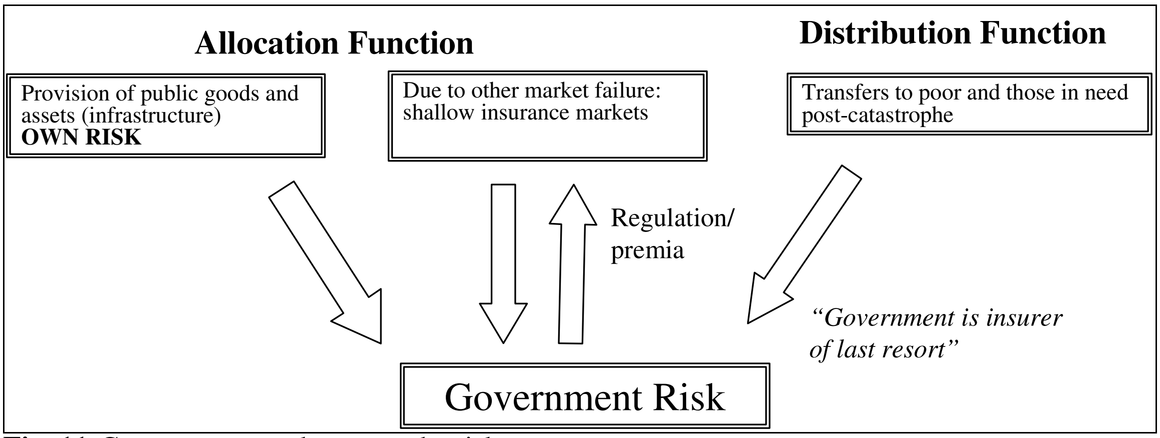

Fig. 11: Governments and catastrophe risk

Due to their role as a de facto insurer of last resort for private sector risk, there is a large extra burden to absorb for government at times of disasters in addition to their loss of own assets. For dealing with the total loss burden, as outlined, a first set of measures governments will turn to are measures to reduce the risks by mitigation. After using available mitigation measures to reduce risk ex-ante, a residual risk remains which in case of a disaster creates an obligation to fund relief, rehabilitation and reconstruction activities. Two main strategies exist to deal with that risk: Risk-bearing or risk financing. Governments may bear the risk themselves by relying on their internal resources domestic savings, taxes or credit from the financial sector. If governments perceive themselves to be unable to bear risk, risk financing options need to be investigated. The ability to deal with risk is generally described by the term risk-preference and will be the subject of the next section.

[18] Public goods are not provided by the market due to their characteristics of non-rivalry (one person's use does not affect another person's utility of using it) and non-exclusiveness (no-one can be excluded from usage).

5.2 Risk financing and Governments' risk preference: Arrow and Lind theorem

The preference to risk of an individual, firm or government depends on how much effect a risk is assumed to have on the specific agent. If the effect is deemed to be large, then this is termed risk aversion; if the effects is thought to be small, one can be risk-neutral. The typical firm or household is assumed to be risk averse as it will value potential losses higher than gains. Bearing risk will cause a cost for these agents (Dinwiddy and Teal 1996: 222).

On the contrary, national governments are usually assumed to be risk neutral, as they are considered the entity best suited to deal with risk (Arrow and Lind 1970: 364)**.** In contrast to the definition of risk from above where risk was defined as the general variation in outcomes measured by a probability distribution, risk in this context is defined as the variability of outcomes around the mean as measured by variance. Economic theory holds that a government can assume risk if it can deal with it efficiently, the risk-bearing country is then behaving "risk-neutrally." The theoretical basis was provided by Arrow and Lind (1970). According to this theorem, a government may

- Pool risks as it possesses a large number of independent assets and infrastructure so that aggregate risk is negligible, or
- Spread risk over population base, so that per-capita risk to risk-averse household is negligible.

Consequently, the Arrow-Lind theorem holds that if risk can be pooled or spread, risk can be neglected in government decision-making. More precisely, Arrow and Lind do not argue in favor of completely neglecting uncertainty, rather they argue for assessing the expected values only: "[…] the government should behave as an expected-value decision maker" (Arrow and Lind 1970: 366) without accounting for volatility around the mean. However, as outlined, natural disasters are extreme events, not average events, and it is exactly the variability that is of importance.

The Arrow and Lind theorem serves as the basis for government strategies for dealing with risk. In practice, most governments assume catastrophic risks themselves (Guy Carpenter 2000: 39-40), thus implicitly or explicitly they behave risk-neutrally.

5.2.1 Risk Pooling argument: Law of large numbers

Fundamental to the risk pooling argument is the *Law of large numbers*. The *Law of large numbers* states that for a series of independent and identically distributed variables the sample mean over the variables converges to the theoretical population mean of the probability distribution and thus the variance around the mean decreases for large numbers (Kunreuther 1998a: 24).[19]

Similarly, by pooling different uncorrelated risks to government assets, a government is able to reduce the spread of losses which may constitute the "actual risk" for natural disasters due to its rare but potentially catastrophic outcomes. A government usually undertakes a greater number of diverse projects and is thus able to diversify risks to a

[19] The Law of large numbers will be explained in more detail in chapter 6 in the context of risk transfer.

much greater extent than private investors. However, as will be demonstrated later, the fundamental assumption of uncorrelated risks is not tenable for natural disaster risk and has far-reaching implications.

5.2.2 Risk Spreading Argument

In practice, the spreading mechanism is of more importance. Arrow and Lind (1970) show that if the government spreads its risk over the whole population (most notably by means of taxation), the individual's costs associated with this risk go to zero due to the sheer size of the population (Arrow and Lind 1970: 372). They state, that

> [...] when risks associated with a public investment are publicly borne, the total cost of risk-bearing is insignificant and, therefore, the government should ignore uncertainty in evaluating public investments" (Arrow and Lind 1970: 366).

The risk-averse individual faces a negligible risk that will not strongly affect him or her. On this basis, the ability to spread risk over a larger population, governments can take a risk-neutral position, i.e. neglect risk though individuals in economic theory are standardly assumed to be risk-averse.

A government can also be compared to a wealthy individual engaging in small bets (Reutlinger 1970: 51). Thus, there will be no need to include risk (e.g. in form of variance of project benefits) in decisions whether to conduct certain public projects. Governments are assumed to be able to deal efficiently with risk. The Arrow-Lind theorem is standardly accepted in the literature and is the theoretical underpinning for dealing with risk for governments. The seminal manual of Little and Mirrlees on the evaluation of public investment decisions postulates (Little and Mirrlees 1974: 316): "In the absence of special reasons to the contrary one should measure the value of a project to the economy by its *expected* social value." This thesis argues that some of these special reasons apply and that in some cases governments should act risk aversely. These qualifications will be discussed in the following.

5.2.3 Conditions under which risk pooling and risk spreading are not feasible

This theorem generally holds true for developed countries. For developing countries there are a set of qualifications under which it may not be applicable. Several of these are important for developing countries in the presence of natural disaster risk (table 7). The qualification of the narrow tax and financing resources base for spreading risk can be illustrated by taking a worst case scenario approach. For this purpose, this entails looking at the impacts of the largest disasters in terms of direct and indirect economic losses that have ever occurred in the USA (Northridge Earthquake 1994), Argentina (floods of 1998) and Honduras (Hurricane Mitch 1998) and comparing these losses to important economic indicators to spread risk. The latter two countries are the case studies countries in part III of this thesis. In the USA, the Northridge Earthquake caused the highest loss ever of ca. 45.2 billion USD, Hurricane Mitch in Honduras had a devastating impact with a loss of ca. 3.7 billion USD, and in Argentina the floods in the La Plata river basin in 1998 resulted in a loss of 2.4 billion USD (all in current 1997 USD) (table 8). In addition, table 8 also shows the current annual average losses in Honduras and Argentina as estimated based on input data from Swiss Re.[20] In the case of risk neutrality, these average losses would need to be considered only rather than the highest losses as listed here.

Table 7: Qualifications to applicability of risk neutrality - theorem

Qualifications related to risk pooling	
Existence of few and large government projects	Usually, developing countries' governments undertake just a few large investment projects, which does not result in a highly diversified portfolio of projects, thus risk pooling is not viable (Brent 1998: 217-218).
Large local or regional consequences when assets are lost	Disaster risk is covariant risk: Disasters usually will affect whole regions thus there is loss correlation.
Qualifications related to risk spreading	
Narrow tax and financing resources base for financing losses of projects	In smaller developing countries the tax base is often too narrow to spread risk sufficiently. Other potential government financing sources such as domestic credit or private sector lending used to spread risk are generally very limited as well.
Distributional impacts	In developing countries large distributional impacts may occur post-disaster when infrastructure projects whose prime goal is poverty reduction (e.g. through road or sanitation projects) are affected. The poor are the group most affected by a loss of infrastructure.
Irreversibility	If additional funds are not available to continue crucial projects or rebuild assets there can be irreversible effects, such as on health service provision (Little and Mirrlees 1974: 320).

Governments may spread risk by using tax revenue, tapping into domestic savings or the domestic credit market. If a risk and incurred losses are shared out among a large group of risk bearers, individual risk may become negligible. Three factors are of importance here:

1. the magnitude of the risks,
2. the size of the group sharing the risk,
3. resources for spreading risks.

For illustrative purposes, these losses are compared with domestic resources for risk spreading. This will overstate the potential losses governments face, but shows the entire country risk. In chapter 7, a detailed methodology is developed to derive the total sum of domestic and external resources governments are able to access post-disaster. This ability will be termed economic vulnerability. A significantly different capacity to assume risk emerges for the three countries (table 8 and figure 12).[21]

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[20] For the USA no information on the average annual losses was found in the literature. However, as will become clear in the following, for the USA this number is not of importance for this discussion.

[21] Using aggregate direct and indirect losses as the indicator for government's exposure to natural disaster risk overstates the burden governments face. Typically, only 20% of total capital stock is infrastructure. However, due to government's role as de-facto insurer of last resort and redistributor of incomes, they also have to assume part of the other potential losses. In the USA where natural disaster insurance markets exist at least partially, part of the losses will be borne by private market insurance.

Table 8: Historical and average annual disaster losses and availability of resources for spreading risk for the USA, Argentina and Honduras.

1997 values	USA Northridge 1994	Argentina Floods 1998	Argentina average loss	Honduras Mitch 1998	Honduras average loss
GDP (millions)	7,834,000	293,005		4,725	
GDP/percapita	29,267	8,214		790	
Aid/GDP	-	0.03%		6.3%	
Losses (millions)	**45,181**	**2,432**	**325**	**3,697**	**45**
Losses/capita	168.8	68.2	9.1	618.1	7.5
Losses/capital stock	1.2%	0.2%	0.03%	39.9%	0.49%
Losses/GDP	0.6%	0.8%	0.09%	78.2%	1.0%
Losses/Tax revenue	2.9%	6.7%	0.5%	555.6%	6.8%
Losses/Gross Domestic Savings	3.6%	4.1%	0.4%	358.9%	4.4%
Losses/Net domestic credit	0.7%	2.8%	0.03%	314.2%	3.8%

USA: Northridge Earthquake 1994; Argentina floods of 1998; Honduras Hurricane Mitch 1998. All absolute values in 1997 current USD. Data sources: World Bank 2001a, Munich Re 2000.

For the U.S. disaster risk on an *aggregate* level is not a significant risk. The, in absolute terms, enormous losses of $45 billion from the Northridge earthquake amounted to only 0.6 percent of GDP and 2.9 percent of tax revenue. For Argentina, risk as measured by the losses due to the floods of 1998 is in the same order of magnitude as for USA if measured against important economic indicators. E.g. the losses amounted to 0.8% of GDP. For Honduras, on the other hand, the losses due to Hurricane Mitch, the largest disaster so far, had severe implications and the resource base for financing the losses was clearly overwhelmed. In terms of GDP, the losses of this event amounted to 78% and in terms of tax revenue to 556%. Consequently, post-Mitch Honduras experienced significant aggregate economic impacts with an economic recession in 1999 after years with a growing economy.

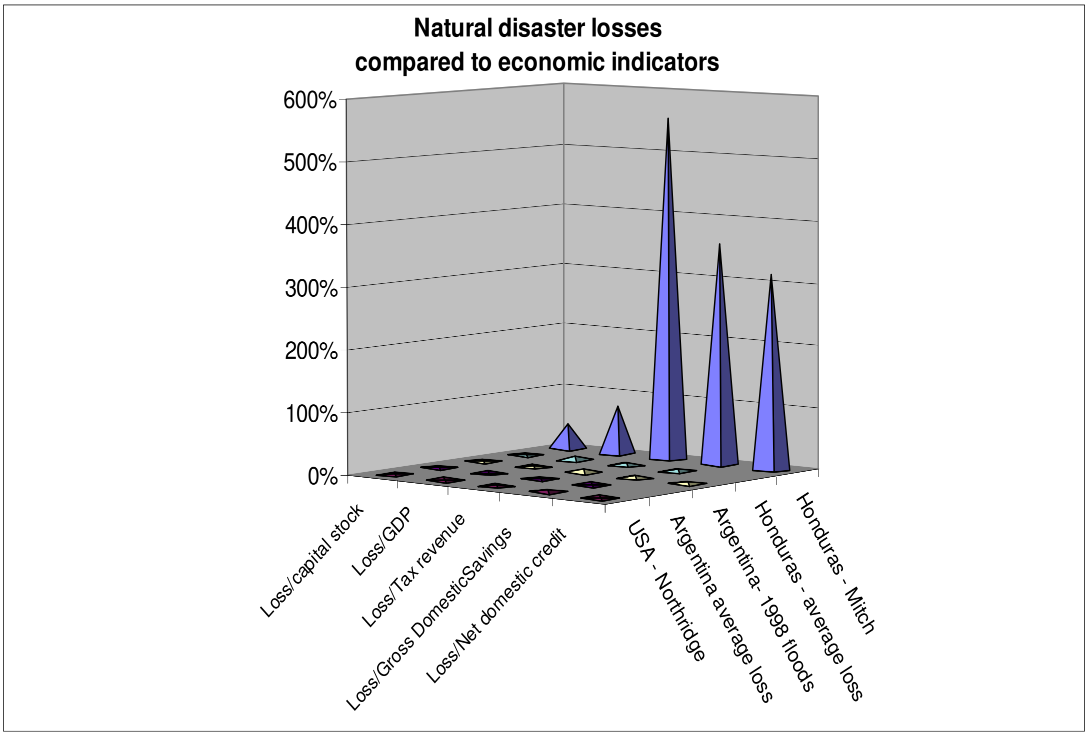

Fig. 12: Important indicators for ability to spread disaster risk for the USA, Argentina and Honduras

Honduras has traditionally relied on external aid to help with economic development and in the event of natural disasters. Already before Hurricane Mitch occurred in November 1998, foreign aid amounted to 6.3% of GDP in 1997 (6.1% in 1998), and rose to 15.2% in 1999 when major disaster aid flows materialized. This reliance reflects the high cost of disasters in relation to GDP and the inability to spread risk internally. Consequently, Honduras is one example for a country and government that should act aversely to natural disaster risk. The extremes and volatility of disaster risk clearly are of importance. Examining only average annual losses (as proposed in the case of risk neutrality), in Honduras the dimensions of this risk are concealed and the impression is provided that it can be handled without major difficulties: the expected loss of $45 million constitutes 1 percent of GDP and 6.8 percent of tax revenue in 1997. For Honduras, however, it is necessary to look at the extremes rather than the averages as disasters by definition are low-frequency, high-consequence events. Averages do not capture these characteristics well. For Argentina, in addition to the much smaller extreme losses as measured by the ratio of the flood losses of 1998 to GDP, the difference between average and total losses is smaller with the average losses amounting to 0.09% of GDP.

This static representation of the capacity to spread the losses was merely meant to illustrate roughly the differing resource availability to finance government losses and give indication of the ratio of potential disasters to the economic capacity. However, without doubt, not all of the existing resources can be used to finance the losses, e.g. the government has to continue using part of the tax revenue to pay wages and salaries to its employees and domestic savings are also used by the private sector. As well, as will be explained later, external savings are a crucial source of reconstruction funding in the form of aid and loans. A more complete and dynamic analysis of resource availability post-disaster determining economic vulnerability will be developed in chapter 6. As well, instead of using the largest historical event as a yardstick, full loss distribution curves of future probable events will be compared to resources available.

5.3 Some countries should exhibit risk aversion

Most developed countries assume (disaster) risk, for them the Arrow and Lind theorem seems to be valid and they are to pool or spread risk so that individual risk is negligible. However, the Arrow and Lind theorem may not apply for a number of developing countries subject to high natural disaster risk and with lesser means at disposal of spreading or pooling the risks they are exposed to. Especially the second argument on the risk spreading capacity of governments and the resulting individual cost being negligible is debatable. In reality, external aid or loans have often to be sought post-disaster.

All of the qualifications discussed are, more or less, of relevance for developing countries facing natural disaster risk. The degree to which they hold defines risk aversion and vulnerability. Under these circumstances, costs of risk bearing will not approach zero and governments are in fact risk-averse to some degree and should not act risk-neutrally. In this case the literature argues in favor of being risk-averse in case of disasters to properly adjust these high loss-, small probability-events. Also, Little and Mirrlees argue that "it is therefore right that projects that add significantly to aggregate uncertainty in the economy should be somewhat penalized in the system of project evaluation." (Little and Mirrlees 1974: 318). The Organization of American States' primer on natural disasters (OAS 1991: 14 ff.) states that the risk neutral proposition is valid only up to certain point and that the reality in developing countries suggests that some governments cannot afford to be risk-neutral:

> The reality of developing countries suggests otherwise. Government decisions should be based on the opportunity costs to society of the resources invested in the project and on the loss of economic assets, functions and products. In view of the responsibility vested in the public sector for the administration of scarce resources, and considering issues such as fiscal debt, trade balances, income distribution, and a wide range of other economic and social, and political concerns, governments should not act risk-neutral (OAS 1991: 40).

In total, the Arrow- and Lind-theorem of risk-neutrality more or less only holds true for more developed countries; there are a number of developing countries that should act in a risk averse manner:

- Countries subject to high natural hazard exposure.
- Countries subject to high economic vulnerability - low tax revenue, low domestic savings and shallow financial markets, high indebtedness with little access to external finance.
- Small countries with few large infrastructural assets and high geographical correlation between those assets.
- Countries with concentrated economic activity centers (e.g. large urban agglomerations) exposed to natural hazards.

Crucial about this section about risk preference is that if governments are perceived to be risk-neutral and thus risk and potential losses are only included as expected value, there is no incentive for a decision-maker to evaluate risk-financing mechanisms as the price of risk financing mechanisms is usually higher than the expected loss. This will be explained later. For the moment suffice it to say, that if governments are risk-neutral they are able to assume risk themselves and should actually do so as this is the most cost-efficient option for them.

5.4 Developing countries governments and reliance on external assistance post-catastrophe: Indications of risk aversion

As shown, a number of developing countries cannot spread or pool risk sufficiently. These countries have to finance their risk externally and rely on external aid or/and concessional external lending post-catastrophe. 56 developing countries have had to rely on external post-catastrophe assistance from the World Bank during the period from 1980 to 1999 (Gilbert and Kreimer 1999: 1). This reliance on access to external resources is a clear indication that these countries cannot assume natural disaster risk effortlessly.

In the following, some statistics on assistance provided by the international donor community, as well as the shortcomings associated with a permanent assistance strategy will be provided.

5.4.1 Statistics on relief and reconstruction assistance

Official development assistance (ODA)[22] is a crucial source of income for developing countries. For the group of the least developed countries, countries defined to be particularly poor and vulnerable, it represented about 20% of GDP in 1995 whereas private financial inflows amounted to only 1.5% of GDP (IFRC 1999: 103). However, ODA has been decreasing (in constant 2000 USD terms), it decreased from $69 billion in 1990 to $53 billion in 2000 (OECD and DAC 2000, 2001).

[22] Official Development Assistance (ODA): Grants or Loans to countries and territories on Part I of the DAC List of Aid Recipients (developing countries) which are:
- undertaken by the official sector,
- with promotion of economic development and welfare as the main objective,
- at concessional financial terms (if a loan, having a grant element (q.v.). of at least 25 per cent) (OECD DAC 2001).

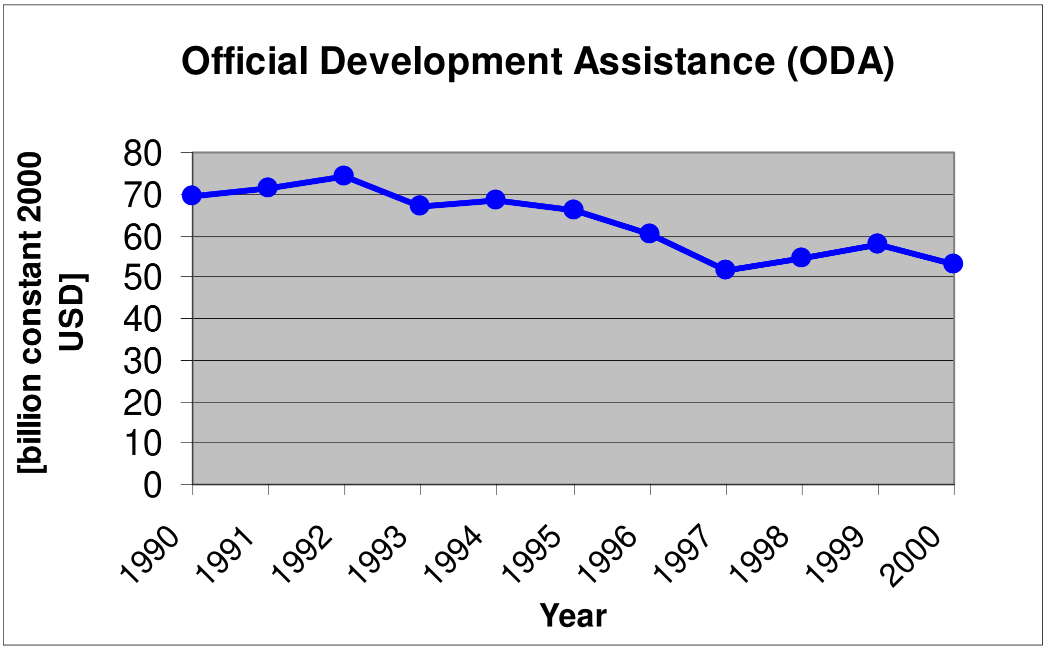

Fig. 13: ODA in constant terms is decreasing
Sources: World Bank 1999a, OECD and DAC 2000, 2001.
Values in constant 2000 USD.

What concerns post-disaster assistance, emergency relief and reconstruction assistance are the two major sources of financing for the costs of natural disasters in developing countries.

Emergency relief

Emergency relief provided after disasters is mainly supplied on a bilateral basis or by international relief organizations like the Red Cross. There was increasing need for money donations in the form of emergency relief in the 1990s by developing countries. In constant terms, relief provided by the international donor community rose from 1.3 billion USD in 1990 to 4.2 billion in 1998 after a slump in the mid-90's, a rise by 230%. While this figure includes spending on civil conflict[23] it nevertheless shows the increasing need for post-emergency relief spending and the increasing vulnerability to unexpected shocks in developing countries

Reconstruction

After urgent relief efforts are handled, loans for reconstruction and rehabilitation needs are usually provided to affected countries unable to finance this effort themselves. These loans are normally low-interest loans often with grant elements. This financing comes from development banks. From 1980 to 1999 the World Bank, the largest multilateral lending institution, has financed 102 post-catastrophe reconstruction projects in 56 countries amounting to a total of about 7.5 billion USD (Gilbert and Kreimer 1999: 1).[24]

[23] E.g. one third of the rise from 1998 to 1999 was due to post conflict emergency spending for the Balkans.

[24] The World Bank focuses on the financing of investment and productive assets for building infrastructure and institutions fostering socioeconomic development rather than relief operations (Lester 1999: 179).

In relation to total World Bank lending, the total sum amounts to 1.9% with a range of this ratio from 0.2% to 6.0% on an annual basis (fig. 14).

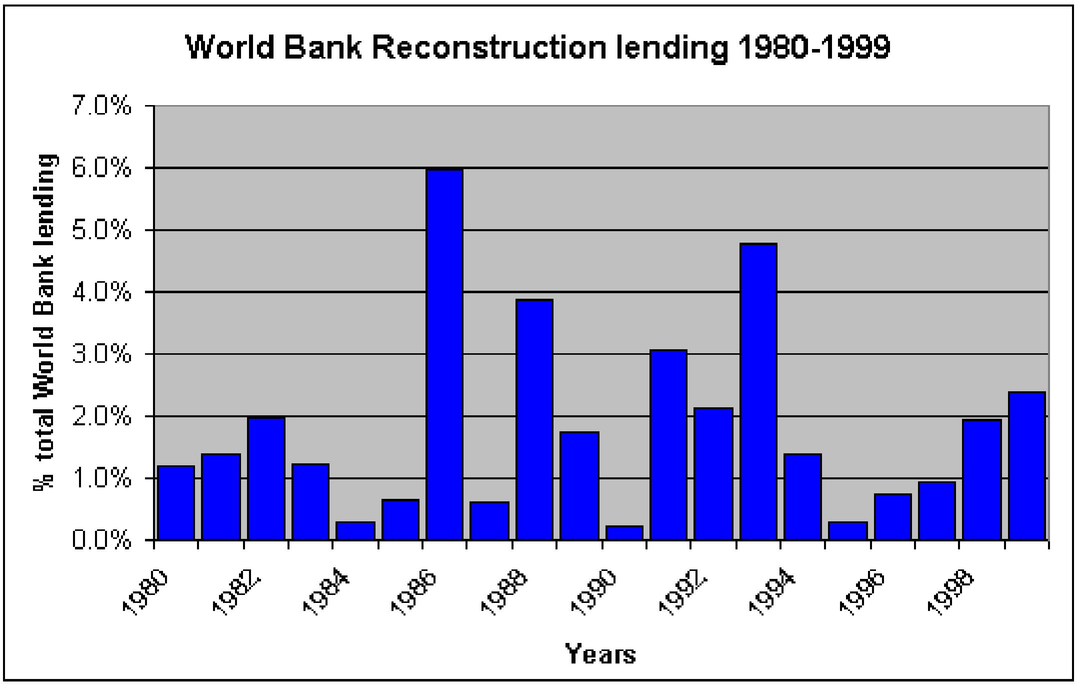

Fig. 14: World Bank post-disaster reconstruction loans and total World Bank lending[25]
Sources: Gilbert and Kreimer 1999, World Bank 2001a.

This figure underestimates the World Bank's reconstruction financing support, as it does not include funds reallocated from other operations. Lester - while acknowledging that it is not possible to quantify the amount of World Bank loans diverted post-disaster, cites a figure of 30% of infrastructure loans diverted in disaster-prone countries suggested by anecdotal evidence (Lester 1999: 180). Thus, the average annual lending for the period from 1980 to 1999 amounted to 375 million USD. The data show that reconstruction lending is increasing. The average annual lending in the 1980s was 318 million USD compared to an average of 427 million USD in the 1990s, an increase of 34%. There is some recurrence involved: 22 countries have had two or more lending operations. This among others is the reason for the high interest for investing funds into mitigation activities by the World Bank: Since 1980 7.5 billion USD have been lent for 102 projects that included one or more components dedicated to this objective (Gilbert and Kreimer 1999: 1). What is interesting to note is that about half of the top clients for reconstruction borrowing from World Bank do not appear among the main borrowers for mitigation projects (Gilbert and Kreimer 1999: 2). This demonstrates that ex-ante disaster risk management measures have not yet pervaded sufficiently development planning activities.

As well, in the last 10 years the Inter-American Development Bank has lent around 2 billion USD post-disaster mainly to rebuild and rehabilitate damaged infrastructure (IDB 2000: 20). From 1996-2000 alone it lent 1.5 billion USD to affected countries to

[25] World Bank lending includes lending by its financing branch institutions International Bank for Reconstruction and Development (IBRD) and International Development Agency (IDA).

help recover from disasters, which increased annual average disaster-related lending by a factor of 10 compared to the previous 15 years (IDB 200: 1).

As was mentioned in the beginning, there is concern at the MFIs about the high and increasing amounts of post-catastrophe aid and loans (IDB 2000: 1; Pollner 2000: 44) while donor funds have become scarcer. As CGCED asserts: "Although funds from donor agencies for post-disaster reconstruction and response are diminishing, international donors continue to be seen by many countries as the prime 'insurers' of natural catastrophe risk." (CGCED 2002: 11).

5.4.2 Problems with reliance on aid

Relying on funding post-catastrophe is problematic due to a number of reasons. As discussed, ODA in absolute terms has been decreasing. In addition, it is not even close to the UN target agreed upon at the Earth summit in Rio 1992 of 0.7% of a donor country's GNP, the overall average being 0.22 % of all donors' GNP in 1997 (IFRC 1999: 102). This trend contrasts with the trends in relief and reconstruction spending rising. As a consequence, relief spending rose from 2.1% of ODA in 1990 to 7.8% in 1999 (fig. 15). A similar trend can be made out for reconstruction funding.

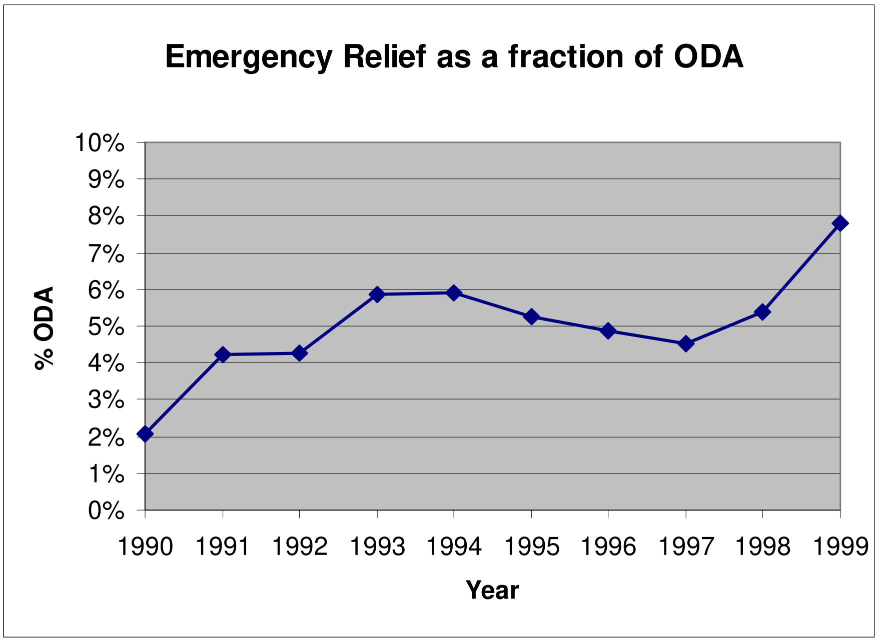

Fig. 15: Emergency relief as a fraction of ODA: Increasing share out of stagnant budget. Values in constant 2000 USD.

What is problematic about this increase, is that these funds while they help to protect livelihoods and return conditions to normal, only reestablish the pre-disaster status-quo, instead of ameliorating socioeconomic development and contributing to poverty alleviation. Post-catastrophe funds have to be borrowed to replace destroyed schools, roads or productive capital stock. Thus these scarce funds are lost for investment into new development-stimulating and poverty-alleviating goals.

While there will always be some need for funds after unforeseen catastrophic events, spending funds mainly post-disaster does not seem to be the most prudent strategy. As already outlined, there is increasingly the conviction that funds invested into ex-ante risk management measures before an event occurs, are wise and good investments. A recent cost-efficiency analysis of floods control preparedness measures in China over the last 40 years, came to the conclusion that the 3.15 billion USD spent had averted losses of about 12 billion USD. World Bank and the US Geological Survey estimate that economic losses worldwide from natural disasters could be reduced by 280 billion USD by ex-ante measures costing about 40 billion USD (IFRC 1999: 110).

Another issue is that while relief funds are provided as grants, borrowing has a cost as it increases debt and has to be repaid. Increasing debt now affects spending and economic performance in the future. Debt at unsustainably high levels may cause several effects: Private investment may get crowded out, as interest rates increase when government demands more credit in domestic capital market. There is a risk of inflation when the central bank takes on unlimited debt, scarce resources may have to be diverted to debt service; also there is some risk of capital flight due to fear of tax increase and devaluation (Peffekoven 1992: 529-534).

All of this has potentially deteriorating impact on economic growth. As well, a consensus has developed that there is a limit to borrowing beyond which debt becomes unsustainable and borrowing is not possible anymore. Realizing that some countries have exceeded this sustainable debt level and are seriously affected by their debt overhangs and repayment obligations, the World Bank and the IMF have recently created the Highly Indebted Poor Countries (HIPC) Initiative to grant debt relief in exchange for the implementation of integrated poverty reduction and economic reform programs. Twenty-two countries are currently receiving debt relief under this framework. Three countries that were subject to large natural disasters in the recent past, Mozambique, Honduras and Nicaragua, are granted debt relief (World Bank 2001b).

Furthermore, reliance on post-catastrophe aid provides adverse incentives for ex-ante measures, is counterproductive to undertake own measures and creates dependency. The case can be imagined where countries that neglected risk management are "rewarded" by international aid after an event while countries that have invested in ex-ante measures receive less attention (Charveriat 2000: 79).

Another important problem with post-disaster aid is the timing issue. Emergency relief aid usually takes a long time to materialize, often it comes too late for the pressing needs of the affected population (Smith 1996: 82 ff.). The same holds true for reconstruction finance loans that usually take at least a year to materialize (Gurenko 2001; Charveriat 2000: 80). Furthermore, reliance on this aid is not sustainable as the inflow of relief is heavily dependent on media coverage that often is in need for fast news. Thus the emergency situation may be focused upon, while the requirements of the reconstruction phase will be of less interest and consequently disbursed funds smaller (Charveriat 2000: 80).

5.4.3 Shift in thinking: increasing role for risk financing measures

Acknowledging the rising costs and the recurrence of disasters in some countries and the risk of socioeconomic development being hampered as well as the numbers of natural disasters rising, has affected altered the approach for lending and operation's activities of the international donor community towards more preventive action. An IDB research paper states:

> To comply with its development objectives for the region [Latin America and the Caribbean], the international donor community should encourage the adoption of more proactive policies by providing financing for risk-identification and reduction programs in the region. Instead of focusing resources on post-disaster assistance, development programs should attempt to bolster the financial preparedness of the region by encouraging the development of insurance and other risk-spreading mechanisms (Charveriat 2000: 95).

In total, there are a number of reasons that may make the current (implicit) reliance of developing countries on external aid and lending an unsustainable and risky strategy for the future:

- ODA is stagnant while relief and reconstruction spending and disaster costs are increasing.
- Increasing unwillingness or rising risk aversion of donor agencies to continue giving adverse incentives to ex-post behavior.
- Borrowing creates long-term debt service problem.

Mitigation efforts decreasing vulnerability to natural disasters should be stressed, but also risk transfer options are worth investigating. E.g. some Latin American countries (Honduras, Mexico) are currently examining whether to invest in risk transfer for some of its disaster risk exposure. This could help particularly in providing funds for reconstruction post-catastrophe. Risk transfer options and their relevance for natural disaster management in developing countries will be analyzed next.

6 EX-ANTE RISK FINANCING INSTRUMENTS: RISK TRANSFER

The latter chapter explained the prevailing strategy of governments financing disasters losses by relying on ex-post financing, and outlined its limitations. The term risk aversion was used to signify a situation where disaster risk could not be easily assumed and the impacts could be large. In the case of governments, risk is usually (voluntarily or involuntarily) assumed despite high prevailing risk aversion and external help is needed to help out in case of actual events. If risk cannot be assumed and international donor support cannot be expected to come forth, sufficiently ex-ante financing arrangements may be used to avoid potential financing shortfalls. This chapter will analyze these options in detail.

The chapter focuses on the role of risk transfer, in particular reinsurance for reducing the burden due to natural disasters in general and as an option for governments. Chapter 6.1 first discusses the major ex-ante instruments possibly available, 6.2 and 6.3 deal with the basics of insurance and reinsurance theory, 6.4 examines the insurability of disaster risk, 6.5 discusses the insurance and reinsurance markets and premia, 6.6 deals with governments and the supply of risk transfer instruments, 6.7 analyzes alternative risk transfer instruments, 6.8 looks at risk transfer in developing countries, 6.9 is concerned with governments and demand for risk transfer, finally 6.10 outlines the risk transfer of infrastructure by governments examined in the thesis and 6.11 concludes by discussing the trade-offs involved in risk transfer.

6.1 Ex-ante risk financing arrangements

In order to finance disaster risk ex-ante the following instruments are generally available (see e.g. Freeman et al. 2002b: 47 ff.).

- Risk transfer provides indemnification against losses in exchange for a premium payment. The most common forms of risk transfer are insurance or reinsurance.
- In a reserve fund arrangement liquid funds before events should be laid aside. This should be done in theory on an annual basis, so that capital can accumulate. A fund accumulates in years without catastrophes and can be used in the case of an event to finance the losses.
- Contingent credit arrangements do not transfer risk, but spread it intertemporally. In exchange for an annual fee, the right is obtained to take out a specific loan amount post-event that has to be repaid at contractually fixed conditions. Contingent credit options are commonly grouped under alternative risk transfer instruments.

Table 9 outlines characteristics, and costs and benefits of such instruments:

Table 9: Costs and Benefits of Ex-Ante Financing Tools

	Insurance	**Reserve fund**	**Contingent credit**
Cost before event	Premium times number of years before event	Payment into fund times number of years before event	Holding fee times number of years before event
Benefit after event	• Loss indemnification for elements insured • Increased capital inflows from abroad to affected economy	• Reserve funds and interest available • Funds will not be lost in case of no event	• Funds available immediately • Increased capital inflows from abroad to affected economy
Cost after event	None	None to the extent that enough reserve has been accumulated	Additional debt service, reduction in ability to take out future debt
Incentive for mitigation?	Yes	Only if risk is known	No
Risks	Theoretically risk of (re)insurer going bankrupt	▪ Risk of depletion before disaster events due to political pressures ▪ Risk of insufficient funds	• Risk of insufficient funds • Theoretically risk of financial entity going bankrupt

Source: Extended on basis of Freeman et al. 2002b: 49.

The costs of these instruments, which arise every year, create important opportunity costs. On the other hand, benefits arise only when a disaster event occurs. In case of no event, one could talk about opportunity costs foregone. The opportunity cost foregone in the case of reserve funds is only the interest foregone on the resources invested in the fund, whereas for insurance and contingent credit these costs comprise the full premium or fee payment.

Additionally, there is a risk with the reserve funds that the other arrangements do not exhibit: the risk of depletion of a reserve fund is relatively high particularly in capital-scarce economies where it has been observed that such funds are depleted once there is need for financing of other important issues or disasters have not occurred for a longer while. Sometimes even the budgetary process does not allow to accumulate funds over budget years (cf. Freeman et al. 2002b: 54). Thus the long accumulation time needed to build up substantial capital reserves is a problem. As well, after disasters the reserve fund will be depleted and time is needed to build it up again.

The following example illustrates the costs and benefits of these ex-ante instruments for the case of protecting against a *layer* of disaster events with a return period of 50 to 100 year, i.e. events more likely than once in 50 years and less frequent than once in 100 years remain uninsured. As will be discussed, in the following insuring such a risk layer is typical for natural disaster risk (table 10).

According to this example for El Salvador, reserve funds cost only the expected losses each year while however providing the least protection. Only after an accumulation of 22 years will the reserve fund provide an equal level of protection as insurance and contingent credit. This long accumulation period however constitutes a problem due to the high risk of depletion as discussed before. Also, often reserve funds are annual budget items instead of accumulating funds, thus they will not build up sufficient reserves. The advantage of reserve funds in case of no event happening is that the funds invested will not be lost.

Table 10: Illustrative example of costs and benefits of ex-ante tools to protect against 50- to 100-year events in El Salvador

	Insurance	**Reserve fund**	**Contingent credit**
Cost before event	US$ 38 million times number of years before event	US$ 3.5 million times number of years before event[26]	US$ 19 million times number of years before event=expected losses to government
Benefit after event	US$ 700 million available immediately	US$ 700 million available immediately	US$ 19 million times number of years before event + 5% interest compounded over that period
Cost after event	None	US$ 56 million a year for 20 years after the event in debt service payments	None

Source: Freeman et al. 2002b: 51.

Contingent credit arrangements cost the smallest annual sum before an event, however when an event occurs, large debt service payments are necessary; in this example for an assumed maturity of 20 years each year after the grace period 56 million USD (in constant terms) will have to be paid in debt service installments. Insurance has the highest annual costs, but provides guaranteed loss indemnification for the risks insured and has no consecutive costs in terms of debt service payments.

A comparison of the costs and benefits between different ex-ante measures can be found e.g. in Freeman et al. 2002b and Mechler and Pflug 2002 for five Latin American countries (Bolivia, Colombia, Dominican Republic, El Salvador and Honduras). As figure 16 shows - given the specific assumptions - for the case of Honduras insurance emerged as the most cost-efficient risk financing option for the reduction of the probability of the *financing gap*, i.e. the shortfall of loss financing obtained as compared to losses incurred (Mechler and Pflug 2002: 24).[27]

[26] Assuming 5% interest, maturity of 20 years and a 5 year grace period (Freeman et al. 2002b: 50).

[27] In this study, insurance was modelled as XL-insurance with a fixed attachment point at 5% capital stock lost (equal to the 50 year storm and flood event in Honduras). The exhaustion point was the decision variable in this stochastic simulation exercise and determined by the amounts spent on insurance (Mechler and Pflug 2002: 24).

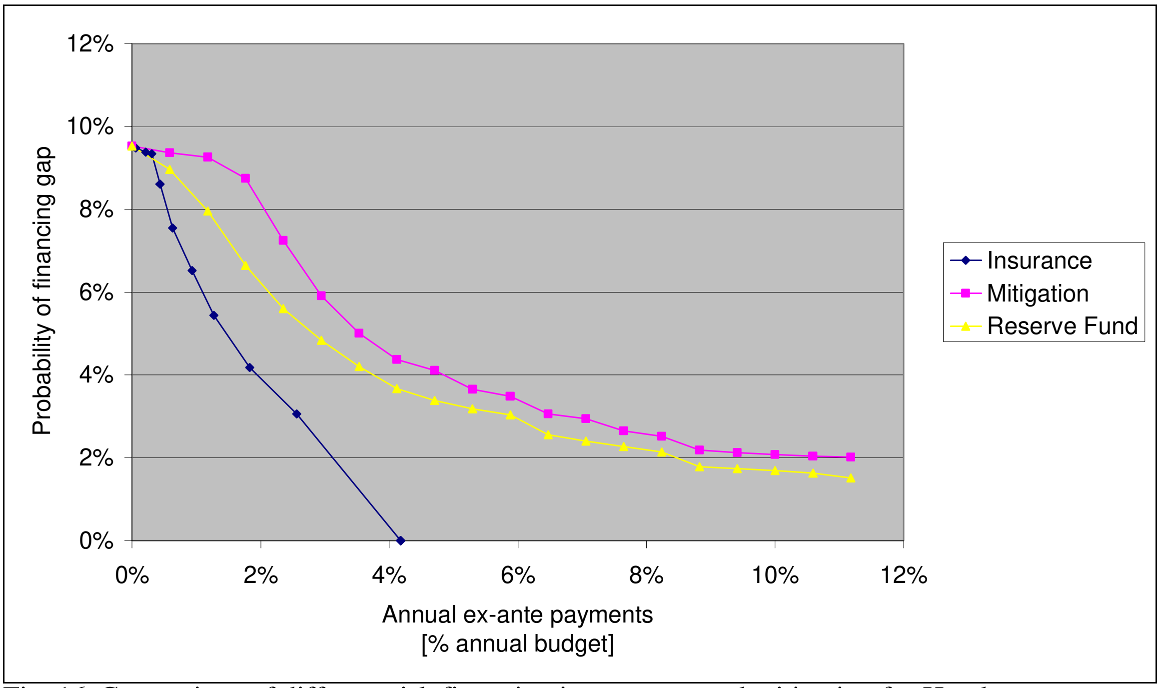

Fig. 16: Comparison of different risk financing instruments and mitigation for Honduras
Source: Mechler and Pflug 2002: 24.

In total, these ex-ante instruments have their pros and cons and depend on the hazard situation and the perceived risk aversion of the risk cedent. However, insurance and reinsurance are by far the most common form of risk financing. Reserve funds exist, but generally are merely annual budget items instead of accumulating funds, and additionally are often underfunded; so they do not represent fully viable instruments, at least not today (Freeman et al. 2002b: 45). Contingent credit arrangements are relative recent innovations and have to date only been used in a few instances in the private sector, and also carry the risk of remaining underfunded.

For these reasons, the following discussion will focus on risk transfer by means of insurance and reinsurance. It should be added however, that insurance and reinsurance are used as examples to contrast financial ex-ante risk management with ex-post reliance on own financing resources. A main focus of this thesis is on ex-ante vs. ex-post financing instruments. In theory, the other ex-ante instruments could also be used in the modeling.

6.2 Insurance

The mechanism of insurance can be explained as follows:

> Insurance is an economic institution that allows the transfer of financial risk from an individual to a pooled group of risks by means of a two-party contract (Kunreuther 1998a: 23).

The insured party, the policyholder, receives coverage, indemnification, against the loss from an uncertain event from the insurer in exchange for a certain payment, the premium. Usually, full coverage is not supplied and deductibles of fixed amounts of ratios are the standard case. The loss to be reimbursed based on an insurance contract is called a claim (Kunreuther 1998a: 23-24) or indemnity payment.

Insurance markets use the same principle underlying the *Law of large numbers* discussed before in the context of risk pooling for governments. For risk transfer, this law is also known as the *insurance principle*, stating that for a series of independent and identically distributed variables the sample mean over the variables converges to the theoretical population mean of the probability distribution and thus the variance around the mean decreases for large numbers. For insurance, this means that the variance of average claim payments to the insured decreases as the number of policies increases. Premiums become calculable with an increasing degree of confidence (Kunreuther 1998a: 24).

The following example illustrates the *Law of large numbers* (Hodgson 1997: 215-216). Under the following assumptions:

- zero correlation between individual events,
- number of events being N,
- equal investment determined by X_i,
- a variance δ_i^2 of 1% in the event payoff.

The variance of an equally weighted portfolio of two events, i.e. $X_1=X_2=0.5$ will amount to:

$$\delta_p^2 = X_1^2\,\delta_1^2 + X_2^2\,\delta_2^2 = 0.5\%$$

The covariance term drops out as zero correlation between the two events is assumed. For three events, i.e. $X_1=X_2=X_3=0.333$, the variance of the portfolio is:

$$\delta_p^2 = X_1^2\,\delta_1^2 + X_2^2\,\delta_2^2 + X_3^2\,\delta_3^2 = 0.333\ \%$$

And the variance for N events is:

$$\delta_p^2 = (\frac{1}{N})^2 \cdot 0.10^2 + (\frac{1}{N})^2 \cdot 0.10^2 + \ldots + (\frac{1}{N})^N \cdot 0.10^2$$

$$= N\,(\frac{1}{N})^2 \cdot 0.10^2 = (\frac{N}{N^2})^2 \cdot 0.10^2 = \frac{0.10^2}{N} \text{ or generally } \frac{\delta^2}{N}.$$

This implies that portfolio variance will decrease with the number of portfolio elements N and finally be negligible. This accumulation of uncorrelated risks in a portfolio is called *risk pooling* and is the fundamental principle of insurance allowing the supply of cheap and widely available premiums. Insurance premiums are based on the risk of the aggregate risk pool rather than on individual risks.

As will be demonstrated later, the fundamental assumption of uncorrelated risks of the insurance principle is not tenable for natural disasters and has implications for insurability.

6.3 Reinsurance

When insurers standardly analyze their exposure of capital at risk in relation to retained capital (i.e. net worth) and find that the exposure is too high they usually will want to adjust: they may reduce their risk exposure, increase the amount of capital or maybe seek risk transfer themselves. The latter is usually done by means of *reinsurance*. Fig. 17 displays the transactions involved in reinsurance as well as insurance. The insurer is referred to as primary carrier. The underlying principle for reinsurance is the same as for insurance, reinsurance may in fact be called "insurance for insurance companies" (Swiss Re 1996a: 11). The risk ceded to the reinsurer is called cession. In addition, typically reinsurers cede risks to other internationally operating reinsurers, which is called retrocession (McIsaac and Babbel 1995: 2). The objective in doing so is to spread risks as widely as possible to construct a relatively uncorrelated portfolio of risks so that the law of large numbers operates (Kunreuther 1998a: 47). Reinsurance is essentially an international risk-sharing agreement that makes it possible to transfer catastrophic risk from the national insurance system to worldwide risk-sharing pools operated by multinational reinsurance companies. Consequently, reinsurance prices are determined in these international markets.

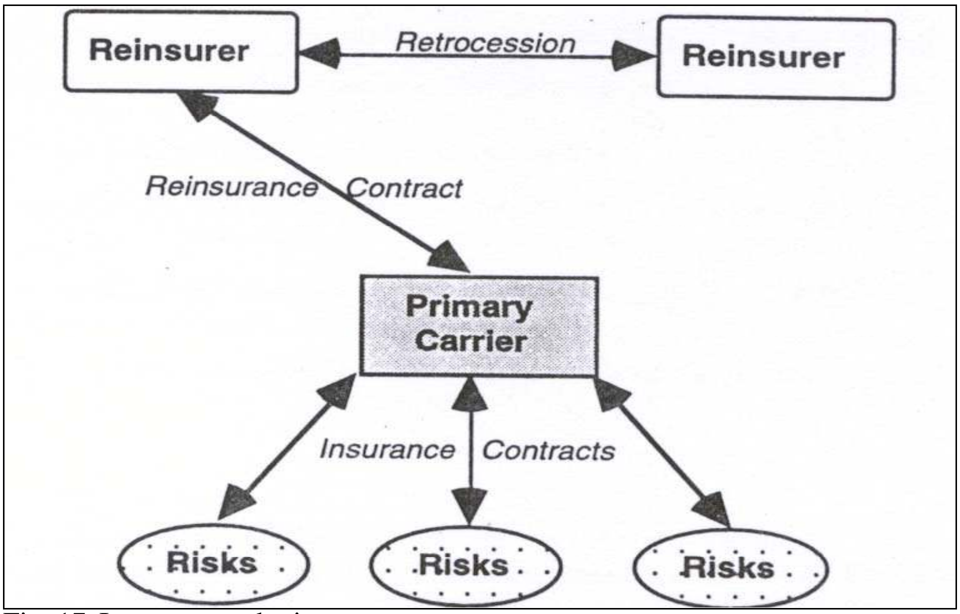

Fig. 17: Insurance and reinsurance
Source: McIsaac and Babbel 1995: 1

Basic types of reinsurance are **proportional** and **non-proportional** reinsurance. The main difference between these two forms of reinsurance is that proportional reinsurance treaties are linked to the sums insured whereas in non-proportional reinsurance it is the losses that are of importance. Different types of these basic forms of reinsurance are used in the market. Figure 18 lists these different types of proportional and non-proportional reinsurance.

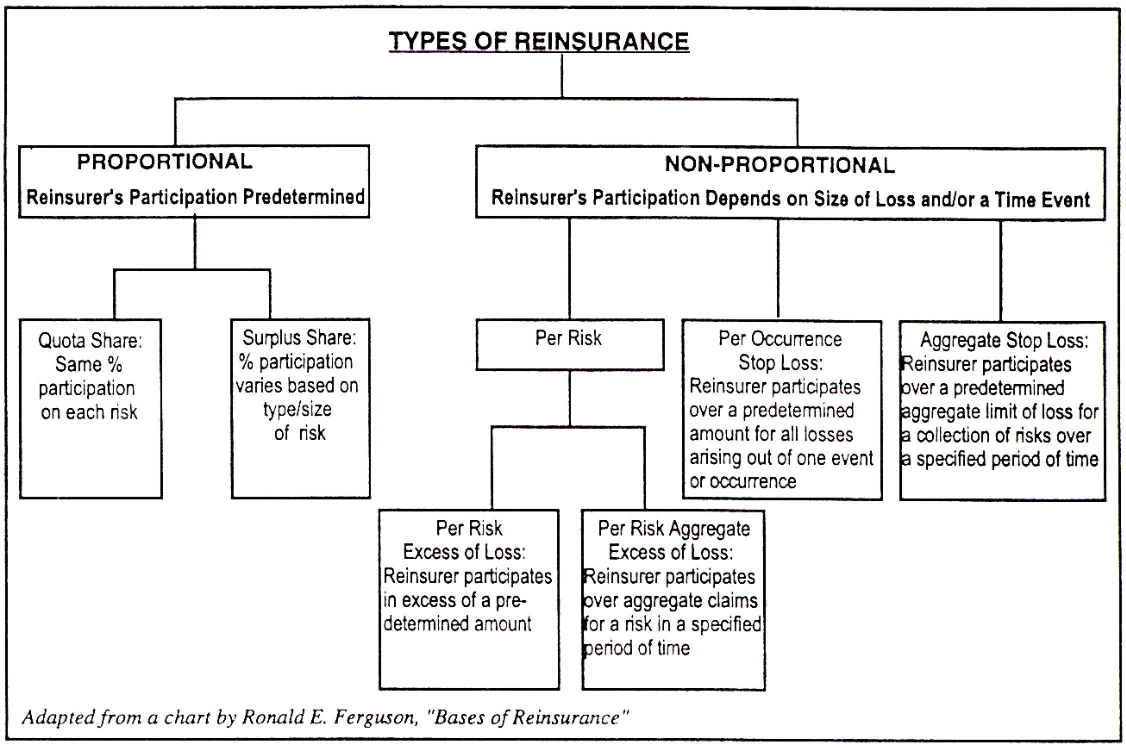

Fig. 18: Types of reinsurance
Source: McIsaac and Babbel 1995: 5.

Well-balanced insurance portfolios are usually covered by proportional reinsurance treaties. In proportional reinsurance the direct insurer and the reinsurer split insurance premiums received by the direct insurer and losses/claims according to a contractually defined absolute (*Surplus* reinsurance) or relative ratio (*Quota Share* reinsurance). In *Surplus* reinsurance, the ceding insurer by contract retains a certain amount of the losses and cedes the liability of the residual to a reinsurer. *Quota Share* reinsurance is the simplest form of reinsurance as each treaty is shared in fixed proportions. A drawback with this kind of insurance is that the ceding insurer will also have to bear a certain part of the losses.

Large unbalanced risks like catastrophe risks are usually insured as non-proportional treaties where the reinsurer contractually agrees to pay for a certain layer of losses, i.e. the ceding insurer bears the losses up to a certain point (attachment point or deductible), then the reinsurer pays, usually however only up to a maximum limit (the exit or exhaustion point) (Swiss Re 1996: 21-22; Andersen 2001: 15). One type of non-proportional reinsurance is *Excess-of-Loss* (XL) reinsurance. It is the dominant reinsurance cover for natural disasters (Swiss Re 1997a: 4; Froot 1999: 2). There are two types: *Per Risk XL* where protection against losses for one risk is purchased and *Per Risk Aggregate XL* with protection for losses for a defined accumulation of individual risks.

In the rarer *Stop-loss (SL)* treaty the deductible is usually defined as a percentage of annual premium income of the insurer, and the reinsurer agrees to pay any part of the loss exceeding this deductible up to an upper limit. Again there are two main types: *Per Occurrence SL* where the deductible is defined for all losses arising out of one event or occurrence, and *Aggregate SL* where the deductible is determined for a collection of risks over a specified time period (McIsaac and Babbel 1995: 5; Swiss Re 1996: 21-22).

Also, combinations of these different insurance arrangements are possible in one insurance contract. Non-proportional reinsurance requires a more detailed and exact risk assessment than proportional reinsurance on which to model the attachment and exhaustion points as premium and loss sharing are contract-specific (Pollner 2000: 9).

Though the emphasis of the thesis is on the general benefits of insurance or reinsurance for risk financing in developing countries rather than on finding the optimal risk transfer arrangements, two types of reinsurance covers will be examined in the case studies in order to analyze a certain range of available instruments: the focus of the analysis will be on the XL covers, as these are typical covers for natural disaster risk. Also, they allow to retain a certain layer of losses and cede higher loss layers, which seems to be a sensible proposition for the case of reinsuring infrastructure, where governments have the ability to finance a certain amount of losses themselves or with outside help, while rarer, but more extreme losses can often not be financed. Also, Quota Share (QS) reinsurance will be analyzed as this is the simplest form of reinsurance and allows to analyze the effects when risks are shared simply by a fixed ratio.

6.4 Insurability of disaster risk

A number of specific characteristics of natural disaster risk pose challenges to insurability. These will be examined in the following.

Low-frequency, high-consequence nature of disasters
While the insurance principle works well for idiosyncratic risk with a large number of events with moderate-sized losses like car insurance or health insurance, catastrophic events are infrequent, high loss events requiring large amounts of risk capital to back the underwritten policies. This characteristic will be reflected in the price and the spread over expected loss as well as the availability of disaster insurance.

Covariant risk
Earthquakes, floods, hurricanes or windstorms often impact entire regions and thus will affect all policyholders in one region; there is *covariant* risk. For insurance companies underwriting a large number of claims in one region, this means that their risk portfolio is highly correlated and the variance of the portfolio of losses is close to the variance of individual losses if all policies are affected by the same event (Kunreuther 1998a: 25). This may question the economic feasibility of national or regional insurance arrangements (Swiss Re 1999: 29ff). The covariant risk issue applies as well to informal insurance arrangements that play a major role in developing countries. These also tend to collapse in the presence of covariant risk (Hoogeveen 2000: 116)

Ambiguity of risk

The uncertainty associated with a risk and its measurement influences the premium considerably. The higher the uncertainty the higher the premium that will be charged by actuaries and underwriters. As natural disasters are rare events, data to base calculations on are scarce and there is considerable uncertainty in measuring probabilities and losses. However, in the last few years research has made great advances in predicting and simulating disasters and calculating its potential impacts.

Adverse selection

Adverse selection denotes the fact that mainly those at risk or at highest risk ("poor risks") will choose to insure themselves. This is problematic as the premiums charged are calculated for the whole population and the risk bearing group may be too small to guarantee profitability for the insurers if those less at risk choose to stay uninsured (Swiss Re 1999: 29). This is often the case for natural disasters.

There a several possible factors explaining low insurance demand. One is that those exposed to risk often exhibit myopic behavior: While immediately after an event, risk minimizing activities like purchasing insurance are undertaken, these efforts are decreased if no events materialize. A rational explanation for myopia found in economic theory is that there is higher time preference for the present than for the future. Myopia can also partly be explained by a misperception of probabilities of natural disaster events which are low probability high consequence events. Often the worst disasters have a return period of hundred years that is beyond an individual's time horizon.

Low insurance uptake is influenced by the availability of disaster assistance granted by the governments (Kunreuther 1996: 177). If the perception of being bailed out after an event by the state or government prevails, it is not rational to pay a premium before an event to be indemnified by an insurer.

Moral hazard

Moral hazard is the risk that an insured decreases his risk-minimizing efforts after having bought insurance coverage. The insurance policy creates adverse incentives to the one exposed to risk once risk has been ceded to another risk bearer. This problem can be dealt with by using deductibles in insurance policies (Swiss Re 1999: 7-8).

These characteristics do not render insurance a useless tool for catastrophic risks: In theory every risk can be insured subject to two insurability conditions. The first being that the risk can be properly identified which entails being able to make fairly accurate predictions about the frequency of the event occurring and potential loss. The second condition is the necessity of the insurer to determine premiums that allow to make a profit while not creating proneness to incurring unacceptable losses (Kunreuther 1998a: 27). The above mentioned factors have to be taken into account when setting premiums and are the reason why insurance companies may want to charge premiums that considerably exceed expected loss.

To address these issues often federal or state institutions are involved in regulating premiums. Possible solutions to these problems are to diversify the risk portfolio by writing policies in regions subject to other risks. Other measures taken include the widening and diversification of the policy-holder base by combining covers against different kinds of natural disasters (e.g. UK), limit the total number of polices written or include deductibles or limit indemnity to a maximum amount (Smith 1996: 91).

However, for some risks and regions, disaster insurance is not available like e.g. the case for flood risk in the Netherlands.

6.5 Insurance and reinsurance markets and premia

Insurance against natural disasters is usually offered as a voluntary extension of property insurance and household contents insurance. The insurance industry is a minority payer for catastrophe losses: In 2001 about 32% of (large) total natural disaster losses were insured (11.5 billion USD out of 36 billion USD total losses) (Munich Re 2002: 2).[28] The larger part of the losses had to be borne by the affected parties themselves, federal, state or local governments, and the international donor community in developing countries.

On a worldwide level, the insurance ratio for catastrophic risk is increasing. Whereas in the 1960s on average only about 10% of losses were insured, this ratio grew to about 18% over the 1990s (fig. 19).

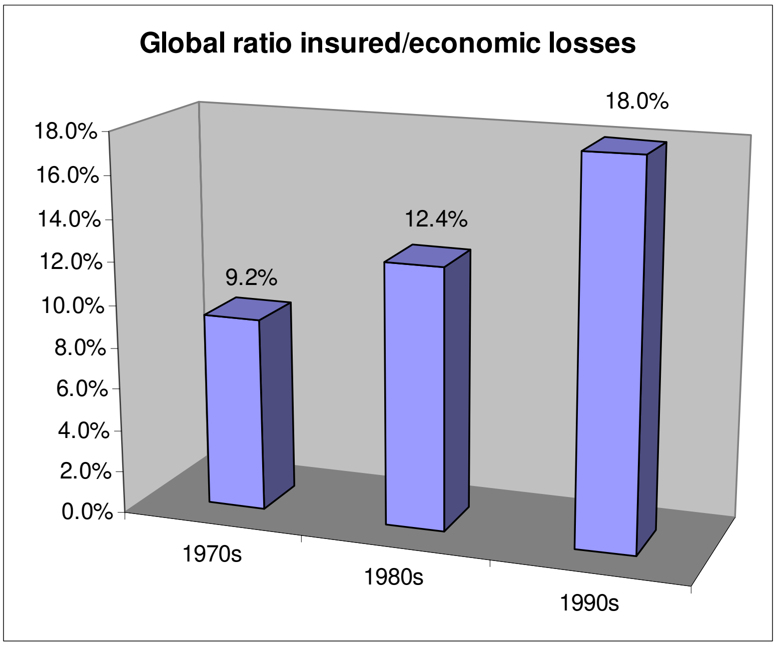

Fig. 19: Development of catastrophe insurance density worldwide over time
Source: Munich Re 2000: 19

Due to the insurability problems discussed before, catastrophic risk insurance markets are not perfectly well developed. Insurance density varies according to the type of disaster: Whereas windstorm risk is generally well insured, earthquake and flood insurance density is lower. This can be demonstrated when comparing economic losses with insured losses: Whereas for economic losses the major categories windstorm, earthquake and flood losses amount to about a third of the losses each, 70% of the insured losses are windstorm losses with 18% earthquake and only 6% flood risk insured (Munich Re 1999a: 42-43) (fig. 20). Reasons are differences in the willingness to take on risks, government activities, financial restrictions while reflecting the insurance industry's aims not to give adverse incentives (Swiss Re

[28] For these figures, Munich Re only listed the losses due to large natural disasters.

1997/7: 8). Private insurance against natural disasters is sometimes unobtainable in high-risk areas.

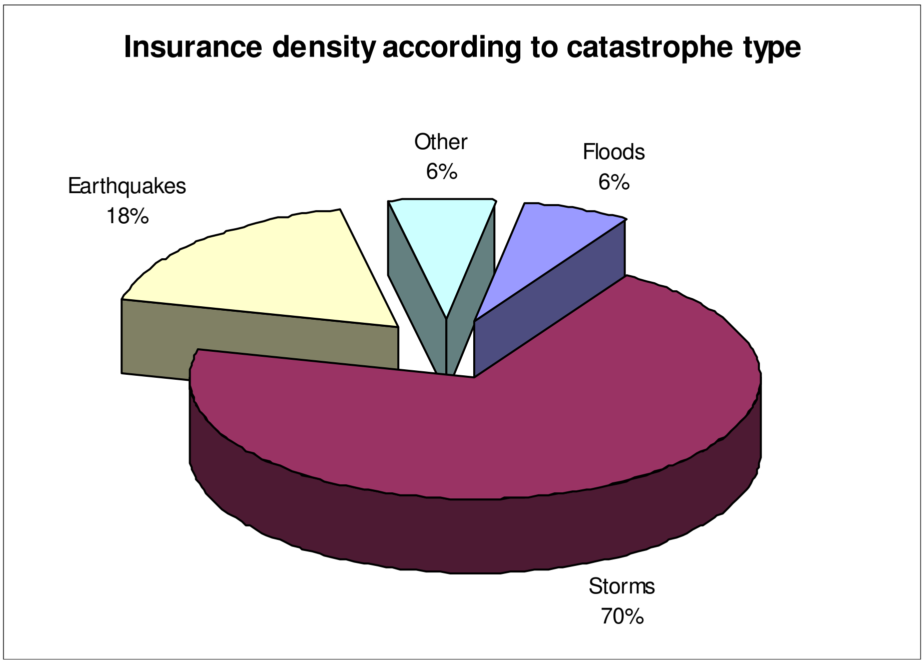

Fig. 20: Insurance density varies according to type of disaster
Source: Munich Re 2000: 42

The global property catastrophe **reinsurance** market capacity in 2000 was estimated at roughly 75 billion USD (Andersen 2001:12). The recent annual insured losses in 1999 of on average 20 billion USD thus represent about 27% of the current capacity and 11% of total insurance and reinsurance available (Pollner 2000: 22).

There are several **problems facing the suppliers of insurance.** Where commercial insurance is available there is often a low voluntary demand, e.g. only 3 percent of home-owners affected by the Kobe earthquake had taken out earthquake coverage (Smith 1996: 93). Reasons for underinsurance are generally an underestimation of probability of loss, short-term horizons for cost-recovery and the expectation of disaster assistance (Kunreuther 1996: 176ff).

As explained in chapter 2, losses are increasing and the individual losses per event are mounting. Before 1988, there had never been an individual event with insured losses of more than 1 billion USD, since then there have been at least 14 events that cost more than 1 billion USD. Some insurance companies (in the US) were driven out of business by large events like Hurricanes Hugo 1989, Iniki 1992, Andrew 1992 and the Northridge earthquake in 1994 (Smith 1996: 94). Consequently, while the excesses over expected loss were in the range of 100-200% until 1992, they climbed as high as 700% as a consequence of Hurricane Andrew in 1992 that was the first multi-billion dollar event in history and remained the most costly insurance loss until the September 11th terrorist attacks (fig. 21).

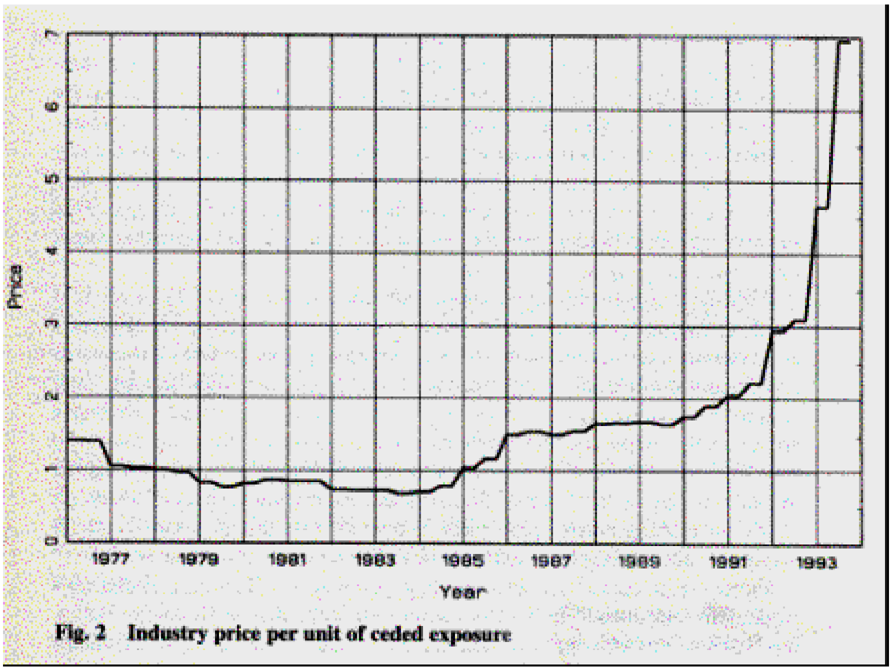

Fig. 2 Industry price per unit of ceded exposure

Fig. 21: Average annual percentage excess of catastrophe reinsurance premiums over expected loss from 1975-1993
Source: Froot and O'Connel 1999: 7.
Note: “Price” denotes the excess of the premium over expected losses, thus 1 indicates a premium with a 100% excess over expected losses.

However, from 1994 to 2000 there was a “soft market” with falling prices as no super-insurance catastrophes occurred after prices reached a peak due to capacity shortages in the second half of 1993/94. Then, after the winterstorms of 1999 there was a price increase that took place with a delay in 2001 with an increase of 16% worldwide and the market has become "harder" again with (Swiss Re 2001: 12; Guy Carpenter 2002: 57).

There are however two aspects that need to be kept in mind when examining the profitability of natural disaster (re-)insurance: First, (re-)insurance industry's profits are to a certain extent generated by investing premiums into the capital markets (Smith 1996: 91). Furthermore, rather than spatially spreading losses, reinsurance uses an implicit intertemporal financing approach where losses today will be paid back from (increases in) premia in the future (Vatsa and Krimgold 2000: 148). This is facilitated by the fact that the reinsurance market is characterized by long-standing business relationships and trust allowing cost-recovery over time (Andersen 2001:12).

The global reinsurance cover of approximately 75 billion USD constitutes ca. 40% of total insurance coverage, the rest being retained by primary insurers (Pollner 2000: 22). The insured losses consume a considerable amount of total available insurance and reinsurance. Considering the potential future driving forces as increase of exposed capital and possibly climate change, the limits of traditional insurance and reinsurance are discernible. Already today, a XL capacity gap is generally to be found.

Insurance and reinsurance can be expected to cost a cedent more than the actuarially fair price, the annual expected loss. For the international reinsurance market, where prices are determined essentially on a global scale (as contrasted to the more nationally-oriented insurance markets), this "spread" on top of the actuarially fair premium has been high as figure 21 demonstrated that showed the average annual percentage excess of premium over expected loss from 1976 to 1994 in the natural catastrophe reinsurance market. As well, Pollner et al. calculate loading factors and premia from recent reinsurance market prices obtained from Benfield Greig and Guy Carpenter that have a considerable excess over expected losses (Pollner et al. 2001: 20-21) (fig. 22).

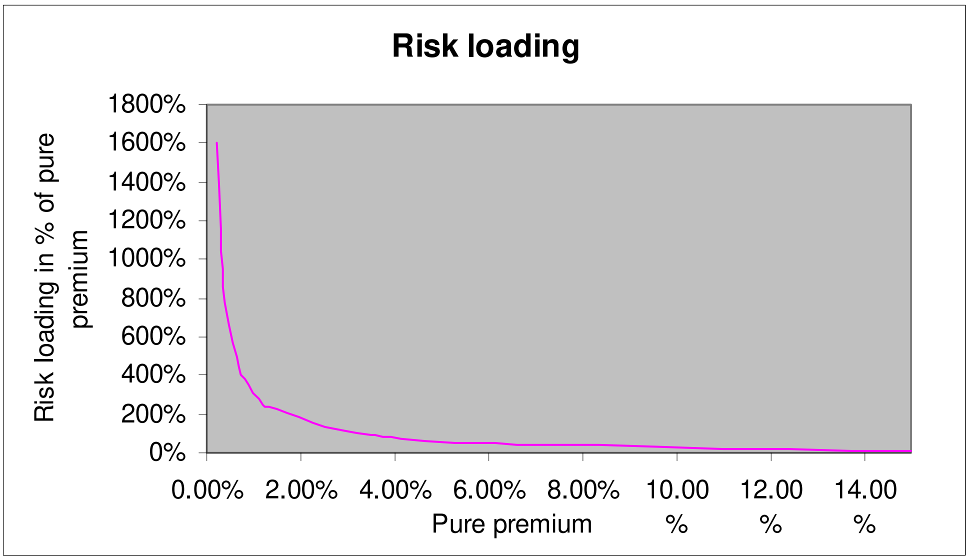

Fig. 22: Insurance loading on top of pure premium (expected losses) as percent of pure premium.

While for a high probability, low consequence event of 15% (thus a ca. 7 year event), the reinsurance premium would constitute 17%, thus only another 13% of the pure premium would have to be added to buy reinsurance for this exposure, for more infrequent exposures, the risk loading factor rises exponentially. For the 500 year event (probability 0.2%) the risk loading factor amounts to 1600% of the pure premium, i.e. the total premium would amount to 17 times the expected losses. The exponential increase is explained by the high variance inherent in lower frequency events which could be posing a large threat to the solvency of an insurance company.

On the other hand, the (re-)insurance industry can also derive benefit from diversifying their portfolio by combining uncorrelated risks like e.g. California earthquake and Honduras Hurricane risk as a personal communication from a major reinsurer states:

> The reader gets the impression, that also for the studied countries [i.e. Argentina, Honduras and Nicaragua) the loading is "many times higher" than the risk premium. This is not true because the studied loss potentials are very much limited compared to the big ones like EQ California, hurricane US East coast etc. or in other words, the reinsurer have, globally spoken, many loss potentials in this range, i.e. they can use the same risk capital several times which reduces the capital costs (loading) substantially. This is actually true for many other developing countries. (Hausmann 2001).

This may allow the (re-)insurer to offer lower premia than the ones shown here. Generally, however, insurance is only sensible if the variability of the losses plays a role for the risk-bearer, if she/he is risk-averse. The theory of insurance holds that - assuming rational expected utility maximizing behavior - that individuals buy insurance because they are risk averse. A potential catastrophic loss in the future is to be avoided by paying a small premium every year (Kunreuther 1992: 120).

> In the usual insurance example, risk averse individuals confronted with risk are willing to pay a fixed price to a less risk averse or more diversified insurer who offers to bear the risk at that price. Since both parties agree to the contract they are both better off (Dionne and Harrington 1992: 1-2).

Both parties, risk cedent and insurer derive benefit from the transfer of risk: The cedent is relieved of risk that he may not be able to bear in case of an event, the insurer is compensated for accepting a risk that he is not averse to or which will increase diversification benefit to his portfolio of risks.

6.6 Governments and the supply of risk transfer instruments

As discussed, in some sectors or regions or for specific disaster types the industry has become reluctant to offer insurance; in these cases the government often steps in and is involved in providing (re-)insurance cover to make up for market failure.

Due to the problematic nature of disaster risk that may cause (re-)insurance market failure, governments (in developed countries) often intervene to promote viability or establish (re-)insurance arrangements so that some sort of cover is established for households, insurers or reinsurers. Governments rarely act as insurance suppliers themselves, most often they either regulate the market or set up funds. Table 11 lists the major programs governments are involved in on the supply side of disaster insurance. The programs most often are privately funded pools, often subsidized by tax exemption, only rarely, however, are governments participating directly by funding or backing these arrangements as for the flood insurance program in the USA and the France program. A large number of programs exist in the USA primarily for earthquake and hurricane risk.

Table 11: National insurance and reinsurance programs with government involvement

A. Government Funded

Program, year	**Type of hazard covered**	**Primary/Reinsurance**	**Mandatory**
France, Catastrophe Naturelles, 1982 after floods in southwestern France	All	Primary for individual and commercial property, a flat percent fee (9%) is charged on all non-life insurance policies as premium, insurance companies cover hazards and may reinsure with government owned reinsurance company. No reinsurance for windstorm damage	Yes
USA, National Flood Insurance Program, 1968	River flooding	Primary insurance for homeowners and businesses	No

B. Government regulated

Program, year	**Type of hazard covered**	**Primary/Reinsurance**	**Mandatory**
USA, California Earthquake Authority (CEA), 1996 due to Northridge Earthquake and insurance availability crisis	Earthquake	Primary, state-run sponsored in part by insurers for homeowners, mandatory for insurance companies to participate or offer insurance themselves	No (homeowners)/ Yes (insurers)
USA, Florida Joint Underwriting Association (JUA), 1993 following Hurricane Andrew	Multi-peril	State-run primary insurance company for Property insurance	No
USA Florida Hurricane Catastrophe Fund (FHCF), 1993 following Hurricane Andrew	Hurricane	State-run reinsurance program for primary insurers underwriting in Florida.	Yes
USA, Hawaii Hurricane Relief Fund (HHRF), Created 1993 and activated 1994 after Hurricane Iniki. Currently phased out as capacity gap in Hawaii overcome.	Hurricane	Primary, premiums collected by insurance companies forwarded to fund, Homeowners	No
USA (31 states) Fair Access to Insurance Requirements (FAIR), 1960s	Mainly hazards that are "hard to insure" in inner cities, but also	Primary insurance for property	No

Program, year	**Type of hazard covered**	**Primary/Reinsurance**	**Mandatory**
	fires and risks to beachfront homes		
US, (7 southern states) -Windstorm Plans, 1990s	Windstorm	Primary insurance for property	No
USA (3 states) - Market Assistance Plans MAP , 1980s	Coverage for shore properties	Primary insurance for property. Voluntarily set up by insurance companies in cooperation with insurance regulators	No
New Zealand, Earthquake Commision, 1944	All but windstorms	Primary, surcharge on all fire policies, homeowners	Yes
Japan, Japanese Earthquake Reinsurance Company (JER), 1966	Earthquakes, tsunami and volcanoes	Reinsurance, Government retrocedes part of the reinsurance portfolio	Yes
Spain Consorcio de Compensacion de Seguros, 1940	All	Primary for property	Yes for all property insurance policies
Norway, Norsk Naturskadepool, 1980	All	Primary for property	Yes, as part of standard fire police
Denmark, 1991	Flood	Primary for property	Yes, fixed amount on property police

Sources: Smith 1996: 96; Van Shoubroeck 1997; Pollner 2000; Mooney 2001.

6.7 Alternative risk transfer instruments

Insurance or reinsurance are the traditional methods to shift risk. However, in the last years due to the situation described above that in many regions of the world, reinsurance cover is lacking when compared to the current risk exposure and actuarial estimates about future losses, new strategies to finance disaster losses through the capital markets have developed since 1996 (Alternative risk transfer, ART). The basic idea is to package insurance risks into marketable financial securities and sell them in the capital markets (Pollner 2000: 65).

The main advantages of this strategy is that the capacity of capital markets in relation to catastrophe risk is almost unlimited. Global reinsurance capital is estimated at 850 billion USD, whereas the capital market capacity is about 50 times as large at 42 trillion USD (Pollner 2000: 16). Another advantage is that with capital markets instruments the typical "insurance cycles" can be avoided where premia rise in the years following large disasters due to the need to finance intertemporally. Due to the considerably larger size of the capital markets these shocks get lost in the noise of the capital markets (Pollner 2000: 64). Until 2000, almost 6 billion USD of cover has been placed in the catastrophe markets since 1996 (Andersen 2001: 15).

The new capital instruments can be distinguished according to two dimensions (table 12): Whether they are issued as equity or debt or whether they indemnify against losses or trigger according to a specified physical event. Six categories of these instruments can be distinguished (Pollner 2000: 64-69; Freeman 2000a: 50-52):

Table 12: Overview over non-insurance catastrophe hedges

Based on	*Equity*	*Debt*
Indemnity	Catastrophe Bonds	Contingent Credit
Event	Exchange Traded Catastrophe Options Weather Derivatives	Catastrophe Equity Puts Catastrophe Swaps

Source: Freeman 2000a: 51.

Catastrophe bonds pay high yields, but interest and/or principal may default if a specified catastrophe event happens during the lifetime of the bond. Funds from placing these bonds in the capital markets are usually invested in risk free financial instruments, so they can reduce the cost of issuing these bonds.

Exchange Traded Catastrophe Options are option contracts that will trigger payments to be disbursed to the purchaser if an established insurance claims index exceeds a specified limit. In the United States the property claims service (PCS) options trade on the Chicago Board of Trade. The claims indexes employed cover different areas of the United States.

Weather derivatives are contracts where payouts are linked to physical triggers, e.g. number of days with temperatures below or above a specified threshold.

Contingent credit instruments are *put*-options allowing the purchaser of this note to take out a specific amount of debt in the case of a catastrophic event. This debt will have to be paid back according to pre-specified conditions.

Catastrophe Equity Puts are options permitting an insurer to issue equity shares after a major disaster. They are similar to contingent credit instruments in that they constitute a put option.

In **Catastrophe Swap** arrangements, insurance portfolios with potential payment liabilities are swapped for securities and associated cash flow payment liabilities. The insurer is obligated to periodic payments to an investor related to a portfolio of securities for which the investor was originally liable, while the investor assumes the catastrophic risk liabilities of the insurer.

In theory, governments as well as private sectors in developing countries could utilize such tools if they are able to pool sufficient capital. Thus, it may become possible for them to buy cover which they usually could not obtain in the reinsurance market due to their low insurance density (lower than 10% for private property) (Kreimer et al. 1999: 31).

ART instruments have been used for catastrophe risks in the developed world, but are still emerging and rates remain higher than for regular reinsurance (Lane 2001). After a rapid increase after its inception, the Cat bond market is currently stagnating at about 1 billion USD per year. The major reason has to be seen in the continued viability, mainly due to lower prices, of traditional reinsurance (Guy Carpenter 2002: 4). Reasons are that the market is still relatively new and small, and construction and placement of bonds is capital-intensive. ART transactions have been done only in developed countries for private enterprises, mostly insurance companies so far. This market can however be expected to develop and ART may become an option for developing countries in the future especially now that reinsurance rates are on the rise again.

6.8 Risk transfer in developing countries

Insurance density is very low in developing countries compared to developed countries. Fig. 23 shows the differences in insurance density for four main country groups differentiated by GDP per capita.

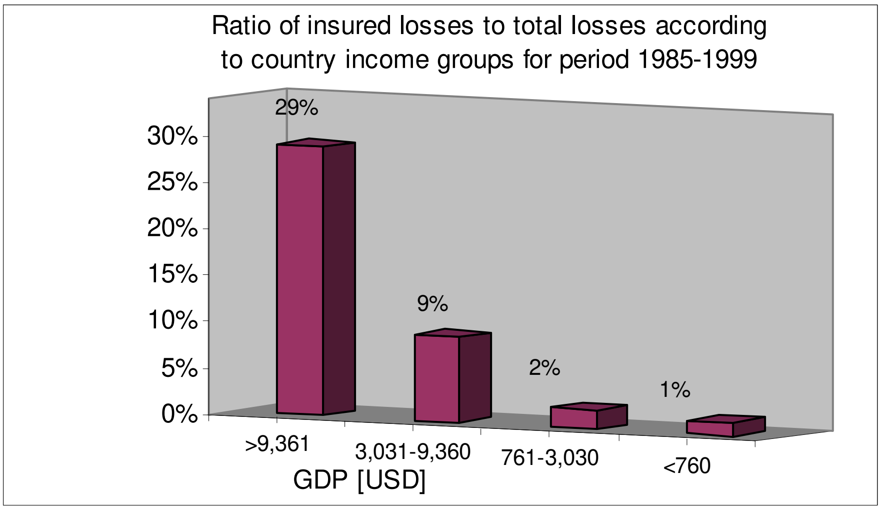

Fig. 23: Catastrophe insurance density according to country income groups (per capita GDP in 2000).
Source: Munich Re 2000: 24-25

While in the developed countries with per capita GDP of more than 9,361 USD, 29% of natural disaster losses were insured over the period from 1985-1999, this fraction amounted to only 9% for the second highest income group with income ranging between 3031 and 9360 USD, to 2% for countries with income from 761 to 3030 USD, and for the poorest countries with less than 760 USD to only 1% of total losses. Furthermore, the global reinsurance market covers mainly assets in developed countries and almost none in developing. As a consequence, the financing of losses in developing countries has often to be done by relying on multilateral donations and emergency loans (Andersen 2001: 1). Main limiting factors for purchasing risk transfer instruments in developing countries are considered the following (Andersen 2001: 39; Kreimer et al. 1999: 26; Litan 2000: 191):

- high premia including high transaction costs,
- lack of formal requirements and economic incentives to purchase insurance,
- lack of formal titles to property of many individuals and firms, without which no formal proof of holdings can be established,
- insufficient risk assessment and mitigation,
- lack of awareness and understanding of the concept of (re-)insurance,
- reliance on government or international donor relief spending.

The importance of financial restrictions is also evident when looking at the large insurance demand by industrial enterprises in e.g. Mexico: While 90% of these companies in Mexico are insured against earthquakes, insurance in the small business and private property sector amounts to only 2% (Kreimer et al. 1999: 26). However fig. 23 also suggests that as a country's economy is growing, the insurance market will develop and insurance supply will increase.

In the absence of well-developed insurance markets, **informal insurance** or self-insurance mechanisms play a role for households dealing with risk in developing countries. Basically three options are discussed in the literature:

First, households may use informal insurance for pooling risks with other households' risks. A large amount of context-specific instruments exist for the insurance of idiosyncratic risks. Examples are funeral insurance, marriage and interlinkages (like sharecropping) observed in agricultural contracts. Due to informational and enforcement restrictions, informal insurance usually is partial and found among parties that have the possibility to monitor each other easily. In the case of covariant risk these arrangements tend to break down (Hoogeveen 2000: 116). Second, for covariant risks, informal or formal credit or credit cum insurance arrangements are used to smooth consumption. Third, another option is to use a buffer stock strategy accumulating liquid assets in good times and depleting them in bad times. While this may prove a sensible strategy for idiosyncratic risks, in the case of covariant risks this can be costly when a large supply of buffer stocks is offered in the market decreasing prices considerably below levels that could be expected in normal times (Hoogeveen 2000: 124 ff.).

To summarize, insurance and reinsurance in conventional and alternative form are generally available for natural disaster risk, though market failure plays a role due to specific characteristics of catastrophic risk. Insurance markets in developing countries remain fragmentary. Informal insurance arrangements exist, however for natural disasters they tend to break down quickly due to covariant risk issues.

6.9 Governments and demand for risk transfer

Governments can also make use of risk transfer mechanisms on the demand-side. E.g. one risk financing option for governments is to seek insurance or reinsurance for their own risk to infrastructure or other public assets. Governments own a large number of individual risks; they in fact act like insurers and pool risks. Accordingly, it is an option for them to directly seek risk transfer for their exposure in the international reinsurance or capital markets thus circumventing the problem of shallow national insurance markets.

In general, there is little evidence on demand for risk transfer by national, state or local governments. In a recent worldwide study five approaches to government's decision concerning the demand for risk transfer have been distinguished (Guy Carpenter 2000: 39-40; Burby 1991).

Table 13: Practice of risk management and insurance uptake by governments on a worldwide scale

Approach	Countries where practiced and description
No risk transfer purchased	Norm for federal or central governments of large developed country.
Centralized risk-management and risk transfer decision	▪ USA: Majority of state-governments ▪ Canada: State governments ▪ Australia: federal government, some state governments and large number of municipalities ▪ Barbados: Government-owned insurance company insures public assets
Centralized risk-management, but local purchase of risk transfer	▪ Mexico: Law requires insurance for public assets, Public entities purchase it themselves. ▪ Some state governments in USA

Approach	Countries where practiced and description
Central "encouragement," but fully decentralized risk management	New Zealand: Individual departments or entities are encouraged to act independently as private corporations.
No central guidance	Purchase of risk transfer is dependent on will of individual managers of departments. ▪ Colombia ▪ Most Asian countries.

Sources: Guy Carpenter 2000; Burby 1991.

The norm is that federal or central governments do not engage in risk transfer arrangements on a planned basis due to their ability to spread risks (Guy Carpenter 2000: 39). Looking at the instances when it is done, there are different approaches:

- Centralized risk-management.
- Centralized risk-management, but local purchase of risk transfer.
- Central "encouragement," but fully decentralized risk management.
- No central guidance.

Centralized risk transfer by national governments has rarely been done. Centralized approaches exist in following countries: Barbados, Australia, Canada, USA. The only developing country with this approach is Barbados (an upper-middle income developing country), where the government-owned insurance cooperation of Barbados is in charge of insuring public assets (Pollner 2000: 35). Else, in the USA and Canada, the majority of state governments insure (Guy Carpenter 2000: 40); also in Australia federal government, some state governments and large number of municipalities insure their risks.

Centralized risk-management, but local purchase of risk transfer exists in Mexico and some states in the USA as well. In Mexico (an upper-middle income developing country), a law was established in 1994 requiring the purchase of insurance for the public assets infrastructure and public buildings. Federal agencies and organizations insure (with multinational insurers): about 82% of losses have been recovered from insurance during 1995-2000, but the local purchase is considered inefficient. Consequently a recommendation was made for Mexico to centralize the insurance purchase and risk management function and as well create a risk pool to increase efficiency: This would result in more bargaining power and a standardized reporting format for exposure and loss data. Still, Mexico is regarded more advanced than many developing countries as to its risk management practice. Also, a reserve pool (FONDEN) exists that however is not an accumulating pool, but an annual budget item (Guy Carpenter 2000: 38ff; Freeman and Mechler 2001: 41ff.).

Another risk transfer decision approach is **encouragement by a central, governmental institution, but a fully decentralized risk management decision** that can be found in New Zealand. Individual departments or entities are encouraged to act independently as private corporations. E.g. the navy and air force purchase insurance for public assets.

No central guidance, but local purchase of risk transfer depending on the will of individual managers of departments is an approach common in most Asian countries and Colombia.

In addition, several efforts are currently underway in Latin America and the Caribbean in this direction initiated by World Bank and Inter-Amerian Development Bank in order to make use of risk transfer mechanisms in lower income countries.

One focus is the Caribbean region for which Pollner proposed a subregional East Caribbean catastrophe insurance pool for public assets with four layers (Pollner 2000: 105).[29] In general, East Caribbean islands have successfully leveraged international insurance capital and transferred commercial and residential risk to insurance and reinsurance market. Insurance density is high.[30] The same is not true for public assets and infrastructure that represent large potential fiscal liabilities in case of disasters (Pollner 2000: 5). The proposed pool would be a purely government risk pool for infrastructure and other public assets (fig. 24). Public assets of neighboring governments could be included as well increasing the size of the pool (increase in bargaining power with reinsurer) and rendering it more diversified. Under this arrangement, World Bank would support the risk financing for the top layer by a contingent credit arrangement. The rationale behind this is that it would be very difficult or expensive to purchase cover against such extreme losses. Also, World Bank would provide liquidity support for the lowest self-retained layer with smaller losses. The middle and upper layers would be covered by purchasing commercial reinsurance or catastrophe bonds (Pollner 2000: 104 ff.).

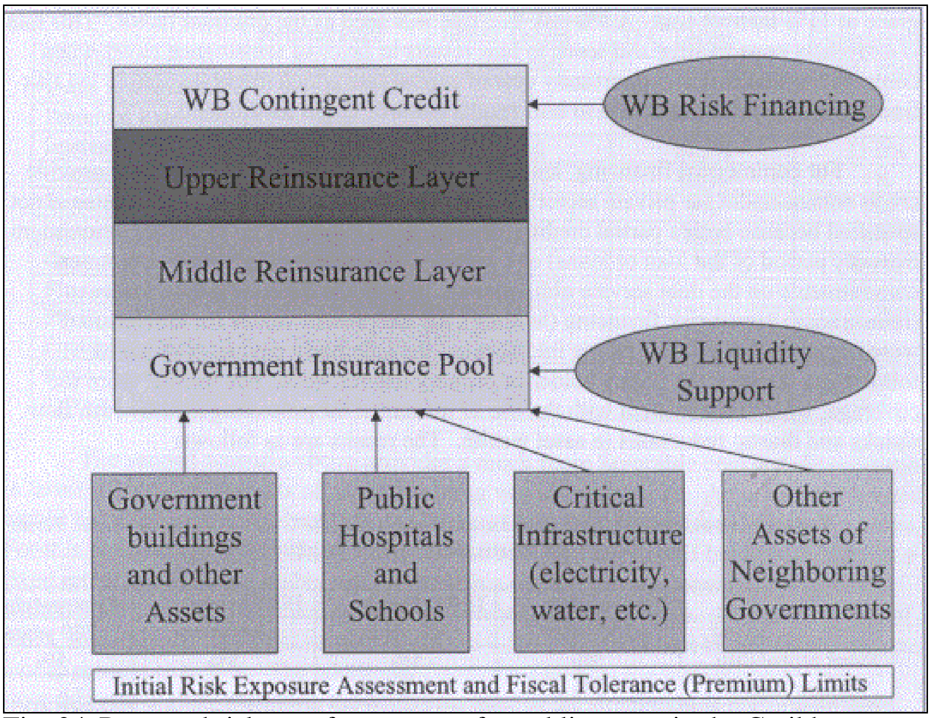

Fig. 24: Proposed risk transfer structure for public assets in the Caribbean
Source: Pollner 2000: 105.

[29] The Eastern Caribbean states (ESC) are Barbados, Trinidad&Tobago and the states of the organization of Eastern Caribbean states (OECS). The OECS constitutes a sub-regional organization with a population of about 800,000 with the small island developing states Antigua and Barbuda, Dominica, Grenada, Montserrat, St. Kitts and Nevis, St. Lucia, and St. Vincent and the Grenadines as full members. Anguilla and the British Virgin Islands are associate members, and along with Montserrat, British dependent territories (World Bank 2002b).

[30] 75% of the ESC market is held by insurers from Trinidad & Tobago, and Barbados (Pollner 2000: 32).

Another focus area is Honduras where a larger effort is initiated by World Bank and Inter American Development Bank . The idea is to set up a national disaster insurance pool with the following characteristics

- (Re-)Insurance of public assets,
- relief for the poor,
- post-disaster emergency funding,
- assistance to agriculture and aquaculture with setting risk transfer in place.

The Honduran government is interested in such a scheme which is also meant as a case study to test this approach for other countries. As well, the IDB is aiming in this direction. It lists risk transfer of public infrastructure as a key element of its risk management strategy (IDB 2001: 13). Currently the IDB is exploring the use of insurance, capital market instruments and other risk pooling and transfer mechanisms for IDB member countries. In a recent study for the *Regional Dialogue on Natural Disasters* sponsored by IDB, the benefits and feasibility of ex-ante arrangements have been investigated specifically for Bolivia, Colombia, the Dominican Republic, El Salvador and Honduras (Freeman et al. 2002b; Mechler and Pflug 2002)

6.10 Governments and risk transfer of infrastructure in the thesis

This thesis will focus on the transfer of risk to public infrastructure by national governments and examine its costs and benefits. The structure proposed above by Pollner et al. will serve as the basis for the modelling approach that will be explained in detail in part II of this thesis. Whereas Pollner et al. propose risk transfer for all public assets and also include assets of neighboring governments, this thesis focuses on risk transfer for economic infrastructure in a given country.

6.10.1 Assumed features of the insurance strategy

The assumed features of the risk transfer strategy are (table 14):

Table 14: Features of risk transfer strategy

▪ Economic infrastructure assets bundled in one country pool, ▪ Government with insurer role, ▪ Transfer of these assets to international risk transfer market, ▪ Purchase of XL reinsurance for specific layers and quota share reinsurance, ▪ Premium diverted from government investment and government spending causing opportunity costs.

This study specifically looks at reinsurance for all economic infrastructure owned by the government consisting of (World Bank 1994: 2):

- Public works: roads, dams, canals.
- Water and sanitation, waste disposal.
- Other transport sectors; railways, urban transport, ports, waterways and airports.

Infrastructure will be insured to the extent it is owned by the government. Infrastructure assets that are held in private ownership will not be included in the assumed insurance arrangements in the modelling.

In practice it would be desirable to undertake a precise analysis and prioritization to find those assets with the highest return and at highest risk (CGCED 2002: 8).

It is assumed that this risk is shifted to the reinsurance market as the government already acts as an insurer; thus shallow domestic insurance markets and missing legal frameworks can be circumvented. As well, transferring the risk out of the country is a desirable feature, as in case of an event, the inflow of foreign funds helps out the domestic economy.

Two strategies will be evaluated with reference to Pollner et al. (2001).

1. Quota share proportional reinsurance.
2. XL non-proportional reinsurance: Buying protection for a layer starting from a loss that is deemed not to be borne anymore for the government up to a realistic upper limit that will not be reached. This is a more typical reinsurance arrangement.

This centralized approach could in theory be assisted and co-financed by Multilateral Finance Institutions and complement efforts to stimulate local insurance markets and insurance for low-income households providing incentives for engaging in disaster mitigation (Pollner 2000: 49).

6.10.2 Role of Infrastructure

In addition to being own risk of the government, infrastructure has important economic characteristics. Infrastructure is an important input to production processes: "Infrastructure represents, if not the engine, then the 'wheels' of economic activity" (World Bank 1994: 14).“ It has the characteristics of a complementary production input to the other productive capital stock used in the production of private goods.

> In view of their distinct natures, the two types [of investment: government and private investment] relate to output growth in markedly different ways. Government investment in roads, schools, and health clinics may have slow and indirect pay-offs, in contrast with private sector investment in directly productive activities that create measurable value added as soon as projects are finished. Public sector investment in infrastructure is complementary to private investment and makes it more productive in terms of value added growth. Of course, if public sector is defined in a broad way to include parastatal enterprises that produce goods in competition with the private sector [...], there will be some substitutability between public and private investment (World Bank RMSMS-X 1997: 24).

If infrastructure is lacking or lost in a disaster, bottlenecks can be created. For example, the loss of roads and bridges can create serious transportation bottlenecks, and hamper the distribution and access to markets considerably. In the case of Hurricane Mitch in Honduras, market accessibility was seriously hampered due to the loss of infrastructure (fig. 25).

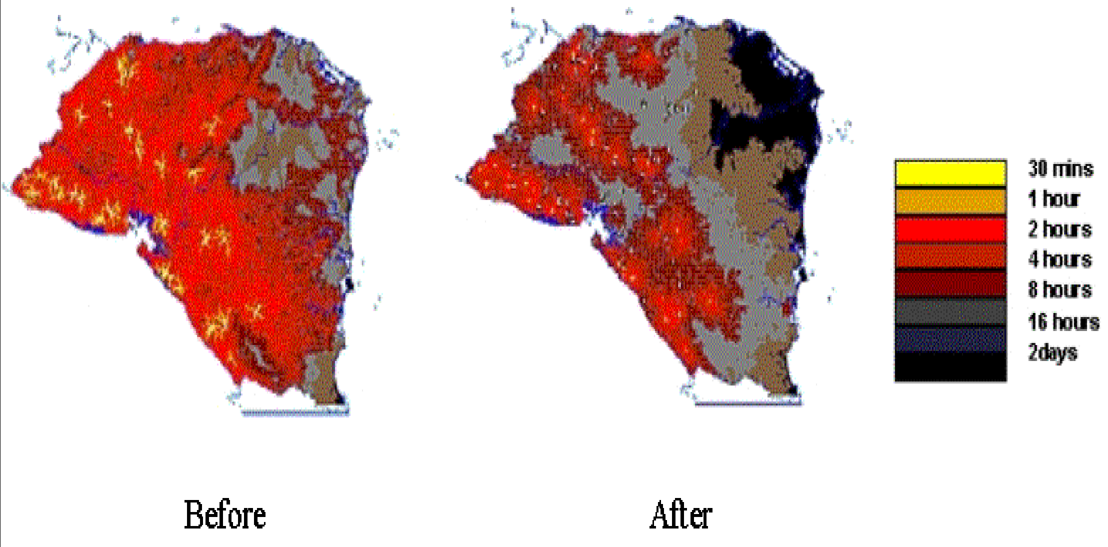

Fig. 25: Accessibility to markets in Honduras before and after Mitch
Source: World Bank 1999b.

While before Mitch, travel time to markets in the majority of regions amounted to less than 2 hours, after Mitch it went up to 16 hours in a large number of regions (World Bank 1999b). Such a large increase in travel time constitutes a severe barrier for the well functioning of an economy and may increase prices severely.

6.10.3 Costs of risk transfer

The following costs and benefits will accrue due to such a risk transfer strategy.

First of all there are the **financial costs** of premium payment. In theory, these are calculated according to the following actuarial formula discussed before (Pollner et al. 2001: 20).

Insurance premium = Expected losses + risk premium (loading factor + transaction costs + profit margin)

The basis for the premium payment are the expected losses, the losses due to natural disasters that can be expected to occur on an annual basis. On top of the expected losses a risk premium will be charged by the insurer consisting of transaction costs, profit margin and loading factor.

As natural disasters are low-frequency, but high-consequence events, the volatility of losses is also taken into account by insurance companies to hedge against the potentially high losses; this is done by charging a loading factor accounting for the variability of losses. Transaction costs like personnel costs for risk assessment and contract delivery have to be included. Last but not least, insurance companies will also charge a profit surcharge. In total, as explained, the premium charged could be considerably higher than expected losses, sometimes several times expected losses.

Pollner et al. in 2001 calculated recent XL market rates based on data from Benfield Greig and Guy Carpenter for specific exposures, and determined the loading on top of expected loss (Pollner et al. 2001: 20-21) (table 15).

Table 15: Average XL reinsurance pricing for natural disaster risks by event probability

Pure premium (% loss of layer)	*Total XL Premium Rate/ROL (%)*	*Risk loading factor (ROL/pure premium)*	*Risk loading (%)*
15.0	17.0	1.1	2.0
5.3	8.3	1.6	3.0
3.5	6.6	1.9	3.1
2.5	5.8	2.3	3.3
1.5	4.9	3.3	3.4
1.2	4.2	3.5	3.0
0.8	3.9	5.2	3.1
0.7	3.8	5.4	3.1
0.4	3.5	10.0	3.1
0.2	3.4	18.9	3.2

Source: Pollner 2001: 21.

E.g. for a pure premium of 0.2% of the loss layer the total XL premium rate is 3.4%, thus the risk loading factor is 18.9 and the risk loading added is 3.2%, which says that the loading on top of the pure premium is 17.9 times the pure premium.[31]

The premium calculation follows Pollner et al. (2001: 25-39) and will be explained in more detail in chapter 7. The procedure is as follows:

- Define loss layer to be covered determined by attachment point and exit point
- Pure premium: cumulative expected losses of layer, i.e. cumulative expected losses at exit point less cumulative expected losses at attachment point.
- Pure premium in relative terms: divide pure premium by absolute loss of the layer.
- For this pure premium value, a loading factor using table 15 is added. This determines the total premium or rate on line (ROL).
- Multiplying the ROL by the layer results in the premium in absolute terms to be paid.

The volatility of reinsurance premia is an associated problem. Reinsurance premia are essentially determined in world markets, e.g. in the Caribbean countries where insurance was bought, price volatility was high (Pollner 2000: 29; Benson 2001: 94 ff.). On the other hand, in practice as shown, premia are often also demand-based, i.e. based on customer demand and can be below rate-on-line.

The financial costs are not the main category of interest in a social cost-benefit analysis. Of more interest are the **opportunity costs** of using these funds, the foregone benefits from not having these funds at disposal anymore. In this case, it is assumed that the government diverts funds from government spending and investment in order to pay for the premium. The part that is diverted from investment will impact economic growth adversely as less investment into infrastructure capital stock can be conducted.

In developing countries, due to a general lack of funds, these opportunity costs can be substantial as scarce resources are taken from other important developmental goals

[31] The data listed in Pollner et al. (2001: 21) differ from what would be derived when taking the quotient of pure premium and XL rate. This must be attributed to rounding. The Pollner et al. values were used to maintain consistency.

like poverty eradication, education or infrastructure development. The opportunity costs that occur on a macroeconomic level will be discussed in detail in chapter 7.

6.10.4 Benefits of risk transfer

There are a number of potential benefits arising due to insurance. The main benefit is stability that is granted by insurance. Indemnity payments for the insured risks will be forthcoming after an event. These payments can be used to quickly rebuild destroyed assets. Consequently, the negative impacts when e.g. important infrastructure services cannot be rendered are minimized. Another benefit is the avoidance of diversion of government resources from other important objectives. Thus, the negative repercussions of so doing are avoided.

Another related benefit is the avoidance of the time lag that comes with foreign borrowing (and other forms of borrowing): Funds for reconstruction will be available immediately. Insurance companies usually take only between two and six weeks to assess damages and reimburse losses (Cuny 1983: 234). This contrasts starkly with post-disaster financing, that usually takes substantially longer to come forward. E.g. after the earthquakes in Turkey the one year time lag that it took a loan granted by World Bank to materialize was considered a "record." (Gurenko 2001).

Also, the covariant risk issue is resolved when risk is transferred out of the country into diversified reinsurance or capital markets.

An important function of insurance is its incentive for mitigation measures: Insurance companies around the world with the objective of reducing the risk they have acquired have created incentives in lowering premia when mitigation measures are taken on by the risk cedents (Cuny 1983: 234).

Insurance claims paid out to an affected country have a stabilizing effect when other domestic sources are heavily constrained; thus there is no *credit crunch* (Cuny 1983: 234).

Insuring is an active risk management strategy instead of relying on ex-post assistance and lending. Reliance on retroactive lending and emergency donor relief is unsustainable and may create the additional risk of not having the funds available (Gurenko 2001).

When risks are underwritten that are uncorrelated with other risks in an insurer's portfolio, an insurer derives benefit from this, as the variance of his portfolio is decreased. Consequently he may be able to offer lower premia. Natural disaster risk in Argentina is obviously of this kind, as disasters affecting Argentina will not affect the major risks in international reinsurers' portfolios in California, Florida, Japan, and Europe. Disaster risk in Honduras is probably weakly correlated to Hurricane risk in Florida, as they both share hurricane risk in the Caribbean.

Governments currently act as "insurers of last resort" already and Multilateral Finance Institutions (MFI) as "reinsurers of last resort" and provide grants and subsidized loans post-catastrophe. The availability of these funds is becoming more and more unclear as e.g. Official Development Assistance decreases. Also, there is increasing pressure on developing countries to become more active before disasters strike and funding post-catastrophe will be tied to ex-ante efforts. This is exemplified by current efforts to develop indices of vulnerability and risk for developing countries (World Bank 2002) which could be used to monitor improvements in risk management over time.

Table 16 summarizes the costs and benefits discussed.

Table 16: Costs and benefits of risk transfer of infrastructure in developing countries

	Ex-ante risk financing by insurance	**Ex-post loss financing**
Costs before event	Premium payment causes opportunity costs	-
Benefits after event	▪ All needed funds available immediately for risks insured, ▪ Increased capital inflows from abroad to depressed economy (covariant problem dealt with) ▪ Financial and economic stability	-
Costs after event	None	▪ Instability of foreign financing: potential for financing gap, ▪ Negotiating external loans may cause time lag and delay in financing reconstruction ▪ Opportunity costs of diverting ▪ in case of financing gap long term developmental impacts
Incentive for mitigation?	Yes	No
Additional	▪ Active strategy ▪ Theoretically risk of (re)insurer going bankrupt ▪ Diversification opportunity for reinsurer	▪ Passive strategy, international donor community demands more ex-ante involvement

Source: Partially based on Freeman et al. 2002b: 49.

6.11 Tradeoff involved in risk transfer

In total, risk transfer has to be regarded as a trade-off: In the case of risk transfer less government funds for important investment and government spending objectives are available which has impacts on development. Thus there is constant diversion from these objectives. Overall, welfare is lower, but more robust.

On the other hand, without risk transfer, no indemnity for infrastructure losses in case of disasters will come forward, and the burden for the governments could potentially be large and reconstruction infeasible or delayed. However, if no catastrophe happens, more funds are available and can be used for crucial projects. Thus the trade-off consists in volatile, but potentially higher welfare versus more robust, but reduced welfare. In the following analysis welfare will be measured by GDP.

6.12 Summary part I

A number of developing countries' governments faces a high risk due to natural disasters. This creates the potential for economic and social disruption when assets are lost and cannot be rebuild due to lack of financing available. One major intervention option is to invest in mitigation and preparedness measures in order to reduce the risk. However, after implementing risk mitigation measures a residual risk will remain.

This risk has to be borne by those that own or assume it. The government has to deal with its risk to the infrastructure and other public assets it owns, the risk it assumes for the private sector due to the shallowness of insurance markets, as well as the risk to the poor that arises from government's distribution objective.

In considering the financing of these obligations, governments usually (implicitly or explicitly) behave risk-neutrally and follow an ex-post strategy of relying post-catastrophe on available sources like diversion, domestic and foreign savings and - in the case of developing countries governments - on aid from the international donor community. While in developed countries governments can usually dispose of sufficient resources to absorb these losses, even when the losses are very large, in developing countries often a portion of the losses remains unfinanced and a financing gap results.

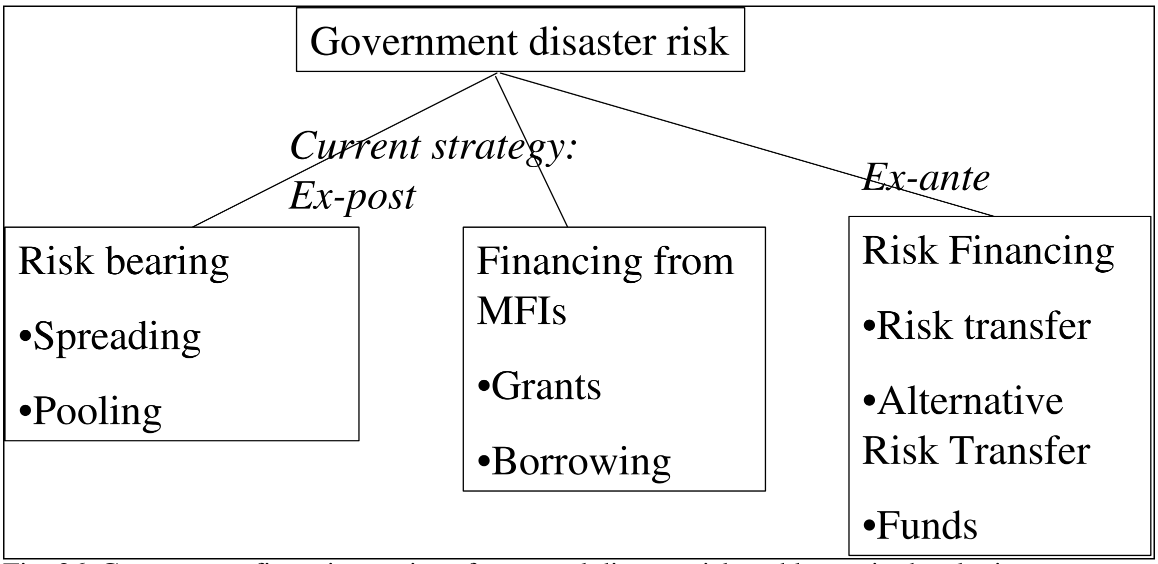

Fig. 26: Government financing options for natural disaster risk and losses in developing countries

This introduces the issue of ex-ante risk financing instruments to absorb the losses. Insurance, catastrophe bonds, reserve funds or contingent credit instruments may be arranged before a catastrophe providing needed post-disaster liquidity for relief and reconstruction.

Due to the imponderabilities related to the ex-post strategy, it seems prudent for developing countries to also consider risk financing measures. As these countries rarely have (full) access to risk transfer mechanisms including new developments from the capital markets, multilateral finance institutions like e.g. World Bank could help improve access to traditional and non-traditional insurance and reinsurance and help guarantee sustainable and affordable financial protection (Pollner 2000: 7).

The focus on ex-ante risk financing can be seen as a third phase of assistance by the donor community: The first phase was – and is still - characterized- by a provision of ex-post disaster assistance and relief by the international donor community thus acting as a reinsurer of last resort for countries hit by disasters. Realizing that this attitude generated moral hazard as it provided adverse incentives for those countries to engage in mitigation or risk transfer activities, there has been progress in the last decade in a second phase in financing and propagating the usage of ex-ante mechanisms to undertake mitigation measures. In a third phase this could now be complemented by focusing on financing measures for the residual disaster risk that cannot be mitigated (Pollner 2000: 12). Risk financing strategies will mean moving away from a strategy of reliance on post-disaster assistance and relief from bilateral and multilateral "reinsurers of last resort" to a more active and comprehensive ex-ante risk management strategy.

There is interest by developing countries and MFIs to give the private sector a more prominent role; the private sector on the other hand is interested in new markets and diversification. In an assessment of insurance options for the Caribbean regions a World Bank study came to the conclusion:

> The conclusion, based on the evidence, is that market arrangements (both domestic and international) can better channel and fund these risks, with governments and multilateral institutions supporting the development of self-sustaining structures (Pollner 2000: 5).

Market-based arrangements are regarded essential risk spreading tools. As these are not developed to a substantial degree today in developing countries, governments and MFIs should help with its development. Of course, this statement is central to the development approach put forward by the MFIs that define privatization and efficient market arrangements as important components of enduring economic and social development. This statement has to be put into perspective by the fact that often substantial market failures exist due to inherent characteristics of some markets or more developmental factors. Also as explained before, market failure in catastrophe insurance is inherent even in the developed countries. As risk transfer mechanisms would transfer part of a countries' and thus also donor community's risk to (re-) insurance or capital markets, this could help to free resources for furthering social and economic development and helping to alleviate poverty. Insurance however comes at price, thus the cost-efficiency of such arrangements has to be examined just as it is already done today for mitigation measures.

However, as outlined, there is a substantial cost that comes with ex-ante options: Significant funds have to be spent on a continuous basis before potential pay-offs arise to imburse the entity that the risk is transferred to. Generally, these funds in financial terms may considerably exceed the average annual risk. In addition, these financial costs translate into high opportunity costs if there is a lack of government funds for essential social spending or infrastructure investment; in this case the gains foregone due to paying the premium can be substantial. These foregone benefits have to be compared to the benefits of the ex-ante arrangements, i.e. foregoing potential adverse impacts post-catastrophe when funding is insufficient. This leads to an evaluation of the costs and benefits. In the following a model will be developed that allows to analyze these costs and benefits. To assess the potential benefits of engaging in risk transfer schemes, this thesis investigates the hedging of government risk. The actual option that will be analyzed here is reinsurance of government's own risk in the form of economic infrastructure. Eventually, it will be of interest whether social welfare could be increased by undertaking (re-)insurance of these assets.

II MODELLING PART: MODELLING APPROACH TO ASSESS NATURAL DISASTER RISK MANAGEMENT

In this second part, a modelling framework will be developed in order to analyze the efficiency of risk management measures undertaken by the government. In particular, risk transfer arrangements for infrastructure in developing countries will be studied. This framework will allow to estimate the economic impacts of disasters on developing countries, as well as the costs and benefits of risk management and outline the trade-offs involved in disaster risk management. Costs are estimated on the macroeconomic level. This framework will consequently be used for two case studies on Honduras and Argentina in part III.

The modelling framework consists of three elements:

- A macroeconomic model modified to assess the macroeconomic costs of natural disasters. The model translates the direct losses into macroeconomic impacts and allows to derive a representation of the flow impacts of disasters. The basis for the modelling was developed at IIASA where the author was a coauthor. This modelling approach was modified and extended considerably in this thesis.
- An insurance module to analyze different (re-)insurance strategies for the insurance of infrastructure by the public sector.
- A Cost Benefit Analysis (CBA) approach for comparing the costs and benefits and estimating the cost-efficiency of risk management. In this CBA framework, a mean-variance approach will be used for impact assessment in the context of risk.

The main objective of this modelling approach is to develop a methodology for analyzing the trade-offs in natural disaster risk management, assessing the macroeconomic costs and benefits and cost-efficiency of risk management measures.

The modelling framework aims at filling the following important gaps in the relevant research.

- The development of a methodology to assess costs and benefits of natural disasters risk management (building on IIASA research) with the focus on the macroeconomic costs of natural disasters in ex-ante manner.
- The application of CBA to the transfer of natural disaster risk.
- The explicit accounting for risk preference in the assessment of cost-efficiency of risk management options.
- The development of an insurance module to analyze the consequences of insuring infrastructure.

In the following, the term insurance will be used to refer to insurance and reinsurance alike as the underlying principle is the same. Also, the specific risk transfer arrangement that will be studied is the risk transfer of public infrastructure. Infrastructure could could either be transferred to an internationally operating insurer or, as more common, to the reinsurance market that is international by nature.

7 Macroeconomic modelling approach to assess costs and Benefits of Disaster Risk management

This chapter first discusses the general literature on the existing modelling of the macroeconomic impacts of natural disasters and then outlines the model used to assess the potential costs of disasters. The model used and modified for this purpose is the Revised Minimum Standard Model-X (RMSM-X) of World Bank. RMSM-X is the standard macroeconomic model used at World Bank for macroeconomic projections and analyses of macroeconomic policies for client countries.

Section 7.1 discusses the existing research on the modelling of the different kinds of economic impacts and focuses on the macroeconomic modelling research including the research gaps, 7.2 describes the model used and its modifications for the present purposes, 7.3 goes into more detail on the modelling approach developed and provides some illustrative numerical examples, and 7.4 concludes.

7.1 Literature review on research on economic costs of natural disasters

As with the review of the research on the statistical evidence on the economic impacts of natural disasters, this review on the estimation of potential disaster costs by means of modelling is divided up into research on the direct, indirect and macroeconomic costs.

Direct costs
Potential direct losses are assessed by government agencies, research institutions and private companies such as reinsurance or consulting companies. E.g. in the USA the HAZUS model was developed by the federal emergency management agency (FEMA) and the National Institute of Building Safety (NIBS) to provide a standardized methodology for estimating the potential direct losses due to earthquake and provide local, state and regional agencies with information for planning appropriately for potential earthquakes (CACND 1999: 31). In the private sector, the main actors are reinsurance companies interested in assessing the potential losses to their risk portfolios or consulting companies specialized in model development for reinsurers. The estimation approach used for these purposes has in common the definition of risk as a function of hazard, element at risk and physical vulnerability of these assets, as was described in chapter 2. In addition, reinsurers also need to include the insurance conditions in their models. Outputs of such modelling commonly are loss-frequency curves that display the probabilities vs. the magnitudes of disaster losses. For example, figure 27 outlines the modelling approach of Swiss Re for the assessment of the direct loss potential due to natural disasters.

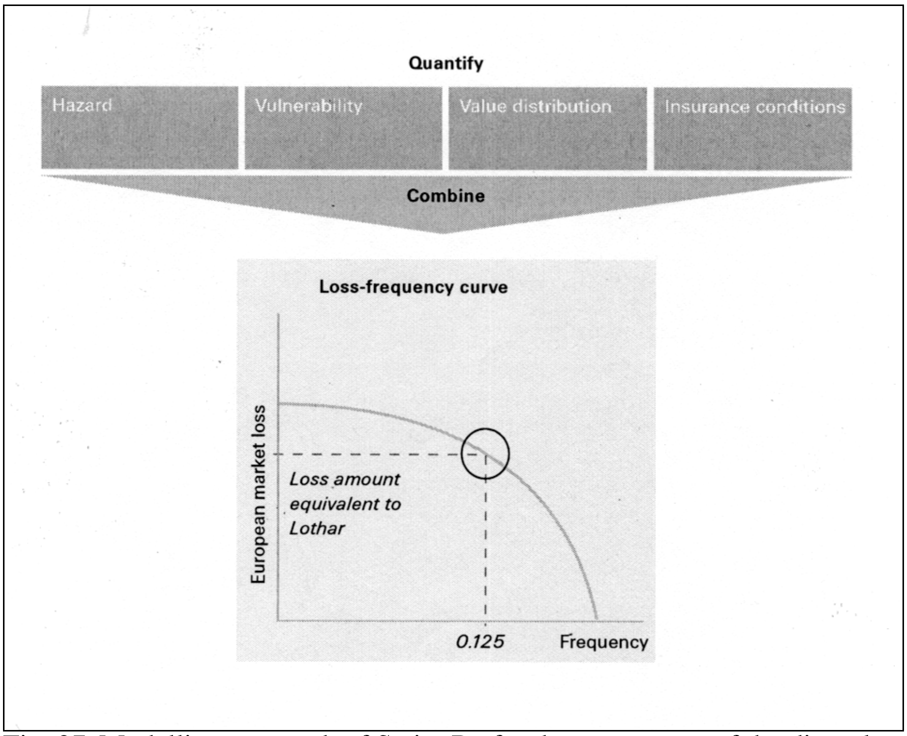

Fig. 27: Modelling approach of Swiss Re for the assessment of the direct loss potential due to natural disasters
Source: Swiss Re 2000b: 17.

More detail on the estimation of direct loss potential is provided in the description of the modelling approach chosen in the thesis in section 7.2.1.

Indirect costs

There is a substantial body of modelling research on the *indirect economic impacts* (e.g. Yezer and Rubin 1987; Ellson et al. 1984; West and Lenze 1994; Brookshire et al. 1997; Chang et al. 1997; Guimaraes et al. 1993; Rose 1997). These studies aim at measuring the regional and sectoral impacts of catastrophes. Existing approaches used for developed countries, mainly the USA, are Input-Output-models, Computable General Equilibrium and simultaneous-equation econometric models.

These studies generally estimate the aggregate impacts on regional economies (in developed countries) to be zero, but find distributional and sectoral effects, e.g. on the housing market, or effects due to the interruption of services. Also, evidence seems to suggest that such modelling overstates indirect regional economic losses from natural disasters and gains from reconstruction. A major problem is that the statistical relationships crucial for these models may not be robust in the face of abrupt, intense events (CACND 1999: 40).

For an useful decision-making tool for emergency response planning and valuing mitigation activities, CACND (1999) sees a need to analyze and simulate potentially affected sectors in detail, and proposes a microsimulation model simulating the behavior on the individual household or business level and the later aggregation of individual impacts in order to derive aggregate impacts on the economy (CACND 1999: 41).

Such an approach seems to be sensible for measuring the impacts in more developed regional economies, where aggregate impacts are negligible; however, for developing countries, where empirical studies have found significant negative macroeconomic impacts, a macroeconomic modelling approach seems to be viable and will be followed here. Furthermore, the focus of the modelling framework developed in the thesis is to provide insight into the magnitudes and kinds of impacts to be expected due to natural disasters as well as outline the potential benefits due to risk financing of infrastructure measures rather than devising a directly operational decision-tool.

Modelling work on macroeconomic effects

While the models concerned with the indirect losses focus on the subsectors of developed economies, the modelling on macroeconomic impacts generally deals with the aggregate effects in less developed countries where – as discussed above – significant effects have been found. This body of research is very limited: little modelling on the macroeconomic impacts of disasters exists, the existing models are rudimentary in nature and were not used for deriving projections for impacts on actual economies in ex-ante manner (table 17).

Table 17: Modelling research on natural disasters

Study	*Countries studied*	*Time frame*	*Model*	*Results*
Dacy-Kunreuther (1969)	Not country specific	1.Short – medium 2.Long term	Aggregate Demand/Supply Growth model (Production function)	• Standard case: output reduction, price increase • Outside aid and altruistic behavior change results • Marginal productivity varies sectorally after disasters • Investment should go to most productive sector
Albala-Bertrand (1993)	Developing Countries	1.Short-medium 2.Long Term	Input/Output, Savings-investment relation Growth Model	• Overall (long-term) aggregate effects not significant • Effects of aid understated • Mainly distribution effects
Okuyama (1996)	Japan	Short-medium	Interregional Input/Output	• Capital stock loss will have accumulating effect on economy • A loss of the size of the Great Hanshin earthquake may decrease aggregate income in Japan
Tol/Leek (1999)	Not country specific	Long-term	Illustrative growth model	• Mitigation investment and/or insurance lowers consumption and investment and thus current and future output

Dacy and Kunreuther (1969) analyzed disaster impacts in a simple aggregate demand and supply schedule framework using historical direct loss data and found economic output to be reduced in the standard case whereas inflation increased. Outside aid and altruistic behavior changed the results in so far as the negative effects of output reduction and rise in inflation diminished.

Albala-Bertrand (1993), though rudimentary, is the only fuller model. Using the information derived from the statistical analysis of natural disasters as critical modelling parameters in a simple economic growth model framework he validates his empirical findings that there are no significant aggregate effects to be expected from natural disasters. However, there are three modelling assumptions used by Albala-Bertrand that are particularly problematic as was referred to in chapter 3 already (ECLAC 2002: 373-374). Concerning the assumption about GDP and inflation not being impacted aversely, ECLAC has shown contradicting examples as discussed. Also, Albala-Bertrand posits that direct disaster damage is overstated for political and technical reasons; ECLAC rather holds on the contrary that there are many examples were damages were underestimated due to electoral reasons when vulnerable social sectors were affected or when strict fiscal discipline was to be maintained. Also ECLAC doubts that, as Albala-Bertrand asserts, that disaster events are scarce and occur only occasionally and rather posit that they happen more of ten - an observation which can clearly be corroborated for Latin America and the Caribbean (see also fig. 45 in chapter 10).

Okuyama et al. (1996) used an Input/Output model for Japan to analyze the impacts on the Japanese economy of a capital stock loss the size of the Great Hanshin earthquake in 1995. This event was the largest ever in terms of direct losses which were estimated at 100 million USD and constituted a loss of 0.8% of Japanese capital stock. They came to the conclusion that this capital stock loss will have an accumulating effect on the national economy through the close interrregional linkages. They developed a number of scenarios each consisting of two versions: one shorter-term version assuming no additional demand in the construction sector for the reconstruction effort, and one longer-term version with additional demand in this sector. One result from the shorter-term versions emphasized by the authors is a negative effect on national income of up to 2%, for the longer-term versions positive income effects are estimated. However, the authors did not compare their model results with actual impacts occurring in Japan after this event. The general evidence on the great Hanshin earthquake is that there were no aggregate economic effects while sectors around Kobe like the shipping and transport sector were affected (Kajitani et al. 2001). Thus, this evidence can be interpreted as the longer-term impact in this model including additional demand in the construction sector.

Tol and Leek (1999) in a growth model framework, theoretically analyzed the effects of mitigation investment and insurance on output with catastrophe events and found that consumption and investment will decrease as well as current and future output.

Several issues emerge from this research body and the research on the empirical effects analyzed in chapter 3:

- Existing modelling of the macroeconomic effects of natural disasters is either theoretical or rudimentary in nature.
- Often ex-post information on historical disasters is used which is an insufficient database for planning for disasters.
- Vulnerability and hazard are not examined independently.
- External and internal resources for reconstruction financing are not analyzed in isolation.
- Modelling is heavily dependent on general and debatable assumptions.

Responding to these shortcomings, the following issues are addressed in this thesis:

- A functional macroeconomic model, employed in policy analysis for developing countries on a regular basis, with best available and detailed data on individual economies will be used.
- Ex-ante information on direct disaster risk is utilized that incorporates state-of-the-art hazard modelling and gives adequate account of direct disaster risk for the exposed countries.
- A concept for isolating and analyzing country-specific economic vulnerability is developed.
- Information from empirical studies is used for the model in order to derive important assumptions.

The major aim of the modelling approach in this thesis is to assess the probable economic impacts on developing countries' economies, outline the trade-offs involved in risk management to reduce those impacts and provide insight into the associated costs and benefits of risk management. The approach developed is not meant to be used as a decision tool (as e.g. advocated by CADND 1999). For such a purpose, detailed spatially-disaggregated loss information as well as a more detailed representation of the relevant decision units would be needed.

7.2 Own modelling approach

The basis for the modelling approach was developed at IIASA in collaboration with World Bank and Swiss Reinsurance Company in which the author participated. This research is described in Freeman, P., L. Martin, R. Mechler, K. Warner with P. Hausmann 2002a. The modelling aimed at incorporating the potential macroeconomic impacts of natural disasters into the macroeconomic projections for developing countries. This approach was revised and extended for this thesis. Major extensions are an explicit accounting for economic vulnerability (defined here as the ability to rebuild post-disaster) and the development of an *insurance module* to analyze the costs and benefits of undertaking risk transfer.

Figure 28 outlines the process of estimating the macroeconomic costs of natural disasters. The methodology developed integrates future probabilistic loss due to natural disasters with a macroeconomic projection model. Expected severity and frequency of catastrophic events are combined with prevalent macroeconomic conditions and vulnerability. There are two steps to the estimation process: The first one entails the estimation of the potential direct, stock losses of a country by combining information on natural hazards, a country's capital stock and the physical vulnerability of the capital stock. This estimation of risk of direct losses is based to a large degree on information obtained from Swiss Re.

The second step involves integrating these stock loss estimates with the macroeconomic model representing the economy and its vulnerability. Outputs are macroeconomic flow impacts. This methodology uses and modifies the Revised Minimum Standard Model (RMSM-X), a flow-of funds model used at World Bank. While the direct losses give an account of the magnitude of potential catastrophes, the macroeconomic losses represent the full consequences that catastrophes may cause to an economy. As outlined in chapter 2, the macroeconomic costs comprise the aggregate indirect impacts as well as the effects of the reconstruction and relief efforts post-disaster.

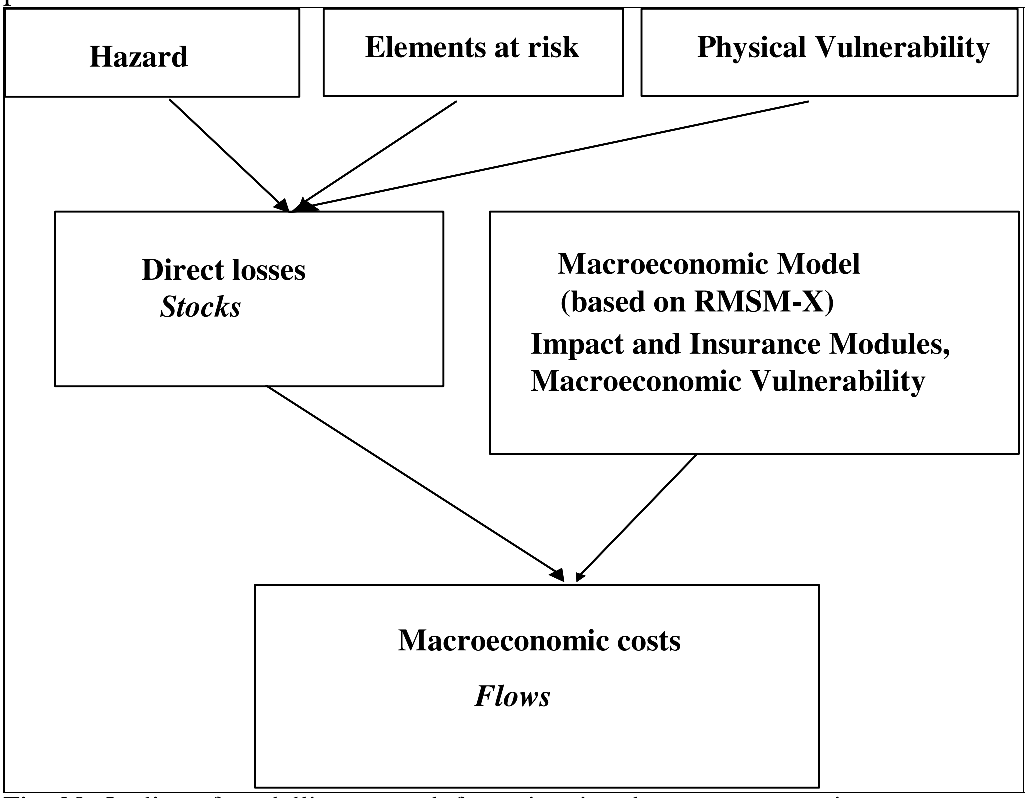

Fig. 28: Outline of modelling aproach for estimating the macroeconomic costs

7.2.1 Assessment of direct loss exposure to capital stock

The following description of the calculation of the direct loss exposure is based on Freeman et al. (2002a: 7ff.). Catastrophe exposure or direct losses is calculated by integrating natural hazards with the distribution and physical vulnerability of a country's assets, which are summarized in the capital stock indicator.

By using hazard models and large databases of historical disaster events the loss potentials from geological phenomena such as earthquakes and volcanoes, and meteorological phenomena such as hurricanes and floods can be assessed.

Catastrophe exposure is estimated as the relative damage to capital stock associated with maximum credible events with a given return period. The return period of an event is defined as the inverse of the probability of occurrence. Thus, a "10-year event" denotes an event for which at least the given loss will on average take place every ten years, or an event with this severity happening in a given year with a probability of 10%. Results from the Swiss Re loss exposure studies are provided in this format.

In order to translate the relative losses to capital into stock monetary values, estimates of capital stock on a country basis are needed. Capital stock estimates are often not readily available and have to be approximated. Three independent methods were used for this purpose. The first one combines World Bank's estimate of the previous year's output with capital-output ratios taken from the Penn World tables (Heston and Summers 1991). The second estimate accumulates historical time series data on depreciated real gross domestic fixed investment from the World Bank's World Development Indicators (World Bank 2001a). The third method employs data obtained from third parties. For Argentina, estimates were provided by the Centro de Estudios de Produccion (CEP) and the UN's Economic Commission for Latin America and the Caribbean (ECLAC).[32]

The results of the Swiss Re analyses were used to fit loss-frequency distributions relating probabilities to fractions of capital stock destroyed. Cumulating probabilities, cumulative probability distributions can be derived indicating the probability of damage not exceeding a specific fraction of capital stock (see fig. 29). E.g. for Argentina and flood risk the following cumulative distribution was obtained.

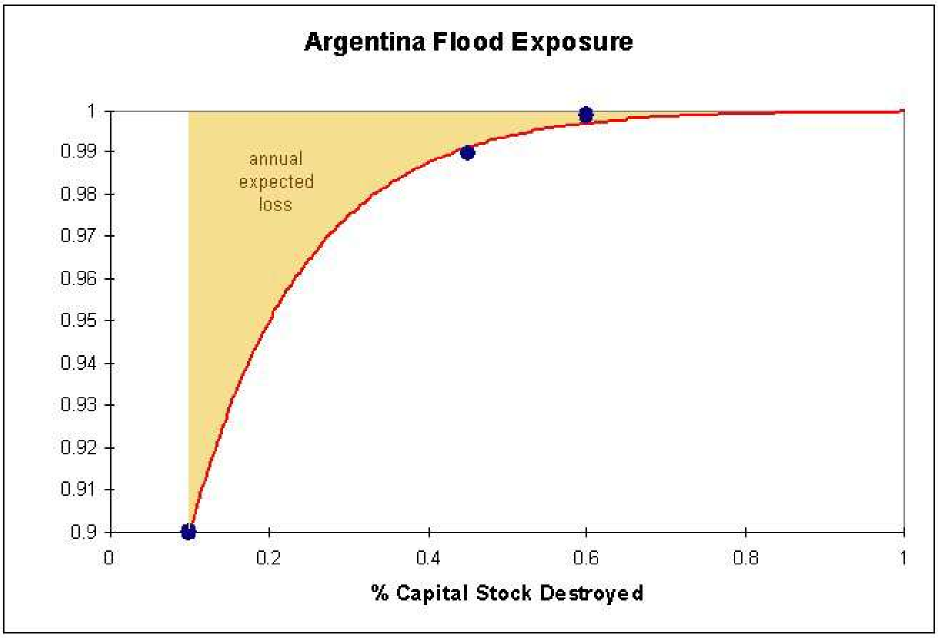

Fig. 29: Example of a cumulative loss distribution curve
Source: Freeman et al 2002a: 38.

The x-axis shows the fraction of capital stock destroyed, the ordinate represents the probability of losses not exceeding a given level of damage. An important summary measure of this distribution are the annual expected losses, the losses to be expected on average every year. The annual expected losses is the sum of all losses weighted by the probability of occurrence. Graphically, the expected losses are represented by the area above the cumulative distribution curve. Of course, events like the ones analyzed here, do not happen on an annual basis, but over a certain time period like 100 years some catastrophes will occur, and the losses suffered over this period will be close to the sum of annual expected losses over these years. The expected loss as a metric allows to relate infrequent events to an annual basis which often is an appropriate planning horizon for government budgets and insurance. The pros and cons of such a metric and an extension will be discussed later in this thesis.

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[32] CEP: http://www.mecon.gov.ar/cep/default1.htm. ECLAC: http://www.eclac.org/

7.2.2 Assessment of macroeconomic costs via RMSM-X Model

The assessment of the economic costs is undertaken using the flow-of funds model RMSM-X of World Bank modified for the present purposes by IIASA and extended by the author. A main reason decisive for using the model was the interest by World Bank to incorporate natural disasters into RMSM-X, that is used on a regular basis as a simulation tool for deriving macroeconomic projections and external financing needs. For this purpose the model and calibrations for Honduras and Argentina as well as Nicaragua were obtained

RMSM-X has the advantage that it emphasizes economy-wide consistency inter- and intrasectorally and uses a national accounting framework. The flow of funds methodology assures that every source of funds to one sector is a use of funds to another and total sources in one sector equal total funds in the same sector, i.e. budget equations have to be fulfilled. The consistency conditions imply that all budget constraints for all economic agents have to be observed. The focus of the model is on short-to medium term macroeconomic imbalances, and projections are usually conducted for a time horizon of up to 10 years with a detailed focus on the first 3-4 years and the rest providing insight into the general economic trends.

The model is supply-side oriented. A production function relationship determines aggregate supply in every period which then via the national accounting identity determines aggregate demand. The supply-side in RMSM-X is standardly specified as a Harrod-Domar type economic framework where GDP growth in a given year is proportional to last year's investment to GDP ratio.[33] Labor is not included explicitly in this production function due to the assumption that because of the relatively large unemployment in the countries studied labor is available abundantly and thus does not constitute a bottleneck. As will be explained later, the Harrod-Domar specification in this analysis was exchanged by a more detailed production function using a Cobb-Douglas specification.

RMSM-X belongs to the class of *two-gap models*. In this class of models, the shortage of capital stock in developing countries is considered the main limiting factor for economic development, and accordingly finding the sources for investment is a main task of RMSM-X. The two sources for increased investment into capital stock are considered to be limited: There is a domestic savings gap due to low per-capita incomes and a foreign exchange gap due to insufficient export earnings. Consequently, looking for foreign savings via foreign borrowing is encouraged in this framework.

Modelling economic growth only as a function of capital stock and the availability of new investment into capital stock, has to be regarded as a limitation of the model. Solow and others have shown in the 1950s that in advanced countries more than 50% of economic growth can be explained by productivity increases. This number may not be as large for developing countries, but suggests that a considerable amount of growth is not purely driven by the amount of capital but rather its quality (Dinwiddy

[33] More specifically: $g(t)=I(t-1)/ICOR(t)$
where g is GDP growth, I is investment and ICOR is the incremental capital output ratio in time t which is the technical relationship defined as the historical ratio of units of investment needed to produce one unit of GDP.

and Teal 1996: 85). Also, today economic theory generally stresses the importance of incentives, the role of human and social capital and the importance of robust institutions for economic development (Meier 1995: 99).

On the other hand, it is generally acknowledged that there is a shortage of capital in developing countries and investment without doubt is a key driver of economic development in developed countries as in developing countries. Thus, the investment approach to development inherent to RMSM-X has to be seen in this light and regarded an approximation.

There are three main purposes of using the RMSM-X model: First, for economic purposes, the major issues are to monitor the effects of stabilization packages and structural adjustment lending (short- to medium-term) and development packages (medium- to long-term). For stabilization issues, macroeconomic imbalances in the current account, government deficits and the savings-investment balance are of major interest. For development strategies, the growth and investment relationship and the structure of production need to be analyzed closely. Second, RMSM-X can be used to quantify policy decisions, analyze internal and external sustainability of policies, and evaluate trade-offs between policy packages. Furthermore, for the operational field it is a dialogue tool for countries and donors. Its function is to support the formulation and study of different policy packages.

7.2.3 Basic Structure and Closure of RMSM-X Model

RMSM is consistent in an arithmetic sense. The user has to assure that results are economically meaningful. Using RMSM-X by the World Bank has to be understood as an iterative process in which assumptions are modified based on model runs to provide meaningful outcomes.

RMSM consists of **four sectors**: The government, monetary, foreign and the private sector. The government sector comprises the central government. When better data is available this sector can be enlarged to a consolidated public sector comprising other levels of government and non-financial enterprises. The monetary sector includes the central bank and money deposit banks. The foreign sector represents the balance of payments (viewed from the outside). The private sector is the residual sector consisting of all remaining entities including non-monetary financial institutions.[34] The consolidation of all sectors is the national accounting identity which can also be seen as the equilibrium condition for the real goods market where total output equals demand in all sectors. Residual variables in the **5 budget equations** assure consistency. All of the sectors are split up into a current and a capital account. Current income less current expenditure for each sector is defined as savings or dissavings adding to or subtracting from the stock of wealth. Savings are interpreted as a current use of funds in the current account and are introduced in the capital account as a source of funds. By definition there are no savings in the financial sector.

In addition to the four sectoral and the consolidated budget equations, RMSM-X contains **behavioral equations for four financial assets.** There are four market

[34] Thus if the public sector consists only of the central government, non-central government agencies and parastatal enterprises are also part of the private sector.

clearing conditions for the following assets: money, domestic monetary credit, foreign credit and government borrowing from the private sector via government bonds. In addition to these core equations there are additional behavioral functions of exogenously specified variables and values determined by assumptions.

Also, RMSM-X employs a **Foreign Debt Module** that in a very detailed way lists current public and private debt obligations, and distributes pipeline debt as well as shows the availability of new debt. Appendix I provides a more detailed account and the main equations of the RMSM-X modelling framework.

In order to guarantee consistency the model uses residual endogenous variables in the nine equations. These variables adjust to guarantee consistency and clear markets. A set of residual variables employed to solve the model is called a closure. There are several closures, but three different closures have proven to be particularly useful in usage by World Bank staff: These are private, public and policy closure. Private and public closure calculate the sources required to achieve a given growth objective, they are also called "requirements" modes. Policy closure determines the effect of the limited availability of resources ("availabilities" mode).

In **private closure** the residual variables comprise private consumption and private borrowing, in **public closure** these residual variables are government spending and government borrowing. In both of these closures, foreign credit is calculated as the sum of previously committed loans and new loans that are determined by the balance of payments constraint. The model assumes that the source of this lending done by the private sector in private closure and by the public sector in public closure are foreign commercial banks. Private and public closure are used to assess consistency between macroeconomic targets as GDP growth, inflation, foreign reserves and exchange rates and fiscal polices as fiscal spending, current and capital expenditure and its sources of finance. As well, users may assess the sustainability of fiscal policies by analyzing indicators like government debt to GDP and interest payments on debt as a function of tax revenues.

By means of the third closure, **policy closure**, effects of the non-availability of borrowing in excess of already committed loans can be studied. Imports are determined as the residual variable that closes the balance of payments. The purpose of policy closure is to specify the effects of government policies and private sector behavior on economic growth. If private and foreign savings are insufficient sources of financing disaster losses, then the model can be used to forecast macroeconomic impacts based on the inavailability of domestic savings and the ability of the analyzed country to access foreign financing. For this approach, the model has to be run in policy closure. This approach was chosen for this study for Honduras and Argentina, two countries that are heavily indebted, Honduras classified as low-income and Argentina as medium-income countries. In total, the following strengths and limitations of using RMSM-X can be listed (table 18).

Table 18: Strengths and limitations of using RMSM-X for macroeconomic projections

Strengths
▪ Transparent structure with little assumptions.
▪ Economy-wide consistency framework.
▪ Good data basis and assumptions by experts.
Limitations
▪ 1 year time step.
▪ Capital stock as driver: Investment drives GDP.
▪ Relatively little behavioral detail due to the consistency framework characteristic.

7.3 Catastrophe Module

The following *catastrophe module* to RMSM-X was developed to determine the macroeconomic impacts due to natural disasters in a series of developing countries. The original policy closure was modified to account for the effects of natural disasters. Several additional assumptions were made.

As inputs the module uses samples in Monte Carlo[35] fashion from the loss-frequency distribution of capital stock losses due to natural disasters. Outputs are reconstruction financing requirements due to capital stock loss and adjustments of macroeconomic variables such as GDP, investment and consumption in RMSM-X contingent on the availability of those requirements. As the catastrophic loss inputs are stochastic, model outcomes are expressed stochastically as well.

Several extensions of the model applied by IIASA are developed in this thesis:
First, the determination of the macroeconomic impacts was modified. The original IIASA approach was to calculate optimal foreign financing needed to continue economic growth objectives and determine the availability of this foreign financing only from the supply side by means of assumptions (0, 50, 100% foreign financing available). This work considers the possible domestic and foreign sources of financing in detail, and determines the availability of foreign financing from the demand side as well (i.e. the maximum feasible amount so that foreign debt sustainability is still maintained).

Second, another major extension is the development of an *insurance module* that allows to define and analyze the effects of different risk transfer strategies for the government transferring risk to its infrastructure.

Third, an approach was developed to compare the effects of model runs with and without government risk transfer strategies to determine the cost-efficiency of undertaking risk transfer. This was done by means of a CBA approach.

[35] Monte Carlo simulation uses a given input probability distribution and chooses values randomly by generating random numbers between 0 and 1 for probability densities and then inversely solving for the value related to the selected probability. Thus, where only a few data points are available a whole series of events can be generated (Hardaker 1997: 46). Here, 5,000 iterations are used to recalculate macroeconomic variables.

7.3.1 Approach

Table 19 summarizes the main features of the modelling approach. In the following the individual features will be explained in detail.

Table 19: Overview over important model features of modelling approach

Model feature	*Description*
Objective of module	Forecast macroeconomic impacts of catastrophes as a function of the country's ability to access domestic and foreign savings for reconstruction and relief and assess costs and benefits of disaster risk management
Assumed government objectives	Maximize GDP, provide relief post-disaster and rebuild infrastructure quickly
Real GDP growth	Endogenous, GDP falls in year of event, in subsequent years GDP is determined by investment in previous year
Reconstruction investment	Government undertakes reconstruction investment for infrastructure, private sector undertakes reconstruction investment for private capital
Domestic savings	Limited supply, decrease after event, as income falls
Foreign savings	Demand-side limited by indebtedness sustainability indicators. Supply-side limited by means of assumption (0, 50, 100% of financing demanded supplied). Foreign borrowing with 1 year time lag effect
Government consumption	Constant except for year of catastrophe
Private consumption	Constant, as low per capita income households increase their propensity to consume to maintain life-sustaining level of spending
Production function	Cobb-Douglas with inputs capital and labor
Treatment of capital	Catastrophe destroys capital
Treatment of labor	Labor force decreased in year of event
Imports	Adjusted upwards post-catastrophe in year of event
Exports	Decrease post- catastrophe proportional to drop in overall output
Economic vulnerability	Model inherent, Additional assumptions: - Aid 10.4 % of losses, - borrowing and government diversion country-specific
Insurance	Premium payment at beginning of year. Indemnity payment after disasters received at once, no time lag
Exchange rate	Constant (nominal)

Source: Extended based on Freeman et al 2002a: 53.

7.3.2 Algorithm

7.3.2.1 Overview

Figure 30 outlines the steps of the algorithm. The location of the description of the individual steps is noted in the right side of the figure.

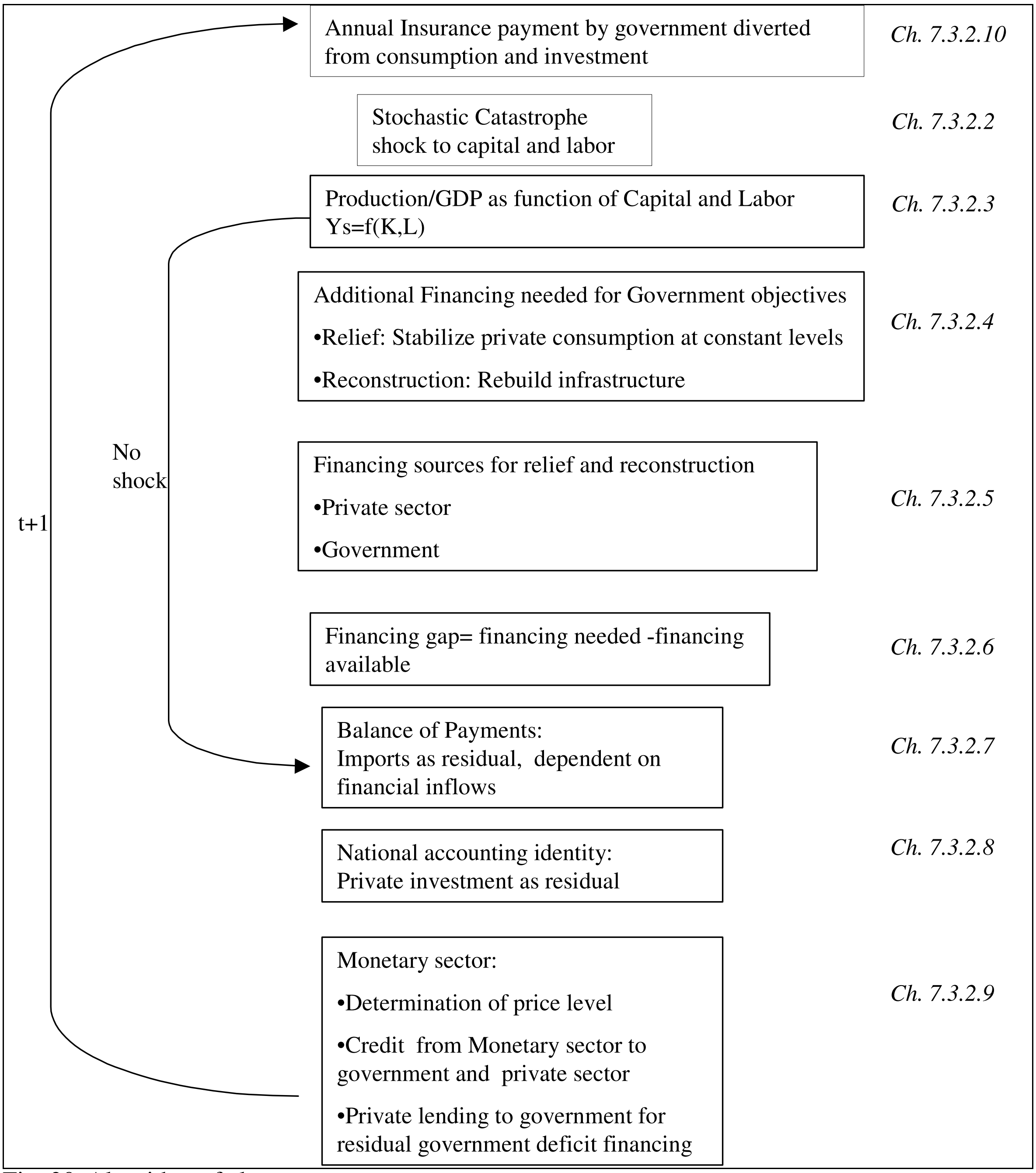

Fig. 30: Algorithm of closure

The algorithm of the catastrophe module in this formulation is as follows:

1. In the model runs that include the purchase of risk transfer the premium payment is assumed to be undertaken at the beginning of the period.

2. Stochastic generation of catastrophe shock.
In case of a catastrophe, capital stock and labor force are affected and these values decrease. The catastrophe is assumed to happen at the beginning of the respective year.

3. Calculation of output/GDP.
In case of a disaster event, production with shocked capital and labor will be decreased; exports will also drop in relation to their share in total output and the decrease in output due to the catastrophe loss. GDP falls in year of catastrophe, then may recover depending on availability of domestic and foreign savings and insurance indemnity payments.

4. Calculation of financing needed for government relief and reconstruction.
Financing is needed for two government objectives post-disaster: First, the government provides relief transfer payments to the private sector whose consumption is adversely affected by catastrophes. Private sector consumption is thus stabilized at baseline consumption levels. Second, the government rebuilds infrastructure that was lost in the catastrophe event.

5. Determination of financing available and reconstruction possible.
Next, the availability of necessary financing is determined. The government finances relief for the private sector and the reconstruction of public infrastructure to the extent financing is available; the private sector undertakes reconstruction to the extent feasible. Additional financing necessary and available is the sum of the different financing sources considered feasible of the private and public sectors comprising

- aid,
- government diversion from consumption,
- insurance claims,
- foreign financing.

For the government, it is assumed that relief has higher priority than reconstruction. Funds will first be used for this objective, before reconstruction is undertaken. Generally, budget diversion will suffice to finance relief transfer payments. To the extent that financing sources post-catastrophe are insufficient, there is a financing gap and reconstruction is incomplete and delayed. The focus of this analysis is mainly on the government sector.

6. Additional goods need to be imported for recovering the economy. The amount of possible import goods is determined by the inflow of foreign financing (insurance and gapfill), aid and goods diverted to close the Balance of Payments (BOP) as reserves and exchange rate stay constant.

7. Determination of effects on national accounting identity:

- To the extent that sufficient financing is available, the economy can rebound. However, there will be a 1 year time lag to foreign financing other than insurance indemnity payments, so optimal growth will not be achieved (immediately).
- If financing is limited, medium to long-term growth impacts will occur as investment is decreased which will subsequently keep GDP depressed.

8. Determination of monetary sector variables

Finally, the change in the price level, monetary credit to public and private sectors and the selling of government bonds to the private sector are calculated. These however do not influence decision-making (which can be considered a limitation of the modelling approach)

The model is to a large extent determined by the Balance of payments (BOP) and the national accounting identity (NAI) equations. The supply of goods is fixed in the NAI for every period and thus aggregate demand has to adjust. Additional investment goods necessary have to be imported. The ability to import is determined in the BOP by the amount of (additional) financing available. Drawing down reserves or changing the exchange rate are generally not considered viable means in RMSM-X to access more imports. Below a more detailed description is given. More detail and equations for the individual steps can be found in Appendix I.

The detailed description of the algorithm starts with the generation of the stochastic shock, the description of the risk transfer purchase is explained in 7.3.2.10 in order to first present the general elements of the modelling approach without the extension of the modelling of the risk transfer strategies.

7.3.2.2 Generation of Catastrophe shock

Catastrophes are generated by means of Monte-Carlo simulation from the estimated loss-frequency distributions for the relevant disaster risks in the countries analyzed. Outcomes are direct disaster losses as a fraction of capital stock. The labor shock[36] is assumed to be proportional to the capital stock loss. For the baseline labor force data, the module gauged the percentage of the population in the labor force. This value was multiplied by population data taken from the RMSM model. A fixed 50% labor force participation rate was assumed.

After a catastrophe, capital stock figures are decreased by the loss of capital stock in the given period and increased by catastrophe-adjusted real gross domestic fixed investment of the last period. By calculating losses to capital stock in this fashion, the model implicitly assumes that infrastructure and other capital stock exhibit equal vulnerabilities to catastrophes which has to be regarded an approximation. Labor force is adjusted by the fraction of labor force affected by the catastrophe. The assumption was made that for every percentage of capital stock destroyed, effective labor force would be reduced by a tenth of a percent in the same year.[37]

7.3.2.3 Calculation of GDP

Capital stock values in a given year are calculated by adding gross domestic fixed investment (real investment less change in stocks) of the previous year to previous capital stock less depreciation. A 7% depreciation rate was assumed. With the estimates of capital and labor, it is possible to estimate gross domestic product (GDP) by using a production function relationship. In contrast to the *Incremental Capital Output Relationship* (ICOR) formulation originally used in RMSM-X, an explicit production function approach was chosen to study the effects of accumulation (or lack

[36] The term labor shock denotes the persons incapacitated to work due to injury and death and thus is an euphemism for the dramatic humanitarian consequences of natural disasters.
[37] Based on information on Hurricane Mitch in Honduras in 1998.

of it) of capital stock. For this purpose a Cobb-Douglas function was used with inputs capital and labor.

$$GDP = AK^{\alpha}L^{\beta}$$

where K represents capital stock, L effective labor force, A is a technological efficiency parameter, alpha and beta represent the production elasticities of capital stock and labor.

A more flexible form than the Cobb-Douglas-function is the Constant-elasticity-of-Substitution (CES) production function, which allows inputs to be either complements or substitutes. However, a limitation of this form is that all inputs can only be either substitutes or complements. So, for the present purpose, the two inputs infrastructure capital and private capital were used whereas labor was represented by a trend term assuming it to be a substitute to both kinds of capital. A CES function has the following specification (assuming constant returns to scale):

$$\text{CES: } Y = Ae^{gt}\left[\delta K_I^{-\rho} + (1-\delta)K_N^{-\rho}\right]^{-\frac{1}{\rho}}$$

where δ, ρ are estimated and e^{gt} is a trend term included to reflect growth in the labor force at rate g. The parameter δ determines the relationship between the input parameters: A value of ρ that is close to zero implies substitutability and in the limit determines a Cobb-Douglas relationship, a high value specifies complementarity and for ρ converging to infinity determines a Walras-Leontief function (fig.31).

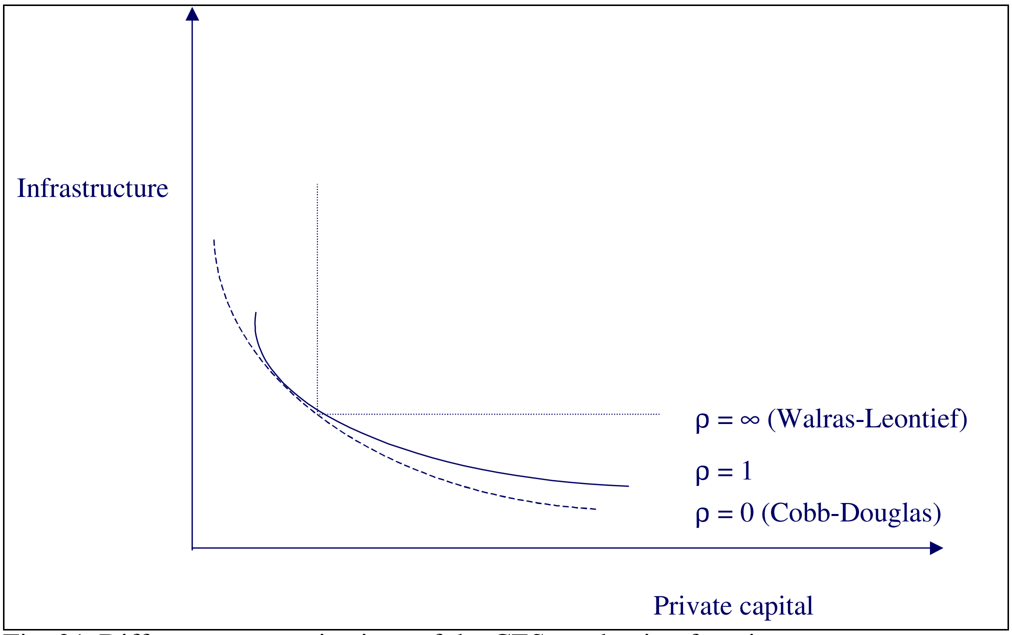

Fig. 31: Different parametrizations of the CES production function

Ordinary least square regressions were conducted to estimate the parameters of these production functions. While the results for the Cobb-Douglas function parameters were significant, the results for the CES function were unfortunately not of sufficient quality to be used for the analysis. Thus it was resorted to using a Cobb-Douglas function with the inputs capital and labor, although the economic effects of natural disasters will be underrepresented in such a formulation as the complementarity of infrastructure with other capital stock is not captured well.[38] The production elasticities for the two case study countries were estimated as shown in table 20 (more detail in Appendix II).

Table 20: Parameters of Cobb-Douglas aggregate production functions for Honduras and Argentina

Parameter\ Country	Honduras	Argentina
Alpha	0.25	0.28
Beta	0.52	0.72

While for Argentina constant returns to scale were determined, i.e. the sum of the production elasticities is one, for Honduras decreasing returns to scale were determined, i.e. the sum of the elasticities was less than one. The efficiency parameter A was calibrated each year to fit GDP as calculated by the Cobb-Douglas production function with original baseline GDP given by the ICOR relationship.

If a **catastrophe** has happened, real GDP is recalculated using the base case elasticities, the base case efficiency parameter, and catastrophe-adjusted values of capital and labor. Due to the supply side-characteristic of the model, GDP determined by production will determine the demand-side and affect the components of aggregate demand. If a disaster occurs, real GDP will fall relative to the base case in the year of an event and will remain depressed in future years if insufficient gross domestic fixed investment to counterbalance the capital stock loss is undertaken in the year of the event.

In the module, **export** volumes decrease in relation to the share of exports in production. In RMSM-X export volumes are specified for the specific kinds of commodities. In order to model the effect of catastrophes on exports, the module converts export volumes for each commodity from constant US dollars into local currency. Then the ratio of the export volume of each commodity to real GDP is calculated at market prices in local currency. After determining new catastrophe-adjusted real GDP values, catastrophe-adjusted export volumes can be calculated for each commodity. The last step consists in converting from local currency to US dollars.

7.3.2.4 Additional financing needed post-catastrophe

As standardly done in economic theory, private sector disposable income is modelled as a function of national income and thus will fall when GDP is adversely affected. As discussed above, **providing relief** to the poor or affected can be seen as one of the central obligations of governments and is generally done post-disaster. Particularly for the case study countries relief payments seem to be of necessity considering the already high incidence of poverty (Honduras 53%, Argentina 18% in 2000 and currently rising) and low levels of consumption which prohibits a further decline in private consumption. For the modelling it is assumed that **the government stabilizes the consumption of the private sector** by means of transfer payments, so that private consumption stays on a constant level.

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[38] In the estimations the parameter ρ was estimated at 0.5, however the other parameters and the significance of the regression were not entirely satisfying.

The other aim and obligation of governments post-catastrophe is to rebuild lost capital stock. Assuming that catastrophes do not lead to structural changes in the economy and that prices for the restoration of capital stock are constant, **reconstruction investment** required to restore GDP to pre-catastrophe levels is calculated as the amount destroyed by the catastrophe. By assumption, the government takes on the reconstruction of infrastructure stock (which it owns and maintains), the private sector the reconstruction of the other capital stock. In this manner, needed relief and reconstruction financing can be established.

It is assumed that undertaking relief has higher priority than reconstruction immediately after the event; thus, first the financing required for the relief transfer payments are secured, before the financing of reconstruction is begun.

7.3.2.5 Financing sources for relief and reconstruction

Additional financing needs post-catastrophe for relief and reconstruction can in theory be financed by the following domestic or external sources listed in table 21.[39,40] Not all of these sources are considered viable; the feasibility of individual items is discussed in the following. A number of assumptions had to be made concerning the availability of these sources. These are country-specific and represent to the extent possible the conditions in the case study countries Honduras and Argentina. Of course, when better local information can be obtained, these default assumptions made for this modelling exercise could be overwritten.

Table 21: Description of ex post financing sources for relief and reconstruction in model

Sources	Feasibility pre-catastrophe in model, regular policy closure	Feasibility post-catastrophe
Private		
Decreasing consumption= increasing private savings Borrowing domestic	 No extra feasible	Not considered feasible, as consumption stays constant and savings actually decrease due to lower income.
Borrowing foreign	Baseline borrowing	Limited by indebtedness indicators and assumptions on the supply made available (0, 50, 100% available)
Aid	-	Total aid is 10.4%,[41] the fraction accruing to the private sector is assumed to be proportional to the share of non-infrastructure stock in total capital stock.
Insurance	-	Indemnity payment (exogenously specified)

[39] The RMSM-X model is a model focusing mainly on the flows, it does not explain economic behavior as a function of assets or stock. Thus depleting assets to finance unexpected contingencies is not modelled as an option.

[40] The concept of the available financing sources post-disaster were developed by the author for work on a report for the Inter-American Development Bank as described in Freeman et al. 2002b and Mechler and Pflug 2002.

[41] 30 data points for economic losses over US 50 million and international assistance including 16 Latin-American countries since 1960 were used to estimate an average inflow of aid to be expected post-disaster. In the IDB study a value of 8.6% was used. Excluding some outliers of this data set leads to a more robust value of 10.4% which was used here.

Sources	**Feasibility pre-catastrophe in model, regular policy closure**	**Feasibility post-catastrophe**
Government		
Diversion from budget	-	7.5% diversion of current expenditure assumed
Taxation	No extra	No extra assumed feasible
Central Bank credit Reserves Domestic bonds and credit	- Constant - fixed fraction of deficit financed by credit - remaining deficit financed by private sector borrowing	- Shallow domestic markets: No extra financing assumed. Absolute amounts kept constant as domestic financing negative in case study countries
Insurance	-	Indemnity payment according to specified insurance strategy and existing insurance arrangements
MFI borrowing International bonds (gapfill loan)	Baseline borrowing	Limited by indebtedness indicators and assumptions on the supply made available (0%, 50%, 100% available)

Sources: Benson 1997c: 74, Freeman et al. 2002b; Mechler and Pflug 2002.

In theory, the financing sources of the **private sector** are increasing savings or borrowing, aid and insurance.[42] In this approach, due to the low level of per capita income in Honduras and the inequal distribution of incomes in Argentina despite higher average per capita income, *savings* are not considered a viable source of financing the losses. *Borrowing* is assumed to be feasible to the extent debt sustainability as determined by debt indicators is maintained. This borrowing is assumed to come from abroad. Also, *aid* is an important source of reconstruction financing. Based on a regression analysis, aid is assumed to be received at ca. 10.4% of losses (Freeman et al. 2002b). This is probably an upper limit for foreign financial assistance inflows, another study estimated aid to be about 4% (Zupka 1988 as quoted in Charveriat 2000: 79). Aid is assumed to be allocated evenly between the public and private sector in proportion to the losses incurred. Private *insurance* undertaken in the countries is assessed and will prompt indemnity payments in case of events.

The **public sector** has more options at disposal: the ex-post instruments available in theory are diverting funds from the budget, imposing or raising taxes, international aid, tapping into the reserves of the Central Bank, borrowing domestically and internationally and insurance payments. All of these sources of financing have associated effects that constrain their usage (Benson 1997c: 74).

- *Diversion* means using funds that were earmarked for other purposes and thus implies foregoing the returns and benefits of these projects. As well, there is often high political cost to diversion when money is taken from ministeries. It is assumed that the government is able to divert some funds from government spending to reconstruction activities. In recent research maximum diversion post-disaster for the four Latin American countries Bolivia, Colombia, Dominican Republic and El Salvador was estimated at 5-10% of current expenditure

[42] The module developed here focuses on the government's behavior, the other sectors particularly the private sector are not considered in very much detail.

(government spending) (Freeman et al. 2002b: 35). For this thesis, the mean value of 7.5% will be used for both Honduras and Argentina.

- Establishing additional *taxes* after a catastrophe will decrease private savings when consumption is to stay constant and exert additional depressionary effects on the economy. For this reason, no additional tax revenue is assumed. If revenue is limited and cannot be expanded a deficit is incurred that has to be financed.

- *Deficit financing* options are credit from the Central Bank or the private sector (commercial banks and private households), tapping into the foreign reserves of the central bank, obtaining loans from MFIs or selling bonds abroad (Benson 1997c: 74).

  Central bank credit is usually granted by selling government bonds to the Central Bank resulting in money creation which is potentially inflationary if money growth is not held in proportion to real GDP growth (Fischer and Easterley 1990: 131). Using *foreign exchange reserves* of the central bank creates the potential for a balance-of-payment crisis due to the lack of needed reserves for imports. The sources reserves and central bank credit are generally considered to be particularly problematic, e.g. a recent assessment of a World Bank and IMF team on reconstruction financing options in El Salvador after the earthquakes in 2001 stated:

  > Under any monetary system, a country needs to maintain a strong underlying fiscal position and a sound credit policy, with an adequate cushion of net international reserves, to preserve macroeconomic stability. Expanding the money supply or reducing the central bank's net international reserves are never optional sources of financing for reconstruction costs. (IMF and World Bank 2001: 5).

  Central Bank credit and tapping into reserves are used in practice as deficit financing sources, but from a normative planning point of view, they should not be considered in the case study countries in Latin America where inflation and external debt issues are important policy issues (Ferranti 2000: 61). For these reasons, these two sources will not be considered as viable sources for ex-post catastrophe finance in this report.

- *Borrowing domestically* also incurs costs: domestically, credit may be compressed particularly so in shallow credit markets resulting in a rise of the interest rate and a crowding-out of domestic investment. Borrowing from the private sector via issuing domestic government bonds is another option. However, it is a common characteristic that in developing countries domestic bond or financial markets are shallow (Ferranti 2000: 54). In RMSM-X, credit is distributed to government as a fixed fraction of deficit, to the private sector as the residual of the change in credit in one period. For the case study countries, domestic credit has historically been negative, so for the module it was assumed that in case of a disaster no extra borrowing is assumed feasible (table 22).

Table 22: Domestic and foreign government deficit financing in Honduras and Argentina (% of GDP) - federal government[43]

Honduras[1]	**1997**	**1998**	**1999**	**2000**
Budget deficit	-2.0	-0.2	-0.7	Na
Domestic financing	-0.9	-1.1	-10.2	Na
Foreign financing	2.9	1.3	10.9	Na
Argentina[2]				
Budget deficit	-1.4	-2.6	-2.5	-2.4
Domestic financing (residual)	-0.9	-0.6	-0.7	-0.6
Foreign financing	2.3	3.2	3.2	3.0

[1] IMF and IDA 2000; [2] World Bank 2001c.

- *Aid inflows* from abroad after a catastrophe include private and public donations from private institutions, government agencies and inter-governmental agencies in the form of relief, technical assistance, grants, commodities and money (Albala-Bertrand 1993: 31). The amount of aid is as much dependent on the event as on the will of the donors to grant assistance. Thus there is considerable uncertainty as regards the amount of aid obtained post-catastrophe necessitating a case by case examination. As discussed, a value of 10.4% of direct losses for this parameter was estimated. It is assumed that all aid inflows will be divided up between the public and the private sector in relation to their the share of infrastructure (government) and non-infrastructure (private sector) in total capital stock. As there is uncertainty whether aid will in fact be made available, the availability of aid is assumed to be constrained in three scenarios: 0, 50, 100% made available, i.e. 0% of losses are financed by aid, 5.2% and 10.4%. These scenarios will be looked at in combination with the scenarios on the availability of foreign borrowing as is explained below.

- Also, an important financing source and the focus of this thesis are indemnity payments due to *insurance* arrangements. In both case study countries, some insurance is already done in the private sector. The amount of private insurance coverage is taken as an exogenous parameter.

  For the public sector, different strategies of insuring are considered. The indemnity payments received due to these strategies is an important source of financing for the government. The concrete insurance option assumed here is the government pooling risk to its infrastructural public assets and transfer this risk to insurance markets.[44] All infrastructure assets are assumed to be bundled in one pool, and this pool reinsured internationally. The model representation of the insurance purchase is discussed in 7.3.2.10.

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

  > From the standpoint of macroeconomic policy, the key question is how much and how rapidly can the government afford to borrow to finance the reconstruction costs, while keeping fiscal policy on a sustainable path (IMF and World Bank 2001:3).

[43] Negative domestic financing represents debt amortization payments.
[44] In the case of catastrophe bonds, the transfer would occur to the capital markets.

In the model, this is the residual financing item. Constraints for external credit come from the demand side as well as the supply side. Demand is restricted by external debt sustainability. Borrowing abroad incurs an increase of future debt service obligations and thus the potential for a fiscal and debt crisis if large portions of the revenue have to be used for debt servicing or insufficient foreign exchange is available to service the external debt. The Highly Indebted Poor Countries Initiative (HIPC)[45] assesses on a regular basis the debt sustainability for developing countries. The main indicator used in the Initiative is the ratio of the present value of debt[46] to exports. A ratio of less than 150% is generally regarded as a sustainable value for this indicator (World Bank 2002a: 5). This constraint will be used for determining the potential to borrow additionally from the MFIs while maintaining debt sustainability. Maximum extra borrowing is considered the amount that keeps this indicator below critical levels (fig. 32)

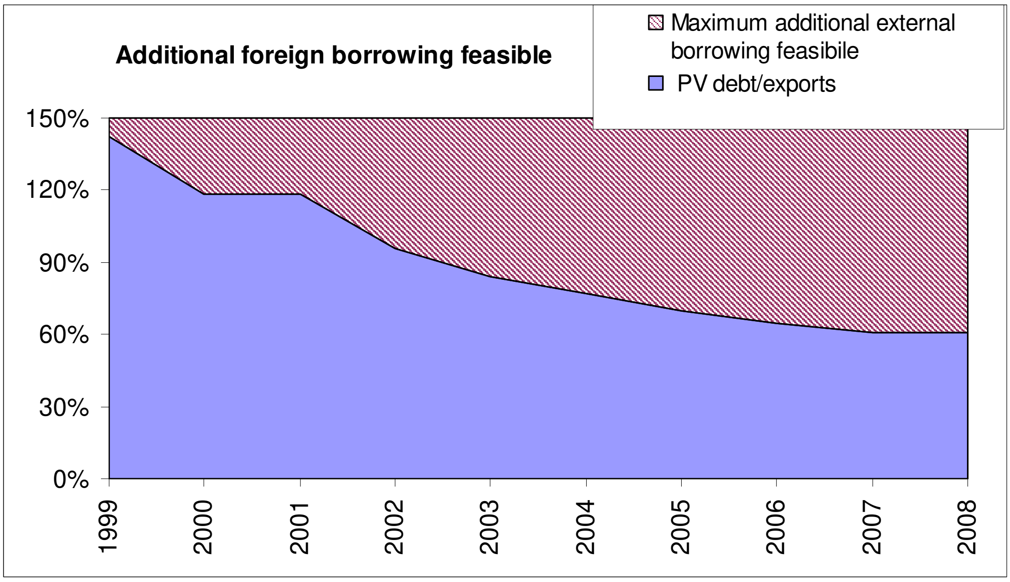


Fig. 32: Maximum additional borrowing in Honduras.

On the supply side, MFIs offer loans at more generous terms than borrowing at market conditions. Whereas the supply of international loans is potentially unconstrained for the purposes of reconstruction financing, the availability of MFI loans is limited by the willingness of the donor community to grant subsidized credit. In this study, similar to the assumed availability of aid inflows, constraints on this

[45] The HIPC Initiative was initiated by the IMF and the World Bank as a comprehensive effort in 1996 with the aim to reduce debt for the most indebted poor countries and was enhanced in 1999 by granting deeper, broader and faster debt relief by bilateral and multilateral creditors. Under the enhanced initiative, the aim is to reduce the present value (PV) of debt to a maximum of 150 percent of exports and 250 percent of government revenue. Debt relief will be provided in addition to traditional debt relief mechanisms (Paris Club debt rescheduling on Naples terms, involving 67 percent debt reduction in PV terms and at least comparable action by other bilateral creditors). It is expected that thirty-six countries will qualify for assistance under the enhanced HIPC Initiative (World Bank 2002a: 3).

[46] The present value of debt is the sum of all future debt service (principal and interest) discounted at a given rate of interest. The interest rate used for the debt sustainability analyses under the framework of the HIPC Initiative are so-called *currency-specific interest rates* (CIRRs). In the HIPC documents the present value is referred to as *net present value*. However, the net present value rather is the difference between the nominal value of the debt (future debt service payments discounted at contractual interest rate) less the present value. Here the term present value of debt is used.

willingness are represented by an availability parameter that is varied from 100% to 0% foreign borrowing available. Also, as outlined before, there is a time lag to borrowing. The lag here is assumed to be one year which according to the literature has to be considered the lower limit.

Thus, the external financing scenarios vary the availability of aid and foreign borrowing.

For external borrowing the assumption was used that half of extra foreign borrowing possible comes from more concessional MFI sources (World Bank, IDB etc.) and half from the capital markets at regular market rates. Country-specific conditions for borrowing are taken for MFI as well as commercial borrowing.

- Calculating extra foreign borrowing is one of the main objectives of RMSM-X. This borrowing is known as *gapfill loan.*[47] Additional external borrowing necessary and available is determined as follows.

- Necessary additional external borrowing is assumed to be equal to capital stock lost (after depreciation) and relief requirements for the private sector less aid inflows, budget diversion and insurance claims received. Depreciation of the lost capital stock is done to reflect the actual loss of production input in the given period.
- Foreign borrowing feasible is determined by indebtedness indicators. The necessary additional external borrowing is limited to that amount that keeps indebtedness indicators just within sustainable limits as discussed before.
- Gapfill loan is assumed to be undertaken by the government, and then allocated to the private and public sectors to same conditions in proportion to the financing requirements of these sectors.
- On the supply side, the willingness of donors to grant the needed amounts for reconstruction is assumed to be limited. To study the effects of insufficient access to these external financing, three cases are distinguished: 0%, 50% and 100% of necessary financing granted.
- Gapfill loans have a one year time lag. As discussed, the arrangement of loans will usually take at least one year to materialize.

Gapfill financing and insurance are thus considered substitutive financing sources: The more infrastructure is protected by insurance, the less gapfill borrowing will be necessary in case of an event.

7.3.2.6 Financing gap

After tapping into the different sources of financing, some financing needs may remain unfinanced, which is called the *financing gap*. The financing gap concept is not a generic concept, rather it has been widely used in the development finance literature. The financing gap used here in the context of natural disasters is a related

[47] The gapfill loan is the marginal foreign financing granted to close the Balance of payments (BOP). It is assumed that exchange rate and reserves stay constant, thus additional foreign financing in the capital account is the residual value. It allows to undertake imports as needed, also when exports decrease. Growth objectives can be pursued as needed. If there is insufficient gapfill, imports of other consumer goods will have to decrease to close the BOP.

concept to the gapfill loan concept. A major purpose of RMSM-X is to estimate the amount of additional external financing necessary to achieve certain growth targets. The financing gap is the amount of infrastructure stock losses that would remain unfinanced after disasters after exploiting all financing sources possible and remaining fiscally sustainable. Consequently, this indicates the amount that would need to be covered by ex-ante arrangements like insurance.

A general caveat has to be expressed concerning the evaluation of potential financing sources. The data points used in this analysis are the result of a top-down approach incorporating several assumptions. The aim in employing these data was to use appropriate data from a fiscal sustainability point of view. The data could potentially be revised with national experts incorporating their information and constraints. However, for the present purpose of demonstrating the general trade-off discussed rather than providing specific policy input, the approach taken seems to suffice.

7.3.2.7 Balance of Payments: Determination of feasible imports

Importing more goods needs balancing of capital inflows in the Balance of Payments (BOP). To the extent financing is received in the public and private sector, additional capital goods for reconstruction can be undertaken. On the other hand, as foreign reserves and the nominal exchange rate and money supply by the central bank are supposed to stay constant, imports could also decrease: If foreign inflows are not available to finance the additional gap in the balance of payments due to lower export earnings and increased imports, imports of "other consumer goods" need to decrease in order to fulfill the balance of payments constraint. These imports are part of the government and private demand for investment and consumption goods, of which the total will be calculated in the national accounting identity.

7.3.2.8 National accounting identity: determination of investment

With the amount of imports determined, the next step is to calculate the residual in the national accounting identity (NAI). This is private investment as required by the policy closure solution in RMSM-X.

The NAI equation is supply-side determined by the output generated with the production function with the inputs capital and labor. The supply of goods produced in one period thus determines demand which has to adjust to fulfill the equilibrium condition.

(1) $GDP=f(K,L)=Y^s=Y^d=C+Ip+Ig+G-IM+X$

where Y^s is aggregate supply, K capital stock, L Labor, Y^d aggregate demand, C private consumption, Ip private investment, Ig government investment, G government consumption, IM imports and X exports.

The following variables change post-disaster

- Supply and exports decrease: $\Delta Y<0$, $\Delta X<0$.

- Government investment goes up to the extent of financing available. The additional capital goods for reconstruction are assumed to come from abroad due to a lack of domestic capital good industries.
- Private consumption C is stabilized at baseline levels by means of transfer payments from the government: $\Delta C=0$.

Thus
$\Delta Ip = \Delta Y - \Delta X - \Delta G - \Delta Ig + \Delta IM\ (C+G+Ig)$

ΔIp is the residual. This means when no extra borrowing is feasible the burden of adjusting to lower absorption is borne by a decrease in private investment. Two cases can be differentiated in theory:

- Financing is insufficient to fully finance imports for reconstruction for public or/and private sector fully. Then investment into capital stock will be done at suboptimal levels, and GDP will remain below desired levels. The build-up of capital stock will remain insufficient for reaching the previously planned and desired growth path.

- All necessary financing needed can be secured. Sufficient financing is obtained for completely replacing lost capital stock. However, it is assumed that foreign financing is obtained with a 1 year disbursement time lag. Thus that part of capital investment to be financed by foreign financing will remain unreplaced for another year causing production shortfalls during this period. Only in this period will the foreign borrowing necessary be disbursed which will allow GDP to recoup. In total, two years after the disaster event replacement capital stock financed by external financing will be in place. Indemnity payments from insurance companies on the other hand are disbursed immediately, which will allow prompt capital stock replacement investment, so that in the year following the event replacement capital stock financed by the indemnity payment can already become productive.

Standardly in RMSM-X, government investment is calculated as a ratio of GDP, and private investment is the residual in the SNA. Here, a new ratio is calculated for government investment which is the old ratio plus the product of the ratio of reconstruction investment to GDP multiplied by the fraction of reconstruction investment undertaken by the public sector.

7.3.2.9 Monetary sector variables

Finally, the monetary sector variables are calculated. The price level is calculated by means of the *Fisher*-equation[48] as a function of GDP and the exogenously projected money stock and money velocity. The change in domestic monetary credit is calculated as the stock in the current period less the stock in the last period. The change in credit is divided up between the government and the private sector: An exogenously fixed ratio of the government deficit is assumed to be financed by

[48]The Fisher equation is defined as follows:
$M*V=P*Y$
where M is money stock, V money velocity, P price level and Y GDP, and V and P are assumed fixed. The Fisher equation holds that the growth in money stock is proportional to GDP growth.

monetary credit, the rest of the credit is allocated to the private sector. Finally, the residual government deficit is assumed to be financed by borrowing from the private sector that takes on this entire residual. Deficit financing by monetary credit and borrowing from the private sector do not affect budgetary decisions in the current period.

7.3.2.10 Representation of insurance purchase

Two types of insurance are examined: Proportional excess of loss (XL) insurance insurance and non-proportional quota share (QS) insurance. For the model runs where insurance is assumed to be purchased, the insurance arrangement is represented as follows. The insurance purchase is assumed to occur in the beginning of the respective year.

- The government sector buys insurance from a foreign insurer.
- The government pays a premium accruing to government spending G: G'=G+Premium
- In the system of national accounts (SNA), the expected loss part of the premium is considered a net foreign transfer payment, the risk premium an import of services. The premium needs to be paid with (scarce) foreign reserves,
- The private sector is not buying insurance, only existing insurance arrangements are included.
- In case of an event, the indemnity payment from the foreign sector can be used by the government, whereas the private sector remains uninsured respectively insured to the extent of existing insurance.

The following implications for the sectoral equations arise due to the insurance purchase:

1. Diversion in budget. Less government investment and spending is possible, thus there is less capital stock in next period and GDP will be lower.
2. Diversion in balance of payments. The premium paid is diverted from government imports of government investment and spending, as foreign reserves are required for paying the foreign reinsurer which demands the premium in his currency.
3. There is a change in the composition of imports, as insurance services are imported and less investment and consumption goods are imported.

For the calculation of the **costs of the insurance** arrangements in terms of premium payment the methodology presented in Pollner et al. (2001: 25-39) was used.

The procedure is as follows for the XL arrangements:

- Define loss layer to be covered determined by attachment point and exit point, e.g. a layer stretching from the 100 to the 500 year disaster event, and determine the potential absolute losses in this layer.
- Calculate cumulative losses of layer, i.e. cumulative losses at exit point less attachment point.
- Pure premium is the cumulative losses of the layer divided by the losses of the layer.
- Using table 15, a loading factor associated with the pure premium is added, this determines the total premium rate or rate on line (ROL).
- Multiplying the ROL by the layer results in the total premium.

E.g for the XL 100-500 option for Honduras, the following costs were estimated for Hurricane risk which is here denoted as storm and flood risk (table 23).

Table 23: Pricing characteristics for 100-500 layer for storm and flood risk in Honduras

Abs. Losses	18.46%	% infrastructure stock
Cum. Losses	0.18%	% infrastructure stock
Pure Premium (cum/abs)	0.98%	%Loss layer
Loading factor	4.20	
ROL	4.11%	%Loss layer
Total premium	0.76%	% infrastructure stock
Transfer	0.18%	% infrastructure stock
Loading	0.58%	% infrastructure stock

The calculation is as follows. These illustrative numbers are taken from the Honduras case study in chapter 11.

- The absolute loss of the 100-500 year storm and flood risk layer is 18.46% of infrastructure stock (I) (500 year event: 30.77%, 100 year event: 12.31%).
- The cumulative loss of the layer is the integral over the cumulative loss distribution curve (as e.g. shown in fig. 29) from the attachment point to the exit point. Thus, here it is the integral from the 100 year to the 500 year event. i.e.
- cum. loss (500-100) = 0.18% of infrastructure
- The pure premium is the quotient of cumulative and absolute losses: 0.18%/18.46% = 0.98%
- For the pure premium of 0.98% a loading factor of 4.2 (average of 3.5 and 4.9) can be derived from table 15; multiplying the pure premium by this factor results in a ROL of 4.11% of the loss layer
- Multiplying the loss layer by the ROL results in the total premium: 4.11%*18.46% =0.76% of infrastructure
- Thus the annual premium amounts to 0.76% of infrastructure stock, 0.18% (0.33%*18.46%) is pure premium, 0.58% the loading element.

If more than one risk is bundled in an XL arrangement for a certain loss layer, then the pure premia have to be added (for uncorrelated risks which are regarded here only) and the associated loading factor determined. The loading factor will thus be lower when risks are bundled due to the decrease in variance discussed above in the context of the law of large numbers.

Also, one QS insurance arrangement was examined for each case study. It was assumed that the premia and the losses are shared equally between the government and the insurer, and that all loss events considered feasible are protected. In a simplified manner, premia are assumed to be based on the XL insurance premia. E.g. for the case of Honduras, this means that 50% of the 0-500 layer is insured by the government and 50% of the XL 0-500 premium is paid annually as a premium by the government. For Argentina, the same arrangement was assumed for the 0-1000 layer.

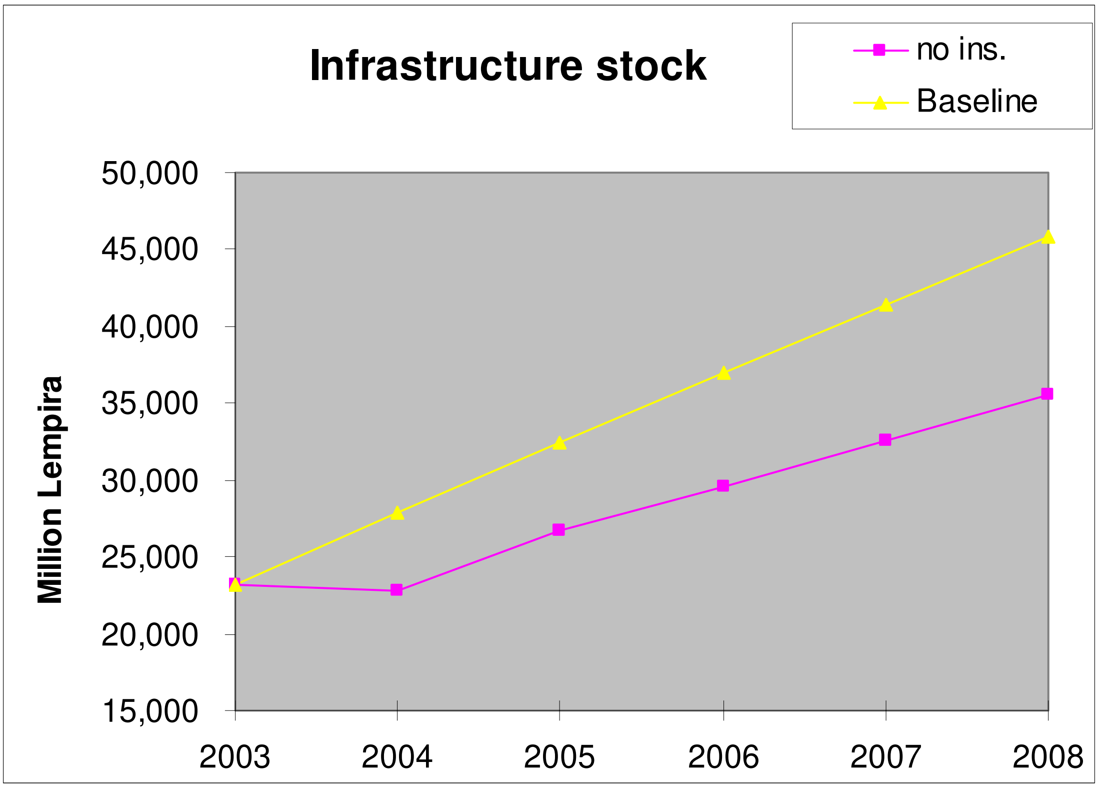
Premia are indicated as a fraction of infrastructure stock. The absolute values will be determined dynamically depending on the stock of infrastructure in a given year.

7.3.3 Numerical example of effects

To illustrate the modelling approach and the costs and benefits accruing, numerical examples are supplied in the following. Information from the case study on Honduras is used to illustrate the effects. The time horizon studied is 2003-2008.

7.3.3.1 Catastrophe shock without insuring

In order to demonstrate the effects properly, one deterministic event assumed to occur in 2004 with a capital stock loss of 18% is looked at. Such an event is similar in terms of capital stock loss to the Hurricane Mitch disaster in 1998. As events in this exercise are generated stochastically, several events in one year or over the time horizon studied are possible. Two extreme scenarios on the availability of external financing from the supply side are shown: 0% and 100% external financing available. Figs. 33 and 34 show the stocks of infrastructure and total capital stock over time as compared to the baseline without a disaster event.



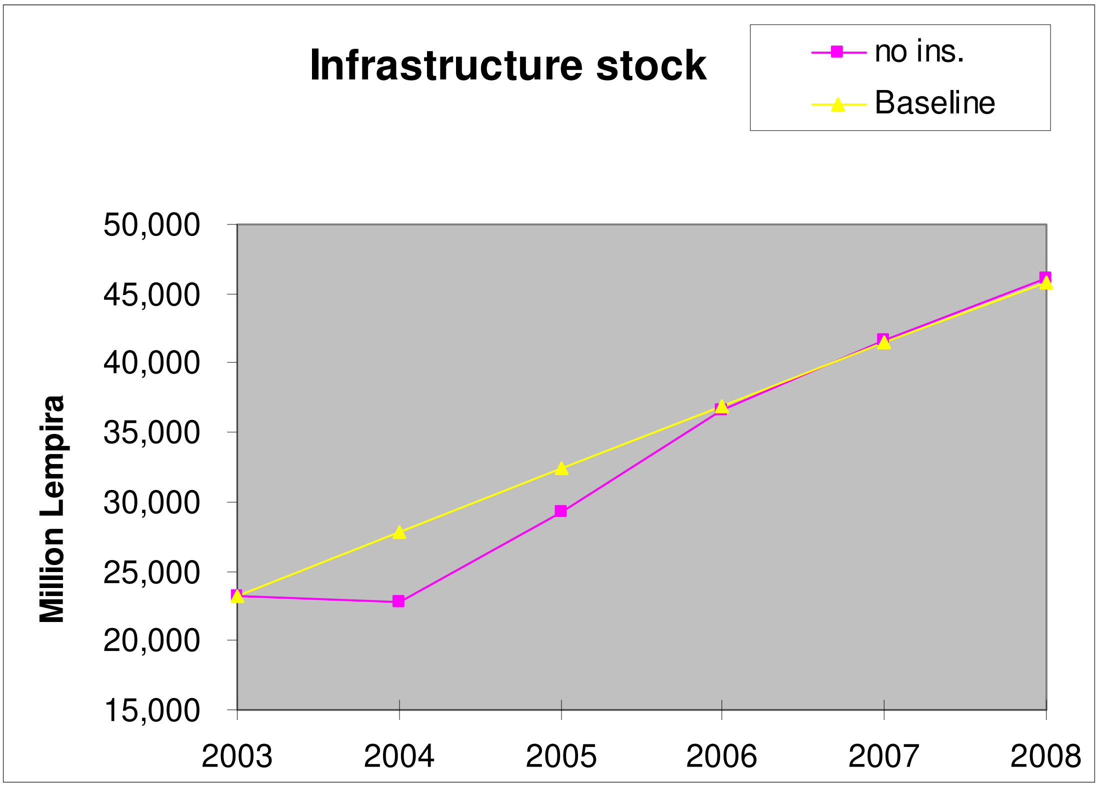
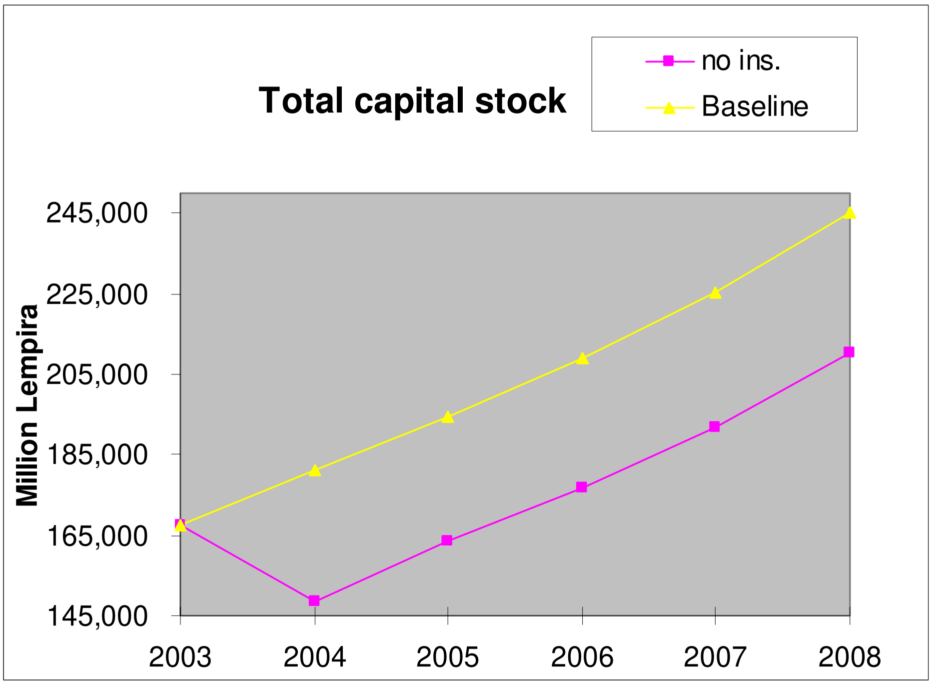


Fig. 33: a,b Infrastructure paths with 18% catastrophe flood and storm shock in 2004 and 0% and 100% external financing received

The disaster is assumed to destroy capital stock in the beginning of the year; in the following periods reconstruction can begin. However, it will take one year, until investment into capital stock adds to infrastructure and total capital stock. Consequently, after the loss of infrastructure in 2004, only in 2005 will some limited reconstruction be possible by using domestic resources and aid. External financing is assumed to arrive with a one year time lag; thus this source of financing in total has a two year time lag before it effectively adds to capital stock. If external financing materializes in 2006 in sufficient amounts (100% scenario), infrastructure can be replaced fully. If no external financing arrives (0% scenario), infrastructure stock will continuously fall short of baseline. Similar, but less pronounced effects will occur for total capital stock levels (figures 34 a,b).



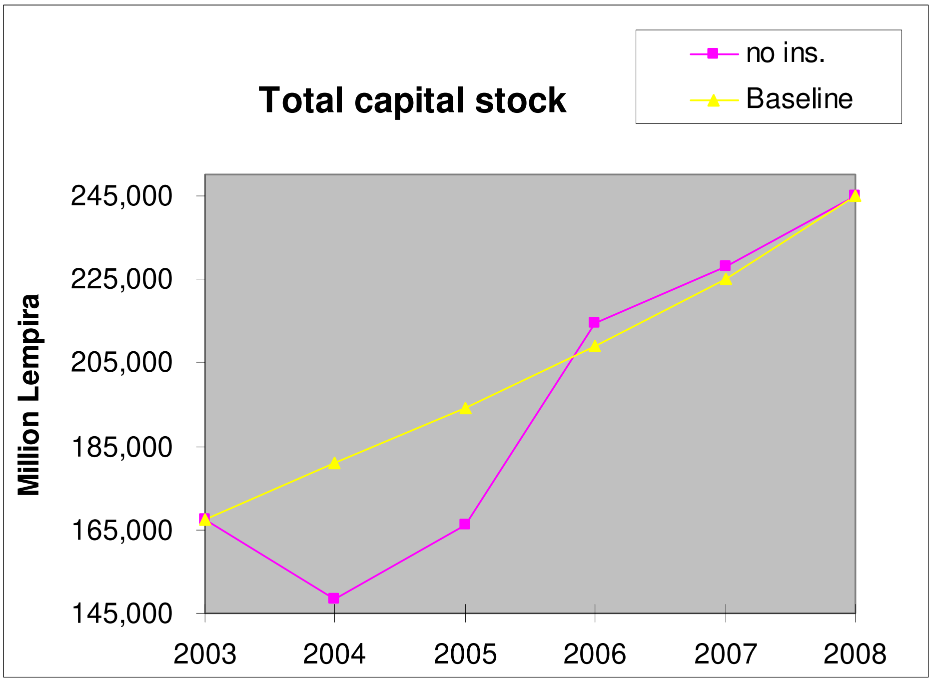


Fig. 34: a,b Capital stock paths with 18% catastrophe flood and storm shock in 2004 and 0% and 100% external financing received

For the 100% external financing scenario, in 2006 capital stock will even "overshoot" over baseline capital stock due to the lagged disbursement of the foreign financing that would have been necessary a year before. Via the production function relationship, these effects on infrastructure and total capital stock will affect GDP (fig. 35 a,b,c). Here, additionally a 50% scenario is shown in order to outline a mean scenario.

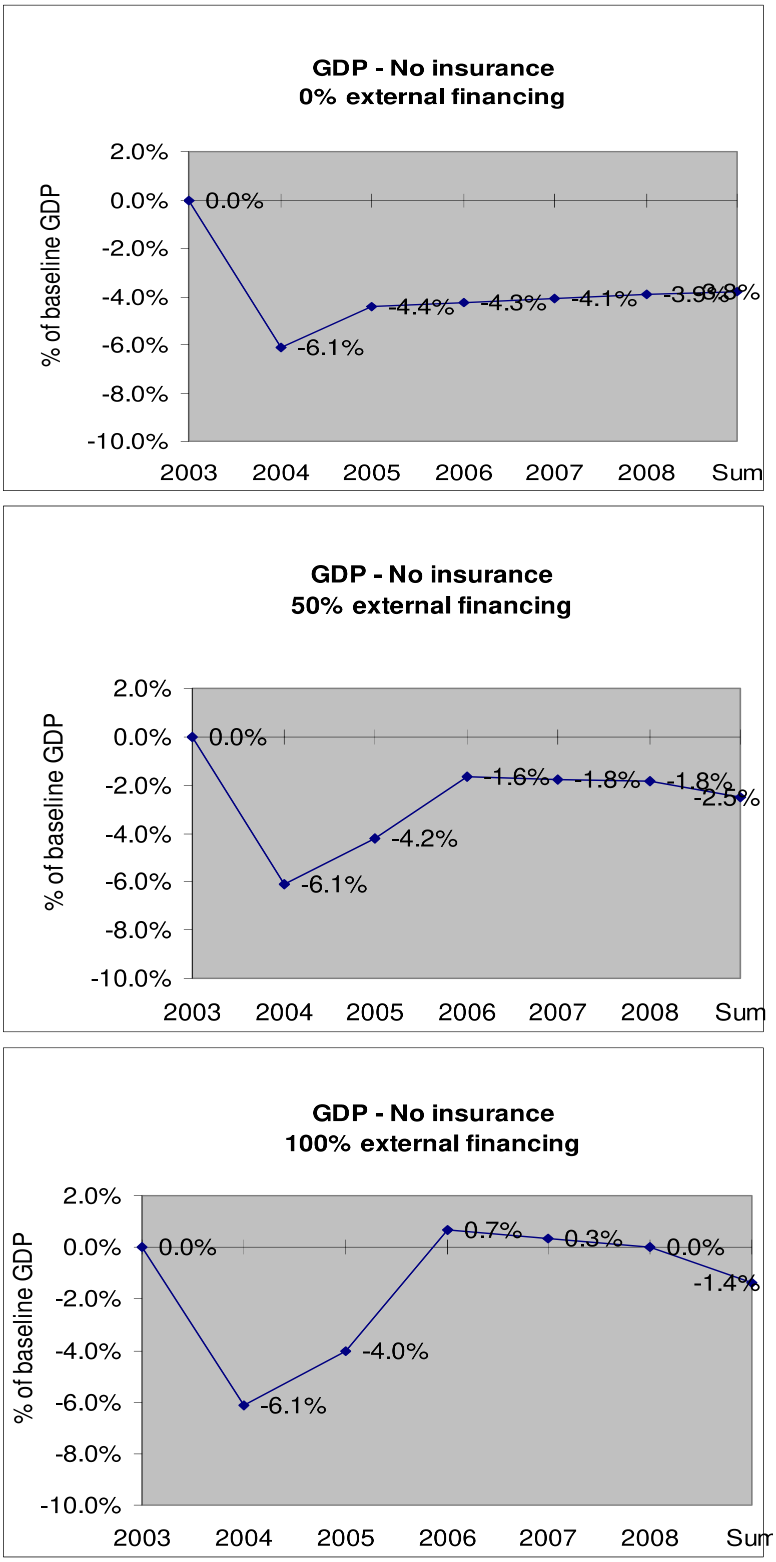


Fig. 35: a,b,c: GDP paths with 18% catastrophe flood and storm shock in 2004 - 0%, 50% and 100% external financing scenarios

In the year of the event, GDP will fall due to the loss of capital stock. Some limited recovery will take place in the year 2005 following the event for all scenarios. The 100% and 50% scenarios are better off as aid payments arrive immediately whereas there is no aid in the 0% scenario. In the 100% external financing scenario, in 2006 the economy will rebound strongly due to the reinvestment undertaken in 2005 with financing obtained from foreign loans disbursed in 2005 with 1 year time lag. In this scenario, GDP will even increase over baseline GDP due to the large inflow of external financing and the high reinvestment consequently undertaken to replace lost capital stock. In the following years when no disaster shocks take place, the economy is converging to baseline GDP again. In this case, the economy would be able to recover largely due to sufficient financing available. If external financing is limited, however (0% and 50% cases), incomplete or no recovery will occur and GDP will fall short of planned growth objectives. Thus the effects of the inability to replace lost capital stock can clearly be discerned. The aggregate non-discounted changes of GDP as compared to baseline GDP without catastrophe shock for the whole period are negative wit -1.4%, -2.5% and -3.9% for the 1000%, 50% and 0% external financing scenarios.

These modelling effects on GDP can be compared with the actual effects due to Mitch that hit Honduras late 1998. In 1998, the economy still grew by 3.3%, in 1999 GDP decreased by 1.9% and in 2000 the economy rebounded with 4% growth. Compared to projections of 3% growth in 1998, 1999, 2000, the effects compared to the baseline in 1997 (=100) amount to +0.3%, -4.8% and -3.9% (table 24).

Table 24: Historical and simulated post-disaster GDP impacts in Honduras

	1998	**1999**	**2000**	**2001**
Planned (1997=100)	103	106.1	109.3	na
Actual	103.3	101.3	105.4	na
Loss to baseline	+0.3%	-4.8%	-3.9%	na
Simulated losses to baseline with		**Year of impact**	**t+1**	**t+2**
0% external financing		-6.1%	-4.4%	-4.3%
50% external financing		-6.1%	-4.2%	-1.6%
100% external financing		-6.1%	-4.0%	0.7%

Sources: World Bank 1999a.

This compares well with the losses in this stochastic simulation of -6.1% in the first year after an event where the event in contrast to Mitch is assumed to happen at the beginning of the year, -4.4% to -4.0%. in the second year and a range of losses of -4.3% up to an increase of 0.7% for the different external financing scenarios.

7.3.3.2 Opportunity costs of insuring

The opportunity costs of insuring without a catastrophe event occuring are illustrated in the following example for XL insurance for the 0-500 year storm and flood and earthquake layer in Honduras. Annual financial costs are 1.15% of infrastructure stock, whereby 0.55% is transfer payment and 0.60% is loading. These amounts have to be diverted annually from the government budget. Figure 36 shows the opportunity cost of insuring and the accumulating effects as less infrastructure capital stock than in the baseline scenario can be built up.

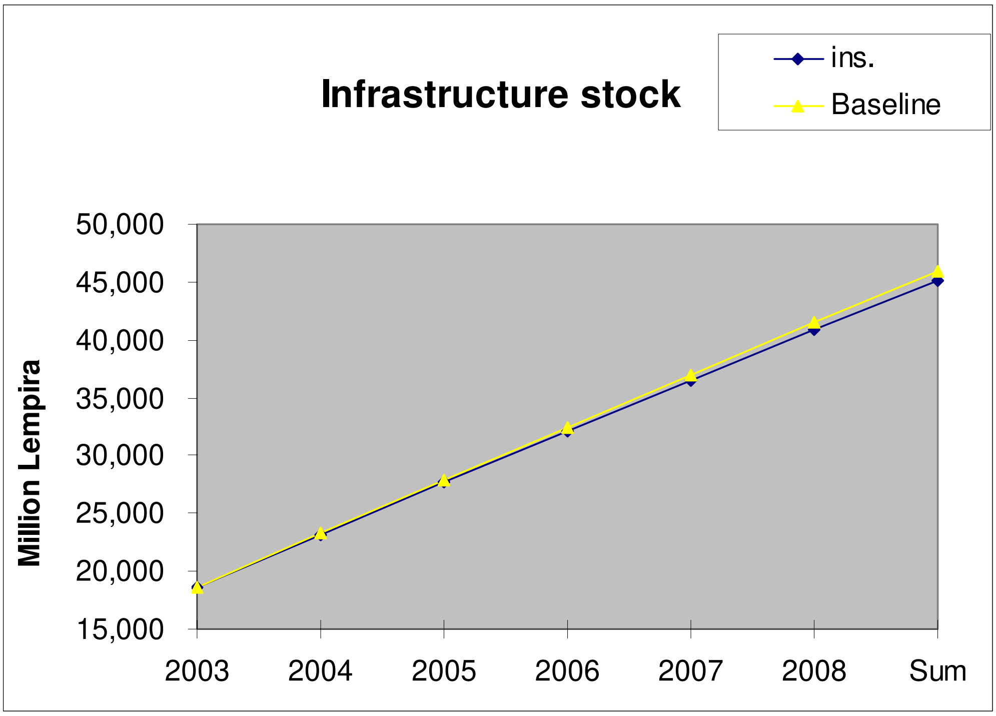


Fig. 36: Infrastructure stock paths 2003-2008 when insurance is purchased

The shortfall of accumulation of infrastructure stock will decrease GDP continuously as figure 36 demonstrates.

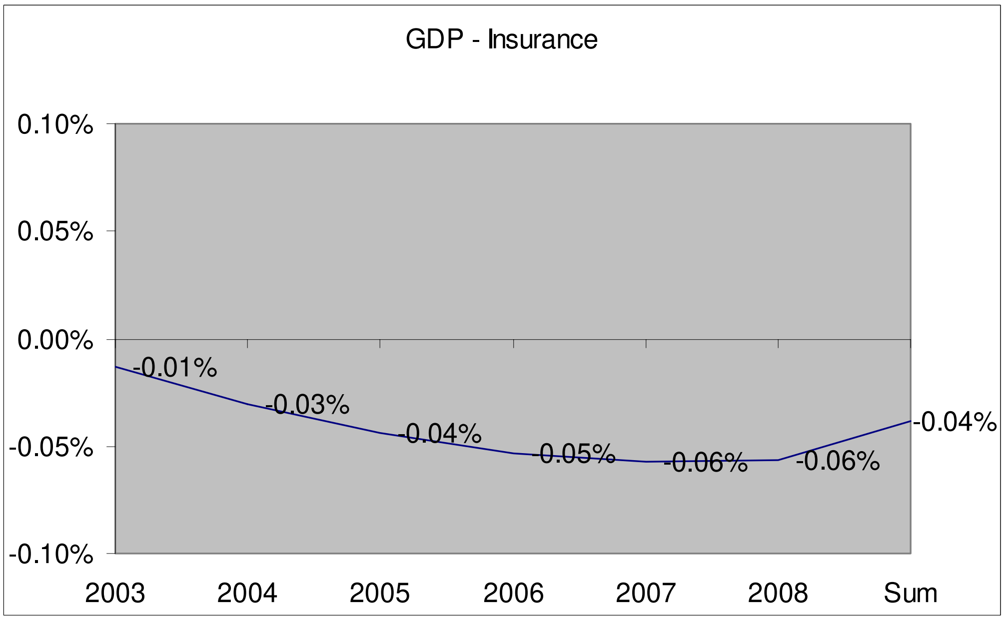
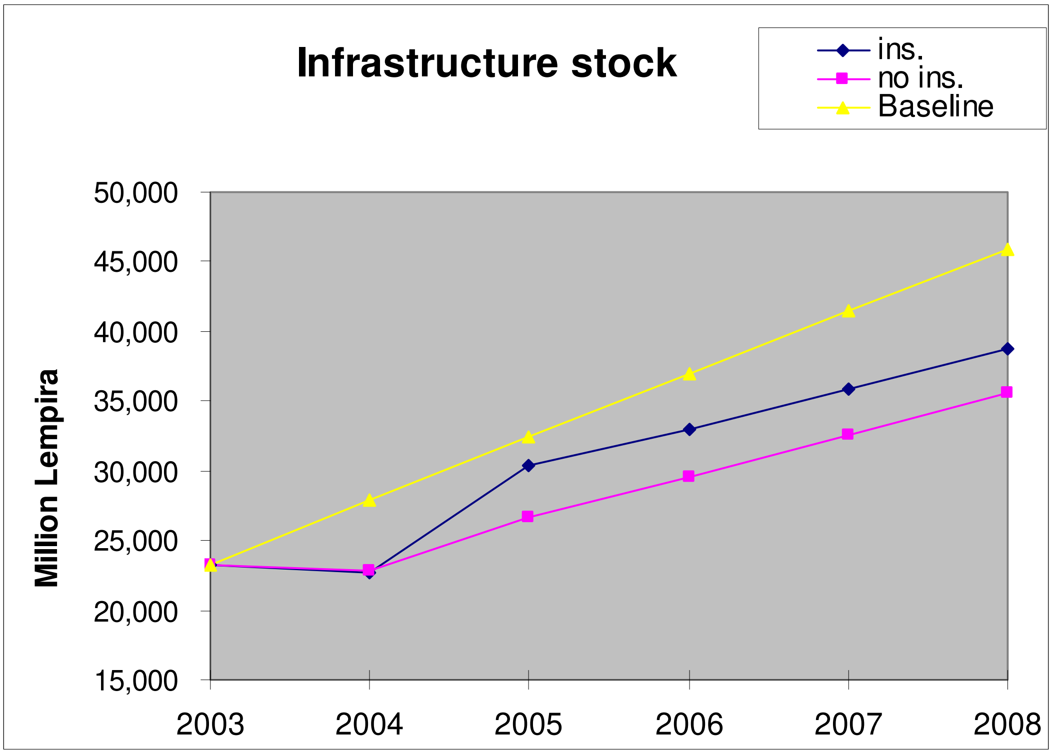


Fig. 37: GDP paths with insurance and without catastrophe shock

7.3.3.3 Comparison of insurance vs. not insuring

Overall, the effects of the insurance vs. no insurance cases can be examined. For the insurance case, XL insurance for the entire 0-500 storm and flood, and earthquake risk layer was assumed. For infrastructure and total capital stock, the paths from 2003-2008 for the insurance and no insurance cases with the 18% disaster event in 2004 and 0% and 100% external financing scenarios look like the following (figs. 38 a,b and 39 a,b).



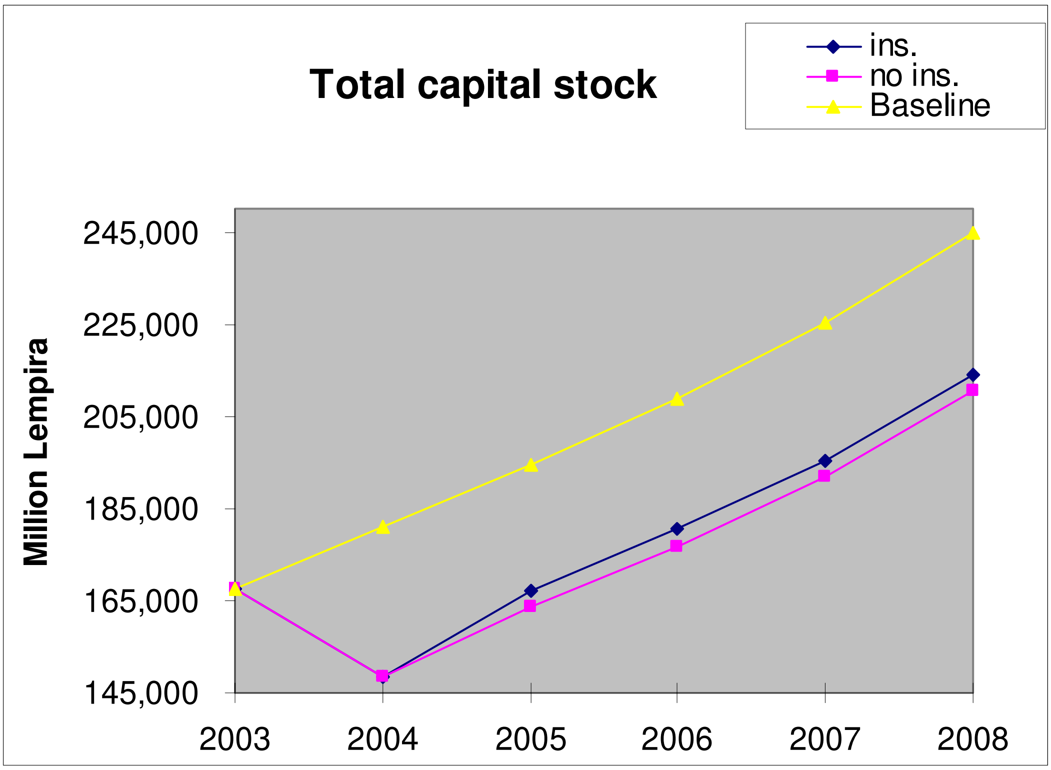
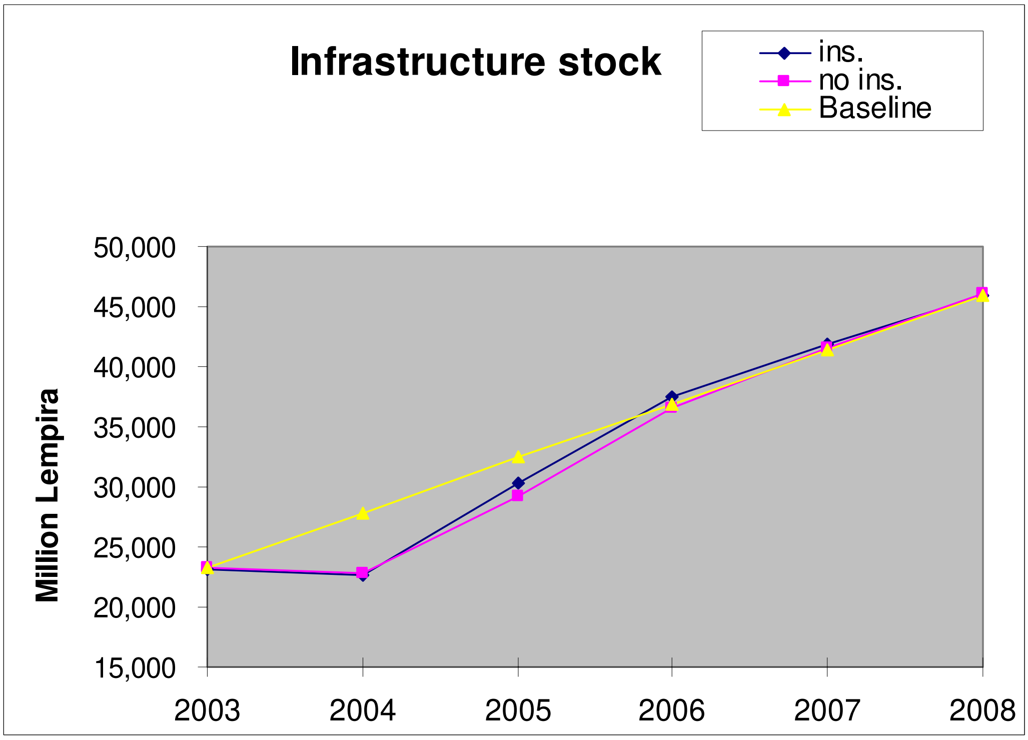


Fig. 38: a,b Infrastructure and total capital stock paths 2003-2008 for insurance and no insurance case with 18% disaster event in 2004, 0% external financing scenario.

In the 0% external financing scenario, more infrastructure can be rebuilt in 2005 in the insurance case, but both paths fall short of original objectives. This effect is similar but less pronounced for total capital stock.



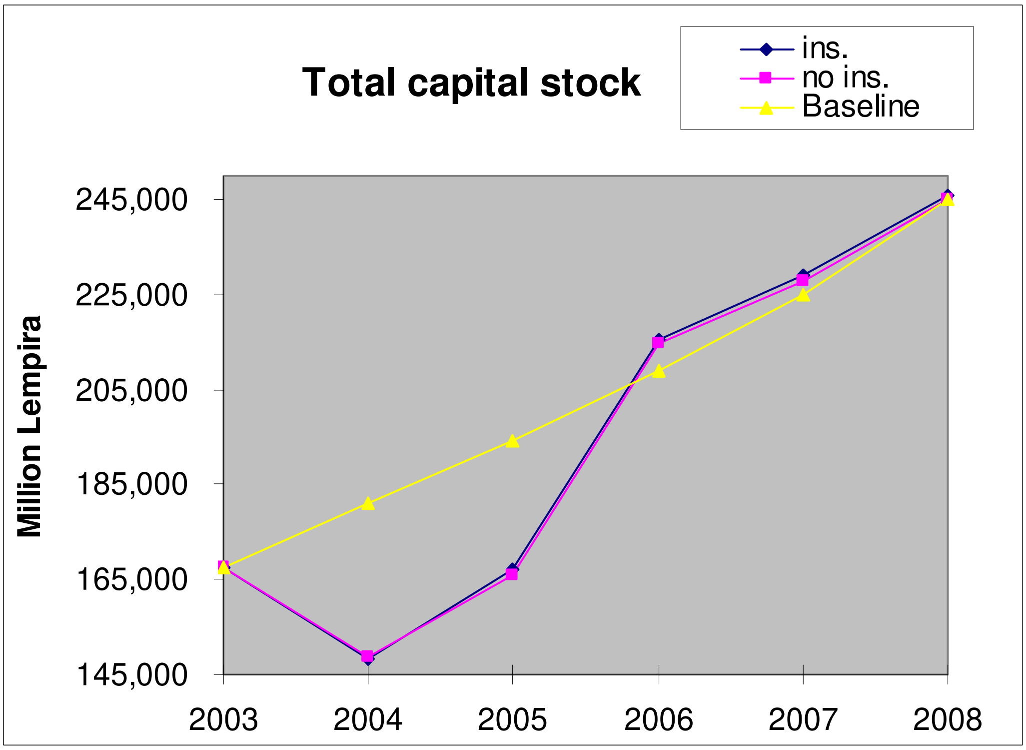
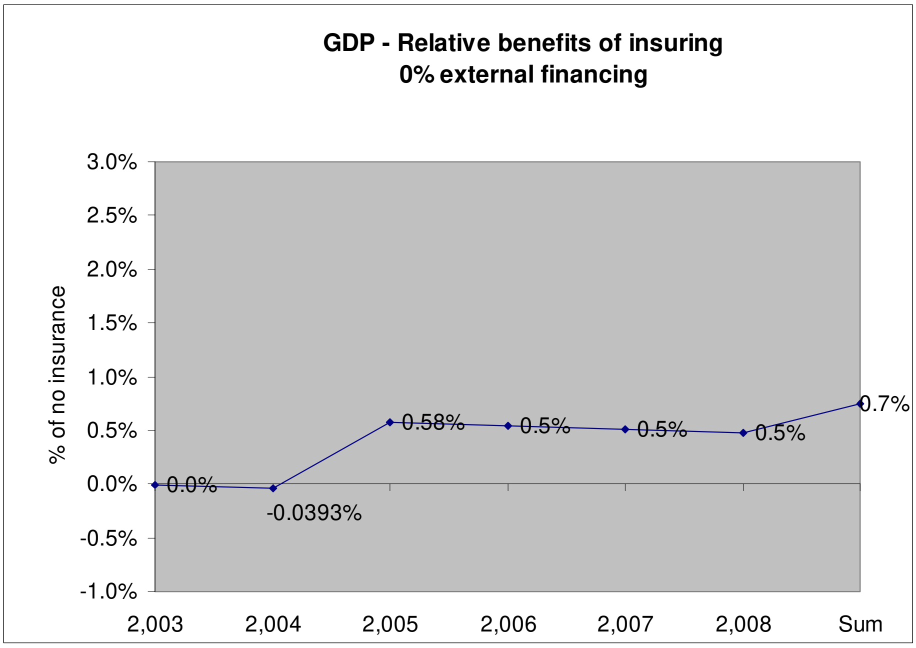


Fig. 39: a,b Infrastructure and total capital stock paths 2003-2008 for insurance and no insurance case with 18 % disaster event in 2004, 100% external financing scenario.

For the 100% scenario, in both cases infrastructure and capital stock can fully be recovered. In the insurance case, more infrastructure is in place and reconstruction is quicker. However, the differences between the two cases is small. For total capital stock, effects are similar, but smaller. When finally looking at GDP, net benefits of insuring can be assessed (fig. 40 a,b).



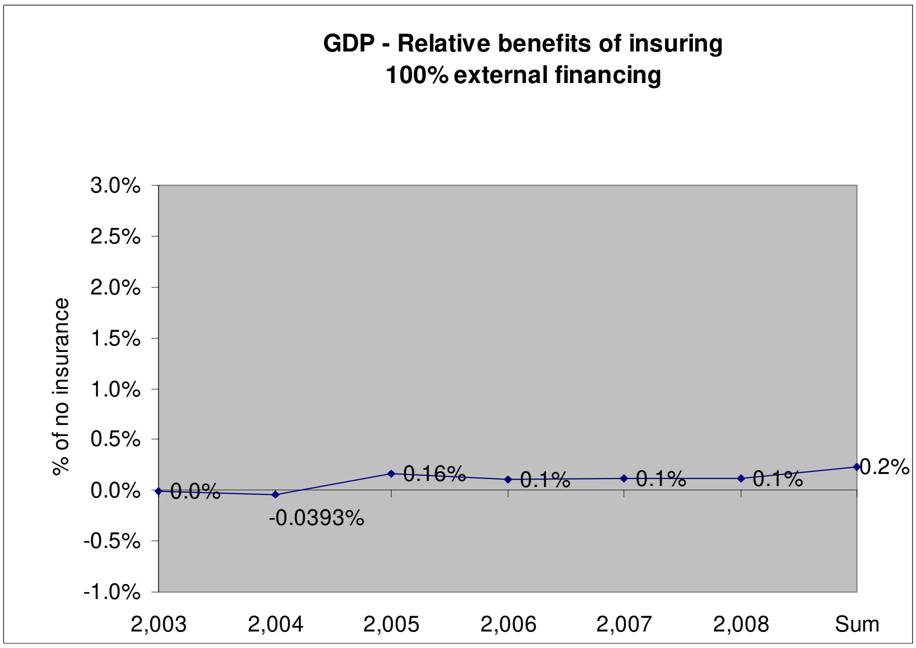


Fig. 40: _a,b Comparison of GDP impacts for 18% loss of capital stock due to a storm and flood in 2004 for insurance and no insurance (as % of no-insurance case), 0% and 100% external financing scenarios

The trade-off growth vs. stability is made explicit here: If no event occurs (here assumed until 2004), insurance fares (slightly) worse, as the annual premium payment causes opportunity costs. In the year of the event, the insurance case will still be slightly worse than the no insurance case due to the investment diverted for the premium payment in the year before. Only in the next year will there be a net benefit for insurance, as indemnity payments arrive immediately. The additional reconstruction investment possible due to this payment will pay off in the year after the event. Thus in 2005 the GDP paths with insurance are 0.5 resp. 0.2 percentage points better off than without insurance.

In the following years whether and how much there will be a net benefit to insuring will depend on the availability of external financing. Net benefits over this period as compared to the no insurance case will be 0.7% for the 0% scenario and 0.2% for the full financing scenario with 100% of financing made available.

Thus, the relative benefits of insurance depend on the size of the impacts (hazard) and the ability to finance losses (economic vulnerability) as well as the loss layer insured (risk management strategy).

These macroeconomic effects due to natural disaster impacts are significant but rather small. This is due to the fact that only about 10% of capital stock (which is estimated to be the uninsured, public infrastructure part of capital stock in Honduras) is insured in the insurance case. Also, effects will probably be higher when the complementarity effect of infrastructure on other capital is better accounted for than it was possible in the Cobb-Douglas production function representation due to data limitations.

7.4 Summary of macroeconomic modelling approach

The catastrophe and insurance modules of RMSM-X (as further extended from the original IIASA approach) represent a methodology to assess the economic impacts of natural disasters and risk management options to limit these costs. This modelling fills a gap in the literature providing a functional and ex-ante modelling approach to assess the economic costs due to disasters, and the costs and benefits due to disaster risk management. The disaster risk management option analyzed in this thesis is risk transfer of infrastructure by governments to foreign insurers. The assumed strategy is to pool infrastructure at risk, and reinsure by means of XL layers or QS arrangements in the international reinsurance market (or capital markets). Insuring has to be seen as a trade-off in context of risk as scarce funds today have to be used for the premium payment, and benefits only accrue when a disaster strikes in the future (table 25).

Table 25: Main costs and benefits of insurance as represented in modelling approach

	Costs (deterministic)	*Benefits (Stochastic, accrue only in case of event)*
Financial	Less government funds for government spending and investment due to annual premium payment	• Indemnity payments from insurance companies, thus government financing gap smaller. • Immediate financing disbursement rather than 1 year time lag as with donor assistance.
Opportunity	GDP reduced due to less investment	• Ability to reconstruct more and more quickly. • Reduction of volatility of development pathway.

The methodology developed creates a framework with which to assess the magnitudes of costs and benefits of the trade-off involved in purchasing disaster insurance. It identifies the variables of major importance and finally gives an idea about the cost-efficiency of this strategy.

The impacts of catastrophes on the economy are modelled as a function of the size of the hazard, the elements at risk and the degree of economic vulnerability. These components are modelled in dynamic fashion. The relative benefits of insurance also depend on these variables as well as the loss layer chosen to be insured. For the case studies to be examined in part III simulations with each 5000 stochastic runs were conducted and the costs and benefits compared.

This modelling approach should be regarded a tool allowing projections of effects of disasters on developing countries under certain assumptions. The main variable isolated is the financial capacity to undertake reconstruction and relief. This is the critical variable differentiating developing countries from industrialized ones. The numerical projections calculated in the case studies have to be taken with caution due to some uncertainty, however values will be expressed as changes in relation to the base case and comparisons will mainly be done between the insurance and no-insurance strategies.

8 COST BENEFIT ANALYSIS OF RISK MANAGEMENT

The modelling approach developed in chapter 7 allows to estimate the effects of natural disasters on the economy and the costs and benefits of undertaking risk management, in this case, insurance, for infrastructure. In order to use the costs and benefits to evaluate the cost-efficiency of certain risk management strategies, a technique to merge this information to a single scalar is needed. Standardly, Cost-Benefit Analysis (CBA) is used for this purpose. This chapter introduces CBA and its main elements. The following chapter will discuss ways to conduct CBA in the context of risk and develop a decision method for the analysis. In this chapter, section 8.1 introduces CBA, 8.2 outlines the development and usage of CBA, 8.3 discusses the major elements and 8.4 deals with CBA on a macroeconomic level.

8.1 Foundations of CBA

Cost-Benefit Analysis (CBA) is an economic technique used to organize, appraise and present the costs and benefits, and inherent tradeoffs of actions governments take to increase public welfare (Kopp 1997: 2). CBA is the standard tool to analyze the net effects of projects or policy measures.

The need for economic evaluation is related to the basic economic functions of a government. As outlined above, from an economic point of view governments[49] have the following obligations: First, the allocation of public goods (education, safety, clean environment) and assets (infrastructure), and second a more equal distribution of income (e.g. Gramlich 1981: 12-35). The overarching objective is the increase of per capita income and consumption (Dinwiddy and Teal 1996: 85). To achieve these aims a government or government institution faces the task of allocating scarce resources (labor, capital, land, foreign exchange) to projects that serve these obligations with the objective of increasing overall welfare. In order to judge if a project is worthwhile undertaking benefits have to be compared to costs by a common yardstick. Costs are the opportunity costs of not being able to invest the scarce resources into other objectives. Broadly speaking if benefits exceed costs then an investment/project should be undertaken. The task of CBA is the assessment and evaluation of costs and benefits of a project with the aim of maximizing social welfare.

Though there are various approaches to CBA, the following general features of CBA can be listed (Rothengatter 2002: 4):

- CBA uses a monetary scale to measure impacts.
- Values underlying CBA are based on revealed, stated or presumed societal preferences.
- A notion of social welfare is underlying the derivation of net benefits.

[49] Government: federal, state or local. In this thesis the focus is on the federal government.

- Finally two aggregate blocks are compared which consequently are aggregated to one scalar (net present value, internal rate of return) to derive an indicator for the change in welfare.

CBA deals with the analysis of social costs and benefits of public investment decisions. This process is similar to the basic logic of private decision-making, however there are important differences. One is that the government is not separate from taxpayers and the welfare of all members of society is the focus. Rather than looking at the financial costs and benefits as a firm does, the government will examine the social costs and benefits. The other difference is that the government has policy measures at its disposal (distribution of incomes, fostering of economic growth e.g. by decreasing taxes) to intervene in the economy and thus affect the results.

CBA is usually the third stage of the project cycle. First, new projects need to be identified. In the next stage, the technical feasibility is checked and costs will be roughly compared to the benefits expected. Alternative versions of a project will be assessed under these criteria. The third stage is the appraisal itself with financial, economic and social dimensions. In a fourth stage, approved projects have to be supervised so that it is carried out as planned. The supervision of projects often leads to the identification of new projects which creates project cycle dynamics (Brent 1998: 4-5).

The notion that individual welfare is to increase due to government policies is basic to CBA. The original criterion used in CBA was the Pareto-criterion (Gramlich 1981: 42-43). This criterion specifies that if social welfare is to increase individual welfare has to increase for everyone. Individual preferences are regarded as decisive and have to be summed up which is the principle of *consumer sovereignty* (Zerbe and Dively 1994: 256-259).

For actual project analysis and policy making this proved too rigorous a condition as in general projects and policies have winners and losers. An extension taking this into account is the *potential Pareto-* or *Kaldor-Hicks-Criterion*. The criterion specifies that winners *potentially* must be able to compensate losers, the gain for those benefiting has to exceed the loss to the disadvantaged. This is the general principle underlying CBA today (Dasgupta and Pearce 1978: 57).[50]

Other important decision-making frameworks are cost-efficiency analysis and multi-criteria analysis.

In *cost-efficiency analysis* a goal is first set (e.g. air pollution should not exceed a certain threshold) and then policies are devised to minimize the costs to achieve the given goal (e.g. reducing emissions from power plants may be cheaper than from cars). In such a framework, the benefits of policies do not need to be known and assessed (Smith 1986: 28 in Bentkover et al. 1986).

In *multi-criteria analysis* multiple objectives are considered instead of one. First, objectives and trade-offs between those objectives are identified, then the different

[50] Another principle for CBA was proposed by Rawls. Social welfare is defined a function of the utility of the worst-off individual or group in a society (Zerbe and Dively 1994: 257).

objectives are weighted with the aim of selecting the best policy (EFTEC 1999: A.2.6).

These approaches have their merits, however CBA is usually regarded the more uniform framework (Squire and van der Tak 1975: 8). For Cost-efficiency analysis a clear quantitative definition of goals has to be done at the outset, which is often not feasible. Also, often decisions are to be made in the context of trade-offs, where no single goal can be established. The main problem with multi-criteria analysis is that when using a number of objectives and attaching subjective weights to them, the analysis is bound to get relatively complicated, solutions may not be found and it is hard to check the robustness of outcomes.

8.2 Development and current usage

Two intellectual strands in CBA can be discerned. Industrialized countries generally use CBA principles for the evaluation of road and rail construction, for estimating effects of noise and air pollution, and for effects of public sector programs in health and education. The other strand of CBA for developing countries, termed project appraisal (Brent 1998: 3), focuses away from non-marketed goods to marketed goods in markets that are imperfect. The theory of project appraisal can be said to be more extensive and more fully developed. Reasons can be related to issues of efficiency and distribution (OECD 1994: 10).

Concerning efficiency, it is generally argued that market failure is the norm rather than the exception and prices do not reflect scarcities. Examples include segmented labor markets, restricted labor mobility by systems of land tenure, split credit markets between formal and informal sectors, price distortions between traded and non-traded goods, and recently market failures connected to environmental damage such as water pollution and soil erosion. Thus an efficient allocation of resources by means of market prices will not be guaranteed and there is a need for government intervention. The other issue is the inequal inter- and intracountry income distribution. For developing countries, project appraisal sometimes uses weights to favor projects that reduce income inequality (Dinwiddy and Teal 1996: 82).

Here, the term CBA will be used in a wider sense encompassing costs and benefit assessment in developed and developing countries. Whereas in developed countries market prices - if they exist - are usually the starting point for analysis, in developing countries market imperfection may be too large to make these prices reliable indicators (Brent 1998: 3-14, Gramlich 1981: 4). Shadow pricing, i.e. the determination and use of efficiency prices for which markets would clear is necessary. In this study, shadow pricing is not undertaken, as the relative changes in welfare, not the absolute values, are important and are measured by the same metric, aggregate income. Using shadow prices like purchase power parity calculations for GDP would only change the scale of the absolute results, not the relative benefits and costs.

Over the years, there has been a shift in the definition of a project: Whereas originally projects denoted investments into physical objects like energy plants or roads, they have come to encompass programs like rural development programs with training and education. Lately, more and more so-called structural adjustment programs have been financed which grant countries money for whatever projects they wish to use provided these projects help to reduce distortions in the economy such as price and tax distortions (Dinwiddy and Teal 1996: 81-85).

CBA is conducted by developing and developed countries as well as large lending institutions (e.g. Asian Development Bank, Inter-American Development Bank, Kreditanstalt fűr Wiederaufbau, World Bank). World Bank is the "chief practitioner" of CBA and largest project evaluator (Little and Mirrlees 1990: 361-362).

The main strength of CBA is that it is an explicit accounting framework and provides a common yardstick with a money metric against which to measure projects for social improvement assuming that decision-maker aims at maximizing differences between benefits and costs (Dasgupta and Pearce 1978: 21). It is a framework for coherent and systematic decision-making (Dinwiddy and Teal 1996: 74).

However, CBA has to be seen as a guide to decision-making and gives an approximation of preferences of society rather than the exact values. CBA and economic efficiency considerations should not be sole criterion for evaluating policies. They should rather be part of a larger decision-making framework incorporating social, economic and cultural considerations. However to many (government) decision-makers economic efficiency is a very important aspect. E.g. in the USA it "at times dominated the policy debate on natural hazards" (Burby 1991: 154).

8.3 Crucial elements of CBA

The following elements of CBA are of importance and need to be discussed.

8.3.1 Social Welfare function and Utility

The aim of CBA is to measure the change in social welfare. The principle of consumer sovereignity maintains that social welfare is measured as the sum of changes in individual welfare though - as will be explained below - no definite aggregation method from the individual to the societal level exists.

Individual welfare can be derived from individual utility. Individual utility U is a function of goods and services y_i at a given point in time and is a representation of an individual's preferences for a bundle of goods and services:
$U = U(y_1,..,y_n)$

The utility function can be either ordinal or cardinal in nature. Usually an ordinal function is chosen where it is assumed that individuals can rank their preferences and know which bundle of goods is preferred over another. A cardinal U function holds that precise values can be attached to a level of preference for a bundle of goods. In the context of risk, a cardinal utility function has to be chosen as will be discussed in chapter 9.

Assuming individual utility maximization subject to a budget constraint leads to the optimality condition that the change in utility weighted by the Lagrange multiplier is equal to the sum of the change in goods and services weighted by the respective prices (see Dinwiddy and Teal 1996: 21ff.):

$$\frac{dU}{\lambda} = \Sigma\, p_i dy_i$$

where λ is the Lagrange multiplier of the objective function, the marginal utility of income.

Defining the change in welfare as

$\frac{dU}{\lambda} = dW$ leads to

$$dW = \frac{dU}{\lambda} = \Sigma\, p_i dy_i$$

Thus the change in welfare can be assessed by the sum of the changes in the amounts of the bundle of goods and services weighted by their prices. This formula can be used for assessing the change in welfare on the individual level.[51]

Instead of looking at a bundle of goods at one point in time, the above method can be interpreted intertemporally as one good/service demanded over time, with the prices p_i being the discount rate (Dinwiddy and Teal 1996: 89):

Thus the change in individual welfare over time due to a change in y_i can be measured as:

$$dW = \frac{dU}{\lambda} = \Sigma \frac{dy_i}{(1+r)^i}$$

with $p_i = \frac{1}{(1+r)^i}$ and r the discount factor.

For analyzing **social welfare**, an aggregate function of the individual welfare functions has to be employed, this function is called a *Bergson-Samuelson* social welfare function:

$$W = f(W_1,.., W_n) = f[W_1(y_1,..., y_n),..., W_h(y_1,..., y_n)]$$

where W_i is the welfare function of individual i.

The crucial question is how such a social welfare function can be derived. Arrow (1963) has shown in the *Impossibility theorem* that no such welfare function exists

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[51] If only one market is analyzed, demand functions are usually established with which the change in utility due to the change in income or change in prices can be studied. The demand curves represent the marginal willingness to pay (MWTP) for a given good or service. The difference between the MWTP and the price given by the supply curve, is the marginal consumer surplus with the integral being the consumer surplus. Two kinds of demand functions exists: The Marshallian demand functions define demand as a function of income and relative prices. However, when using these demand functions substitution and income effects are mixed up. More exact measurement can be done by using the Hicksian compensated demand functions that are a function of constant utility and relative prices. Based on these functions the measures used for assessing changes in utility are compensating and equivalent variation (Dinwiddy and Teal 1996: 21ff.)

that allows the social ranking of alternative social states from individual preferences given intuitively plausible criteria of reasonableness for social choice are satisfied. The question centers around how the weights W_i can be established and by whom. Thus, the *Arrow Impossibility theorem* severs the link from an assessment of individual choice to that of social choice and welfare change (Dasgupta and Pearce 1978: 80) supposed to be provided by the theory of welfare economics.

This is a serious restriction to welfare economics and CBA, as a main proposition contends that individual preferences should count in an assessment of social choice. The way out of this impasse usually taken is to introduce normative judgment by means of postulating an individual observer or commentator that seeks to maximize welfare from his point of view and establishes welfare weights according to his preferences. This can be the government, a project evaluator or a representative agent. The representative agent approach is standard procedure used for economic analysis, e.g. Lucas (1987) used it for the assessment of the welfare costs of business cycles. Also relevant for this work, it has been done on macro level e.g. by Anand and Nalebuff (1987) for the analysis of energy projects in oil-exporting developing countries. This approach will be used here as well.

Thus the change in social welfare is approximated by the change in welfare for the representative observer:

$$dW = f(dW_1, .., dW_n) = dW_k = \frac{dU_k}{\lambda_h} = \Sigma \frac{dy_i}{(1+r)^i}$$

This method accounts for efficiency only. Including equity/distributional considerations as well has been one of the most controversial questions in project appraisal and cost-benefit analysis (Ray 1987: 22).

As discussed, one of the main governments functions is the redistribution of income. If redistribution can be done relatively effortlessly e.g. by means of an effective taxation system, the focus in the public appraisal of investment projects would only have to be on efficiency meaning a maximization of project outcomes. On the other hand when this cannot be achieved without reservation, the distribution of project outcomes may play a role. Usually, developing countries exhibit a high degree of income inequality and tax systems are weak. Normatively, one of the major functions of government is the redistribution of income. In this case, project appraisal can account for this by correcting efficiency benefits for the additional private consumption that takes place. In practice however, hardly any project appraisal uses a distributional weighting approach accounting explicitly for consumption. Evidence on project appraisal at the World Bank shows that distributional weights have only been employed in a few experimental cases.[52] Also, the existing data for distributional weighting are rather weak. For this reason, no explicit distributional weighting will be

[52] Reasons for these are seen in:

Subjectivity: Weighting income to different members of society involves a value judgment, though assuming equal weights is a value judgment (implicitly) in itself.

Practicality: Outlining those that benefit from a project was often regarded as "overwhelming."

Efficiency: Project selection was not regarded the most efficient means of guaranteeing a fair distribution of income. Assuring that overall spending of public expenditure for different purposes was relatively fair rather than assessing individual projects' impacts in terms of fairness was seen as more important (Devarajan, Squire and Suthiwart-Narueput 1995: 6-8).

conducted here. However, the effects on private consumption are considered in the modelling. Post-disaster it is assumed that the government stabilizes household consumption by relief transfer payments and private consumption is kept constant.

8.3.2 Project Evaluation Decision criteria

Costs and benefits have to be compared under a common criterion in order to be able to derive at a decision. Basically, three decision methods are of major importance in CBA : The net present value (NPV) Criterion, the C-B Ratio Criterion, which in effect is a variant of the NPV, and the Internal Rate of return (IRR) Criterion.

Net present value (NPV) Criterion

The NPV is the most widely used criterion (Zerbe and Dively 1994: 177). The NPV is the sum of net benefits (benefits less costs), the social outcomes (S_t) in present values terms, i.e. discounted with discount rate r.

$$NPV = \frac{\Sigma S_t}{(1+r)^t} = \frac{\Sigma B_t - K_t}{(1+r)^t} > 0$$

where B_t and K_t are benefits respectively costs at time t.

If the NPV is larger than 0, the project should be accepted. This criterion is dependent on the choice of the discount rate r that discounts the future income streams. A high value of r discounts future incomes strongly and indicates high social preference for the present, on the other hand if r is zero, future and present incomes are given the same weights.

C-B Ratio Criterion

A variant of the NPV is the C-B ratio Criterion. If the discounted benefits are larger than initial costs, a project should be undertaken. This criterion is also dependent on the choice of the discount rate r. If r is zero, future economic flows will not be discounted and thus equal weight is given to the present and future. On the other hand, if r is positive, the present is valued higher than the future.

$$\frac{(NPV + K)}{K} > 1$$

where $NPV = -K + \frac{\Sigma S_t}{(1+r)^t}$

where K are initial costs.

Internal Rate of return (IRR) Criterion

A major problem with the above criteria is the choice of an appropriate discount rate. The internal rate of return criterion avoids using a given discount rate. In fact, it calculates a discount rate itself. The IRR is that rate that discounts the NPV to zero.

$IRR > R^*$

with IRR so that

$$NPV = \frac{\Sigma S_t}{(1 + RR)^t} = 0$$

If the IRR is larger than the opportunity cost of capital or a (shadow) interest rate R*, the project will be accepted. Often a fixed value is chosen, e.g. the Asian Development Bank (ADB) uses a rate of 12% for R* that has to be surpassed (Hecker 1995: 83).

Comparison of methods
In most circumstances, the three methods are equivalent. Overall however, the NPV method is the preferred criterion (Zerbe and Dively 1994: 177; Dasgupta and Pearce 1978: 165; Brent 1998: 3) though as presented above, there is some uncertainty regarding the choice of an appropriate discount rate as will be discussed below. The preferred role of the NPV is due to some difficulties using the IRR and C-B-R methods.

The main shortcomings with the IRR is that it sometimes cannot be defined unambiguously. Several IRRs may be possible if the IRR is the solution to a polynomial equation. If the polynomial is of degree n there will be n roots to it and n IRRs to choose from. Then, it is not clear which IRR to select (Dasgupta and Pearce 1978: 165).

A major problem with the IRR and the C-B-R is that they should not be used for mutually exclusive projects, i.e. for projects that cannot be adopted in combination with others as e.g. the decision whether to build a two or three-lane highway. The IRR would discriminate against large scale projects with high initial capital outlays. Also, projects with high IRR that only last shortly would be preferred to projects whose returns are smaller but longer lasting (Gramlich 1981: 93).

In total, the NPV is preferred and for this reason will also be used here to assess costs and benefits by a common criterion.

8.3.3 Discounting

In order to calculate the NPV, costs and benefit streams occurring in future periods usually need to be discounted. This entails correcting future benefits and costs by the discount factor $(1+r)^t$, whereby r signifies the social discount rate and t is the time index. The discount rate is an expression of the preference for the present, i.e. it describes the degree to which the present is preferred to the future. Discounting is often criticized as shifting present responsibilities to future generations (Faber et al. 1989: 46).

Concerning the determination and the degree of the social discount rate there is no consensus in the literature. Faber et al. (1989: 43-46) discuss three basic lines of analysis:

- The social discount rate is determined by the market interest rate.
- The social discount rate is determined by (political) decisionmakers/ project evaluators/government

- Discounting future costs and benefits is rejected; this is equivalent to a discount rate of 0%. This is a value judgment and thus does not need to be discussed further.

The relationship between **social discount rate and market interest rate** results from the fact that public investment crowds out private consumption and private investment, which causes opportunity costs in the form of foregone consumption and returns due to the investment. The social discount rate is determined in such a way that the net present value for the planned project (for which the social discount rate is determined) has to exceed the opportunity costs.

In an economy without market failure the market interest rate is determined unequivocally, in equilibrium all individual household's time preference rates are equal and determine the social time preference rate. By means of the market interest rate there is a balance between the social time preference rate and the marginal rate of return in the private sector. In reality, there is market failure, social time preference rate and marginal rate of return diverge and are not defined unambiguously. The inefficient market mechanism is not in the position to bring the individual households' time preference rates into accordance and the marginal rates of return in the private sector are differing. The result is that there is no uniform market interest rate and theoretically different social discount rates could be chosen. In the literature a range of 0-20% can be found (Faber *et al.* 1989: 46*).* The opportunity cost of capital in most developing countries is between 8-15% in real terms (OAS 1991: 11).

The **determination of discount rate by decisionmakers** has its basis in the conviction that the social discount rate determined by the market interest rate is too high and thus needs to be determined independently. There are basically two reasons for that: First, it is assumed that due to lack of awareness individuals will often choose high time preference rates and thus harm themselves by way of this myopic behavior. Second, there is need for protection of future generations which will not be guaranteed sufficiently by the acts of today's generations. Also, time-preference rates are culture-dependent (Faber et al. 1989: 44-46).

Due to practical considerations, this report will choose a discount rate of 12% for the calculation of the NPV which is e.g. standardly used by Asian Development Bank (ADB 2001: 32). However, sensitivity analysis will be done to assess the influence of varying this parameter for different countries with different conditions.

8.4 Macroeconomic approach

Usually CBA is based on the microeconomic level. However it can also be adapted to the macroeconomic level. Then, costs are measured in relation to aggregate national income instead of income in individual markets. A macroeconomic approach to CBA is e.g. proposed by Brent (1998: 243 ff.) for the analysis of structural adjustment lending (SAL), i.e. loans given to a borrowing country for any project it wishes to undertake contingent on the fulfillment of certain conditions. Furthermore, Canning and Bennathan (2000) measured the rate of return on infrastructure on a macroeconomic level, noting that conventional micro CBA does not capture the complementarity effect of infrastructure well.

Specifically, the following reasons for using a macroeconomic approach in this thesis can be put forward:

1.Public infrastructure is investigated which as a public good is input to production activities in all sectors and is considered a complement to private capital stock. Thus, the returns on infrastructure cannot easily be measured in a single market; partial market analysis will not capture all the relevant effects. Effects of disasters on infrastructure can thus be examined best in an aggregate model.

2.Macroeconomic, "ripple" effects due to loss of infrastructure and exceeding governments financial capacity to recover immediately are of major interest and may constitute the "real" costs of disasters, rather than the direct stock loss. These costs are usually not calculated and taken into account, however are important as chapters 3 and 7 demonstrated.

3.The government is considered the decision-maker for the risk to its own infrastructure. The government is assumed to purchase insurance against natural disaster risk to its infrastructure and divert the premium from its investment budget. On a macroeconomic level this causes opportunity costs as less investment can be undertaken. The specific project analyzed in this context is insurance of public infrastructure, which can be interpreted as a secondary project. The benefits of this project consist of preserving the primary projects' benefits which are represented by national income (GDP).

GDP is used as the main welfare indicator complemented by other variables of interest. As discussed. there is a large literature on the shortcomings of using GDP as an indicator for social welfare (see e.g. van Dieren 1995). Major criticism is that non-marketed values like informal and environmental goods and services are not accounted for and income distribution is not considered. Alternative indicators like e.g. the Index of Sustainable Economic Welfare (ISEW) or the Human Development Index (HDI) have been developed to correct these deficiencies. Using these indices, an increase in GDP may not automatically imply an increase in these alternative indicators. However, for this aggregate and macroeconomic analysis, market values are of major importance as the changes in welfare due to insurance and non-insurance are assessed. Also, statistics on GDP are usually readily available and it remains the major welfare indicator used. For these reasons, it will be used here. Future work could aim at using a modified aggregate welfare indicator.

Thus for this macroeconomic CBA, the NPV as calculated by

$$NPV = \frac{\Sigma S_t}{(1+r)^t} = \frac{\Sigma B_t - K_t}{(1+r)^t} > 0$$

can be replaced by the change in the sum of the discounted change in GDP over the assessed time period:

$$dW = \sum \frac{\Delta y_i}{(1+r)^i}$$

Thus the change in GDP represents net benefits. The development of GDP will be compared to baseline GDP. A decrease in GDP constitutes costs, an increase benefits (Brent 1998: 247).

9 CBA IN THE CONTEXT OF RISK

> Building a culture of prevention is not easy. While the costs of prevention have to be paid in the present, its benefits lie in a distant future. Moreover, the benefits are not tangible; they are the disasters that did NOT happen (Annan in UNISDR 2002: 1).

In the context of risk, additional elements need to be introduced into CBA. Usually in evaluating projects risk is dealt with by means of a sensitivity approach. In the rare events, risk is included explicitly, the decision method only calculates the expected value. The risk premium - also called cost of risk - is usually left out. However, this is tenable only if risk-neutrality prevails. This work will argue in favor of using a risk averse attitude and accounting for the spread of disaster risk by including the volatility measure of variance due to the limited ability of developing countries governments to spread and pool risk.

Section 9.1 discusses the distinction between risk and uncertainty and implications, 9.2 summarizes the literature on CBA in the context of risk with relation to natural disaster risk and macroeconomic analysis, 9.3 outlines how to include risk analysis into CBA, 9.4 derives a formula to account for risk and 9.5 concludes.[53]

9.1 Incorporation of Natural Disaster Risk into CBA

Cost-efficiency evaluations by means of CBA are undertaken in the context of uncertainty, which when it can be measured probabilistically is called risk, or "measurable uncertainty" according to Knight (cf. Brent 1998: 206).

A number of methods for CBA in the context of risk have been suggested which are well described in Kramer (1995: 61-76). There are basically two ways to include risk in project analysis: the limited-information approach and the probability-based-approach. When no specific or only partial information on natural hazards and their impacts is available, limited-information approaches are used. Among these, sensitivity analysis is often used where important variables are varied in an ad-hoc fashion to study the sensitivity of outcomes to these variations. Although natural disasters are rare events and thus information on such events often does not exist in abundance, data and software tools are increasingly becoming available with which a fuller probabilistic analysis can be conducted providing considerably more insight than the limited-information approaches.

If sufficient information on the distribution of outcomes can be obtained, a probabilistic approach is to be preferred. This work will follow a probabilistic approach as sufficient data for the case studies in part III were available. A probabilistic approach entails obtaining probability distributions on disaster events and linking them to the major economic variables that will be impacted. With that

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[53] Parts of sections 9.1 and 9.2 are taken from Mechler, R. (2002). Natural Disaster Risk and Cost-Benefit Analysis. Conference "The Future of Disaster Risk: Building Safer Cities," Washington DC, World Bank.

information, a probability distribution of the project outcomes (net benefits) can be generated (figure 41).

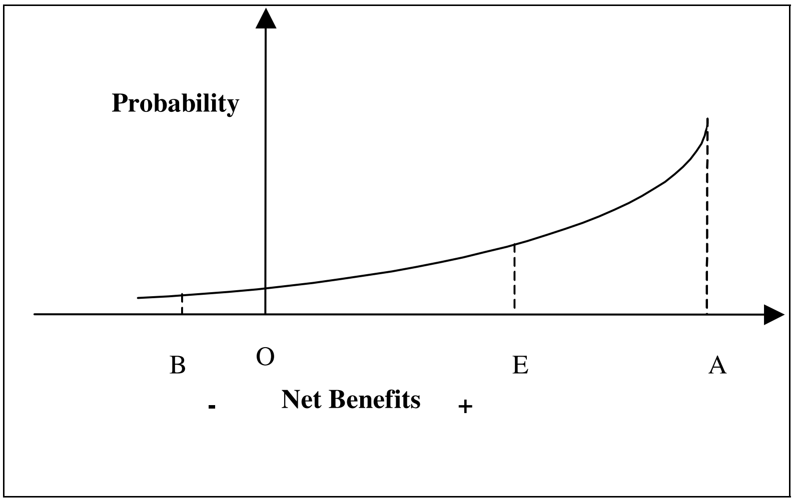

Fig. 41: Project analysis under risk

Assume *A* are the projected net benefits (i.e. benefits less costs) from a project before natural disaster risk has been included in the assessment. *A* is positive, so this project seems a worthwhile undertaking. If a probabilistic project analysis is conducted and a probability distribution is estimated, the average outcome, the expected value *E* can be determined. In the case of natural disaster risk - a purely downside risk[54] - the expected value will be lower than the originally projected deterministic value *A* without accounting for risk. However, the average outcome E represents only that value that over a certain time horizon will materialize *on average*. Actual outcomes may lie along the whole range of *A* and *B* (here *B* is assumed to be the worst outcome); net benefits could be negative if a disaster destroys a significant part of the project and only few benefits materialize while project costs have accumulated already.

For a project evaluator it may be important to examine the probability of net benefits becoming negative, i.e. how marginal a project is. Consequently, if marginality is likely, a decision to abandon the project or site it elsewhere where hazard exposure is lower, or include risk management components into the project may be necessary. These risk management measures, or "secondary projects," protect a primary project's outcomes (Brent 1998: 220). Benefits of these projects are the savings in terms of damage avoided and the decrease in volatility in outcomes. Secondary projects may be mitigation projects that reduce risk or risk transfer projects that cede risk to other parties willing to accept this risk. If the secondary project's costs are lower than the benefits in terms of costs avoided of the main project, it should be undertaken. Thus, secondary projects are also subject to project appraisal procedures. This also applies to secondary projects for existing infrastructure where risk was not taken into account. Cost-effective projects should consequently be implemented.

[54] As contrasted with *speculative risk* involving chances to gain and loose at the same time.

9.2 Status of application of CBA in the context of natural disaster risk

Natural disaster risk is only one risk among several risks (e.g. exchange rate or commodity price fluctuations) that must potentially be taken into account. When a risk is judged to be negligible, it may not have to be considered formally. In contrast, when a risk is found to be large, it needs to be accounted for properly to allow an efficient allocation of resources to these projects.

Natural disaster risk often is not considered sufficiently in CBA. When examining the relevant literature on CBA in the context of natural disaster risk, four issues emerge:

- Natural disaster risk is commonly not accounted for in CBA for investments/ primary projects.
- Risk management (secondary) projects are rarely assessed in a CBA framework. When this is done, the focus is on mitigation only.
- Opportunity costs not measured.
- Risk is usually not included explicitly, but by averages.

These issues are further analyzed in the following section.

9.2.1 Natural disaster risk is not included in evaluation of investment projects

For a number of countries, natural disaster risk is a serious risk. However this source of risk usually is not accounted for sufficiently in developmental planning and project appraisals of investment projects by governments and multilateral finance institutions (MFIs) (Kramer 1995: 62; OAS 1991: 8). Vermeiren et al. remark in an assessment of the costs and benefits of mitigation in the Caribbean:

> Contributing to the precarious state of the infrastructure is the Region's vulnerability to natural disasters - hurricanes in particular - and the tendency of development decision makers, in the public as well as private sectors, to make decisions concerning major investment projects without due consideration of natural disaster risk (Vermeiren et al. 1998: 1).

As a consequence the uncertainty in project benefits is thus not duly accounted for which results in an inefficient allocation of resources. There is the possibility that risky projects may be selected and projected benefits and the investment are lost when a disaster occurs. Furthermore, investment funds often have to be borrowed externally in developing countries if internal resources are insufficient. In the case of a disaster this investment is lost without increasing the capacity to service the recently accumulated debt in the future. Also, funds for continuing these projects or rebuilding lost assets often have to be diverted from other projects causing large developmental impacts. Finally, if funds for reconstruction and relief are insufficiently available, serious negative long-term impacts on socioeconomic development may result (cf. Freeman et al. 2002a).

Demand for including natural disaster risk in project appraisal methodologies has increasingly been voiced (Kramer 1995: 62; OAS 1991: 53). Considering natural disaster risk in project appraisal allows for a more careful selection and design of projects as well as the identification and development of secondary risk management measures to protect the benefits of primary projects. More careful project and development planning is called for when considering loss-increasing trends such as increased urbanization and high population growth in developing countries, that concentrate crucial assets that may be at risk, and a possible increase in the frequency and severity of natural disasters due to climate change.

9.2.2 CBA of risk management projects rarely done

In a similar vein, the necessity of estimating the efficiency of risk management by means of CBA has only been acknowledged in the past few years and CBA is still not widely practiced for natural disaster risk management projects (Dedeurwaerdere 1998: 1ff.). When evaluating risk management measures by means of CBA, in general only mitigation is focused on (Kramer 1995; Dedeurwaerdere 1998). Also, indirect costs and benefits are rarely included in a CBA (Tobin and Montz 1997: 269) while macroeconomic impacts are usually completely neglected. As Gilbert and Kreimer (1999: 37) demand: "There is greater need for an explicit and transparent estimate of all the costs and benefits of natural disaster management."

Several assessments have demonstrated that risk management measures can bring about large benefits. Dedeurwaerdere (1998) estimated the benefits of different prevention measures against floods and lahars[55] in the Philippines and calculated benefits of 3.5 to 30 times the projects' costs. Vermeiren et al. (1998) determined potential avoided losses of 2 to 4 times mitigation costs if mitigation had been undertaken when building infrastructures like ports and schools in Jamaica and Dominica. Both of these projects only included benefits in terms of avoided direct losses in the appraisal; including indirect benefits would have increased the efficiency of these preventive investments. On a larger scale, it is estimated that the $3.15 billion spent on flood control measures in China over the last four decades of the 20th century have averted losses of about $12 billion. As well, the World Bank and the U.S. Geological Survey estimated that economic losses worldwide from natural disasters in the 1990s could have been reduced by $280 billion if $40 billion had been invested in preventive measures (Benson 1998a: 12).

9.2.3 Opportunity costs and benefits not properly accounted for in stochastic manner

Most often, the available studies on the costs and benefits which generally calculate very high benefits, take a non-stochastic approach and balance the costs of risk management (reinforcing structures, building new ones) with the potential or actual costs avoided in case of an event. However, such an approach implies selectively picking those cases where losses have occurred. This entails often that the potentially high opportunity costs due to risk management are not taken into account. While this may not be of large importance for risk mitigation activities where often small one-time investments can bring about large reductions of risks, for risk transfer the situation may be different. Here, on a continuous basis, funds have to be diverted from other important objectives causing substantial opportunity costs while providing due to hedging against extreme and unfavorable outcomes.

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[55] Lahars are volcanic mudflows.

9.2.4 Risk not included appropriately: Necessity of accounting for volatility of natural disaster impacts

In cases where probabilistic CBA assessments are conducted, risk is often not included appropriately since average values are used (cf. Kramer 1995: 61; Szekeres 2000; Dedeurwaerdere 1998). The information about costs and benefits contained in the probability distribution is compounded to the expected value measure. Other information from the probability distribution (as illustrated in figure 41) is thus not utilized.

Adopting a risk averse perspective and including the volatility of disaster risk in decision making has important implications for the evaluation of primary and risk management projects. In the assessment of primary projects, risk is more appropriately captured and a more careful project selection can be conducted when the extreme event character of natural disasters is properly accounted for. For secondary risk management measures there is increased benefit in conducting those measures, as benefits in terms of impacts avoided are higher.

Dasgupta and Pearce (1978: 174 ff. and 235 ff) discuss the general issues of the Expected Utility theory and the Mean Variance approach, but state that usually risk neutrality prevails and variance need not be accounted for. They apply the standard expected value methodology to the analysis of flood control measures in India.

Kobayashi and Yokomatsu (2001) and Yokomatsu and Kobayashi (2001) discuss the need to extend the focus of traditional cost-benefit analysis on expected losses if there are large losses and/or losses are occuring on a collective basis, issues that were discussed in chapter 5. In an expected utility framework, they show that benefits of mitigating catastrophe risk measured by compensating and equivalent variation exceed expected losses.

The most applicable and useful cost-benefit assessment under risk for this thesis is Kramer (1995: 70-73; OAS 1991; Kramer and Grieco 1989) who discusses the general issues and approaches. This is the only study found in the literature that included the volatility of outcomes in the decision formula. A mean-variance model was employed to estimate the impact of disaster mitigation on banana production in the Caribbean island St. Lucia. The costs and benefits of strengthening the roots of banana trees by using nematicides to protect the roots from parasites and thus making them more resistant against low to moderate windstorms was studied. The method used involved estimating the rate of return of a main agricultural development project that consisted in rehabilitating banana production and providing employment on a government owned estate. Including mitigation lowered the rate of return as measured by average yields, however, mitigation reduced also the risk as measured by the coefficient of variation.[56] Mean and variability were not compounded to a single scalar.

Risk transfer of natural disaster risk so far has not been evaluated by means of CBA to the knowledge of the author. Pollner (2000) and Pollner at el. (2001) compare the

[56] The coefficient of variation is defined as the standard deviation divided by the mean.

costs of different insurance strategies for the Caribbean and Honduras, but keep benefits separate from costs. IIASA has developed another model that compares the costs of different risk financing instruments with the benefits defined by several indicators like the probability of a financing gap occurring (e.g. Mechler and Pflug 2002). Also, as costs and benefits refer to different indicators, no aggregation to one single scalar is undertaken.

A study from the literature dealing with other sources of risk which provided useful insight about how to deal with risk in CBA was Anand and Nalebuff (1987). They use a mean-variance approach with a risk aversion factor of 2 (rather risk averse) to measure the benefits of energy projects in oil-importing countries. In a stylized analysis they state that risk plays a decisive role, and that the analysis should be extended from merely assessing expected values. As well they find that it is the covariance between project output and aggregate national output that is of importance rather than the variance of individual projects (Anand and Nalebuff 1987: 198).

This study will also use the mean-variance approach to include variances and potential risk aversion in decision finding.

9.3 Accounting for risk

There are basically two ways to include risk into project analysis: Limited-information and probability based- approaches. In the following a probability-based approach will be used. However, in 9.3.1 the most important limited-information techniques will be shortly discussed in order to provide a more complete overview over the different approaches to deal with risk.

9.3.1 Limited-Information approaches

When there is a lack of information, limited-information approaches can be employed. Lack of information is often the case for natural disaster risk due to the low-probability, high-consequence characteristic of disasters. The database on these events is often small and extrapolation from the few data points to evaluate the general risk situation hard to do. The major limited-information approaches are *Cutoff period-method, discount rate adjustment, game-theoretic methods* and *sensitivity analysis* (Kramer 1995: 63ff.) .

Cutoff period-method

In this ad-hoc method costs and benefit calculation is terminated after a relatively short time frame that is shorter than project life. The rationale behind this is that a project should "earn" sufficient benefits (pass the NPV or RoR test) relatively quickly before an uncertain event affects it. This method is unsatisfactory as it deals with uncertain events in a crude and ad-hoc fashion. It should only be applied if very little information about uncertain events is available (Kramer 1995: 63).

Discount rate adjustment

Risk can in theory be included by adding a risk premium to the discount rate for the calculation of the NPV that contains information about uncertain, but potentially disastrous events.

$$NPV = \sum_{i=0}^{n} \frac{St}{(1 + d + r)^{i}}$$

where r is the risk premium.

However, it is argued against using this approach as it implies that risk increases over time as the discount rate increases over time. Thus, long-lasting projects will be unfairly discriminated against. Also, it scales down the NPV rather than allowing for the dispersion of the estimates. As well, the different concepts of time discounting and allowing for risk are mixed up (Brent 1998: 207-8).

Game-theoretic methods

Another method for uncertainty is to use a number of well-established game-theoretic decision methods (Dasgupta and Pearce 1985: 187ff.):

The *Maximin or Wald criterion* focuses on the worst outcomes, the maximum loss or minimum gain. For gains, for each strategy the minimum pay-offs are determined, then the strategy with the highest minimum pay-off is selected. The *Minimax-regret or Savage criterion* selects the action with the smallest maximum regret. Regret is defined as the difference between the actual pay-off and the potential pay-off, which is the amount that could have been obtained if the state of nature could have been correctly forecast. For each strategy, the maximum possible regret is picked. Then, that strategy that has the lowest maximum regret is selected. Whereas the *Savage and Wald criteria* constitute safety-oriented concepts, the *Index of Pessimism or Hurwicz criterion* bases decisions on the worst and best outcomes which are weighted by the decision-maker and consequently the weighted average is calculated. The strategy with the highest weighted average is then chosen. The *Laplace and Bayes criterion* selects the strategy with the highest expected pay-off based on the assumption of equal probability for all pay-offs.

Sensitivity analysis

This is the most widely practiced method to account for uncertainty. Key variables supposed to be important are varied to the extent deemed reasonable in order to examine the impact of changes on model outcomes. The main benefit of this ad-hoc approach is the ease with which it can be used. However, it may often not be clear which variables to vary and by how much (Brent 1998: 209-210). Also, when varying several variables simultaneously, it is unclear what probability to attach to the combined scenarios. Implicitly, it is often assumed that all scenarios possess equal probability.

9.3.2 Probability based - approaches to project analysis

In a probabilistic analysis, probabilities are assigned to outcomes, and the dispersion of values is represented by a probability distribution. A possible summary variable of the probability distribution often chosen is to calculate expected values. This means, however, losing a considerable amount of information. As indicated above, natural disasters are low-frequency, high-consequence events. For such disaster events, probability distributions are characterized by "fat tails" which means that an important part of the probability density falls into the low-probability area. Expected value calculations only provide partial account of this peculiar shape of the distribution. It is also necessary to account for the volatility of potential outcomes. An approach that is useful if such information is of interest is the mean-variance (EV) method. As the term suggests, the mean-variance method takes account of the mean and variance of a probability distribution. The theoretical underpinnings for this approach are based on the expected-utility (EU) framework which is the standard framework for decision-making in risky situations. The next sections discuss the EU-framework and then derive the EV method.

9.3.2.1 Expected utility (EU) model

The expected utility model is the standard framework for dealing with risk in general and in CBA (Kopp 1997: 31; Jaeger et al. 2001: 154; Doherty 2000: 58; Zerbe and Dively 1994: 315). The theory of decision-making under uncertainty proposes that expected utility is maximized rather than expected value. The main element of this approach is that income gains and losses are weighted differently. This is due to explicitly including the preference to risk.

The expected utility model arose from the difficulty of modern probability theory proposed by Pascal and de Fermat to explain individual behavior in a gamble offering payoffs with certain probabilities. The standard conviction at this time was that expected value was to be regarded as the yardstick for making decisions in such a stochastic context. However, Nicholas Bernoulli in an example known as the St. Petersburg paradox showed that this may not hold for all cases and that expected value was not always maximized. The solution to this paradox was proposed independently by G. Cramer and N. Bernoulli's cousin Daniel Bernoulli who postulated that

- individuals act according to expected utility not expected value. Individuals behavior can be explained by expected utility functions decisive for their actions. And,
- utility does not increase linearly, but rather at a diminishing rate, which means that there is diminishing utility of wealth (Brent 1996: 161). The latter implies that losses will be valued higher than gains. Loosing has a higher cost to it than gaining an equal amount creates in benefits. This is a description of risk aversion.

The insight on the maximization of expected utility was formalized by von Neumann and Morgenstern (1944) who postulated five axioms.[57] Given the fulfillment of these axioms the EU model can be employed and cardinal utility functions used.

In the context of risk, the welfare function of the representative decision-maker has to be redefined. The choices now depend on the income as well as the probability p_i associated with that particular income level.

$W = W(Y_1, Y_2, \ldots, Y_n; p_1, p_2, \ldots p_n)$

[57] On the basis of the following five axioms the EU method can be established (Wik 1996 5ff.; Robison et al. 1984: 13):

1. Completeness and transitivity.
2. Continuity/equivalent standard prospects.
3. Preference increasing with probability.
4. Rational equivalence.
5. Independence of irrelevant alternatives.

Specifically, the von-Neumann-Morgenstern expected utility function is used, that has the following form (Dinwiddy and Teal 1996: 221).

$$W = E(U)=p_1*U(Y_1)+p_2*U(Y_2)+..+p_n*U(Y_n)$$

These functions are cardinal utility functions and differ from the ordinal utility functions of standard consumer theory in that cardinal utilities are assigned to a preference ordering. Ordinal functions only allow the ordering of preferences. For von Neumann-Morgenstern utility functions only positive linear transformations will leave preference rankings unchanged whereas for ordinal utility functions any monotonic transformation is permissible (Machina 1992: 50-51). The reason for this additional restriction lies in the dichotomy between actions and consequences. Individuals decide upon actions whereas utility attaches directly to consequences. In a deterministic environment deciding upon an action is at the same time equivalent to choosing a single definite consequence. By ranking consequences in terms of preferences one determines the preference ordering of actions. On the other hand, with risky choices ranking of consequences does not automatically lead to an ordering of actions, since each action will imply a probabilistic mix of possible consequences. Thus, the expected utility method is only applicable when the utility function is a cardinal one. When the U function is cardinal, the expected utility method becomes equivalent to the standard formula for compounding probabilities (Hirshleifer 1989: 13-19).[58]

Intuitively, the requirement of a cardinal U function can be explained as follows: For the deterministic situation it is sufficient to rank consequences in terms of preferences. Additional information is not necessary for decision-making. The action resulting in the preferred consequence will be chosen. In a risky choice context, a ranking of consequences does not automatically lead to a ranking of actions. The additional cardinality requirement is necessary to be able to rank and choose among risky prospects (Wik 1996: 7). The EU hypothesis shows how to integrate utility (preference) and probability in order to be able to rank risky prospects and allowing rational risky choice (Hardaker et al. 1997: 87).

By using an expected utility function, the concept of risk preference is made explicit and risk preference is exhibited. The functional form and shape of the utility function implies the degree of risk aversion and the risk premium. Fig. 42 shows risk-averse, risk-neutral and risk-loving utility functions. The concave function is the risk-averse case, the convex the risk-loving, whereas the linear represents risk-neutrality. Using the expected value in an expected utility framework means in effect assuming risk neutrality.

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[58] More detail is beyond the scope of this work. But e.g. Hirshleifer and Riley (1992) provides a good introduction into the essentials of expected utility.

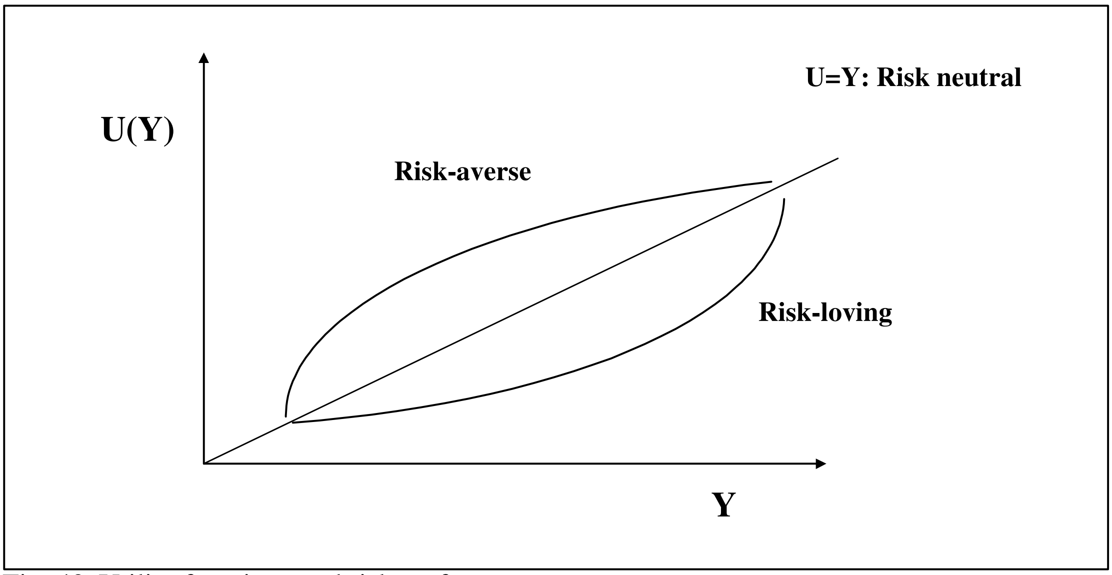

Fig. 42: Utility functions and risk preference

9.3.2.2 Challenges to EU-model and alternative models

There have been empirical challenges to the EU-theory with the realization that individuals or decision-makers do not consistently follow the expected utility method (Machina 1992: 55ff; Wik 1996: 16ff). Main violations where EU is said to fail as a descriptive model discussed in the literature are *framing effect*, *preference reversal phenomenon*, *Allais paradox*, *common ratio effect* and *Ellsberg paradox*. A discussion of these violations is beyond the scope of this thesis, but when summarizing these violations, three characteristics of real life decision-making under risk can be distinguished (Shoemaker as quoted in Wik 1996: 41):

- People do not structure choices or problems in a holistic and comprehensive way.
- Information and probabilities are not processed according to EU theory.
- EU theory is not able to adequately predict choice in laboratory situations.

A prominent example of these empirical challenges is the framing effect established by *Prospect Theory* which holds that different ways of representing the same choice problem will affect the actual choice (Slovic and Lichtenstein 1968; Hershey and Shoemaker 1979; Tversky and Kahnemann 1974). EU theory is insensitive to this phenomenon. Thus EU theory cannot account for a possible switch from risk aversion to risk taking triggered by a different description of the choice problem. Accordingly, the individual context is decisive (status in space and time, the framing of the problem). This makes it difficult to compare different issues and different costs and benefits under the same criterion.[59]

These empirical challenges to the descriptive and predictive power of the Expected Utility (EU)-theory have to be acknowledged. However, EU theory has to be understood as a prescriptive rather than descriptive theory (Jaeger 2000: 142; Doherty 2000: 40). It is useful to explain potential behavior rather than actual. This is the way it will be used in this thesis to analyze the way decisions to undertake risk management measures, particularly insurance, can or should be evaluated. Using an EU approach has to be understood as suggesting e.g. for a representative decision-maker a method to analyze decisions under risk. It is not the emphasis to explain actual behavior though.

In reaction to the violations of the EU method, alternative approaches have been developed.

To solve some violations of EU theory observed in decision-making behavior, **generalized expected utility models** were developed that extend the expected-utility approach.[60] These models increase the complexity of analysis considerably. What is more important, none of these models manages to solve all the violations of the EU theory (Wik 1996: 41). For these reasons they will not be discussed in the following.

Prospect theory was developed by Kahnemann and Tversky (1979) to remedy failures of the EU theory. Like EU theory, outcomes consist of a representation of preferences which are multiplied by decision weights, that are based on probabilities. Small probabilities are overweighted, moderate and higher probabilities are underweighted. Another departure from EU theory is that the value function is defined in terms of gains and losses and is S-shaped: For losses it is convex, for gains it is concave. Kahnemann and Tversky recognize the difficulties of establishing such a function consisting of values and decision weights and contend furthermore that such a S-shaped function may not well describe preferences of some agents (Wik 1996: 33-34). As will be explained in the following, similar estimation problems apply to expected utility functions. Therefore, in this study it is resorted to using an approximative method that avoids specifying a full-fledged utility or value function.

Another class of methods, the **safety-first methods**, starts from the premise that due to limitations concerning the ability to resolve uncertainty completely, decision-makers act in a satisficing rather than in an optimizing manner (Simon 1957).

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[59] Hersey and Shoemaker 1979 describe an example for the framing effect. They gave subjects two formulations with two choices respectively (cf. Wik 1996: 17).

- The gamble formulation with the choice between a sure loss of 10 $ and a one percent chance of losing 1,000$.
- The insurance formulation with the choice between paying an insurance premium of 10$ and remaining uninsured with a loss of 1,000$ at one percent probability.

Though according to E(U) theory the two formulations are identical, 56% of the subjects chose the sure loss in the gamble formulation, whereas 81% decided to pay the insurance premium in the insurance formulation.

[60] For a survey of alternative models see e.g. Wik 1996.

Several kinds of safety-first methods have been outlined in the literature.[61] When using those, first a preference for safety, a safety limit that should not be surpassed, is determined by the decision-maker, before another goal is optimized. This sequential ordering approach is an empirical ad-hoc concept without a theoretical underpinning (Robison et al. 1984: 19).

While these methods can be applied to relatively frequent, minor events, they are less applicable to low probability, high consequence events like natural disasters. These extreme events with very low return periods will evade the constraint formulation of safety-first-principles (OAS 1991: 19). In order to make the constraint applicable, the threshold value will have to be set at very low values affecting the optimization calculus to a minor degree and rendering this formulation redundant.

In total, it can be said that the EU theory remains the canonical model used for decision-making under risk (Dionne and Harrington 1992: 4; Machina 1992: 49). This is due to its simplicity and generality. When understanding the EU approach as a prescriptive rather than descriptive model it retains its usefulness. Keeney and Raiffa (1993) note:

> There are man other ad-hoc schemes that can be found in the literature, but to our mind, no proposal other than maximization of expected utility withstands the scrutiny of careful examination (Keeney and Raiffa 1993: 136).

9.3.2.3 Approximations of EU framework

The kind and degree of risk aversion is determined by the choice of an utility function. There are a several utility functions discussed in the literature exhibiting different kinds and degrees of risk preferences.[62] In order to choose and estimate an appropriate utility function, data on the preferences to risk for the respective decisionmaker(s) are necessary. Often this information is not readily available. This is also the case for the present study, and data collection would have exceeded the scope

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[61] The three major safety-first methods are:

Strict safety-first principle (Telser-criterion):

This method suggested by Telser (1955-56) is the maximization of expected returns (income, utility etc.) subject to the constraint that the probability that returns fall short of a given threshold does not exceed a given probability.

Max. E

Subject to P(E<=T)<=P

Safety-fixed principle (Kataoka-criterion):

The second one put forth by Kataoka (1963) is the maximization of returns at a lower confidence limit (L) subject to the constraint that the probability that expected return falls short of L does not exceed a given probability:

Max. L

Subject to P(E<=L)<=P

Safety principle (Roy-criterion):

The third method suggested by Roy (1952) is to choose the one option where the probability of falling short of a certain threshold is minimized.

Minimize (P(E<T)

[62] These are mostly linear (risk neutral), quadratic (increasing risk aversion), negative exponential (constant absolute risk aversion), Summex (decreasing absolute risk aversion, power and logarithmic utility functions (both constant relative risk aversion (Keeney and Raiffa: 173; Hardaker et al. : 98-99).

of this piece of research; such a task could be an issue for further research. For the present purposes, an approximative method is chosen.

If preferences are unknown and cannot be elicited with ease and thus a utility function cannot be established, a common approach is to make some assumptions about the utility function while consistency with the axioms of the EU approach is maintained. Most common methods are the mean-variance, and stochastic dominance methods. Here, only the basic first-degree **stochastic dominance method** shall be discussed.

For this method, the only restriction concerning the decisionmaker(s) preferences is that positive marginal utility with respect to the outcome measure exists. In first-degree stochastic dominance an alternative A with cumulative distribution F(y) is said to stochastically dominate another alternative B with distribution G(y), if for the cumulative density function of outcomes y the following inequality holds (King and Robison 1984: 146):
$F(y) \leq G(y)$ for all y.

Graphically this implies that a dominating distribution may never lie above another distribution. E.g. in figure 43 the cumulative density distribution F(y) dominates G(y).

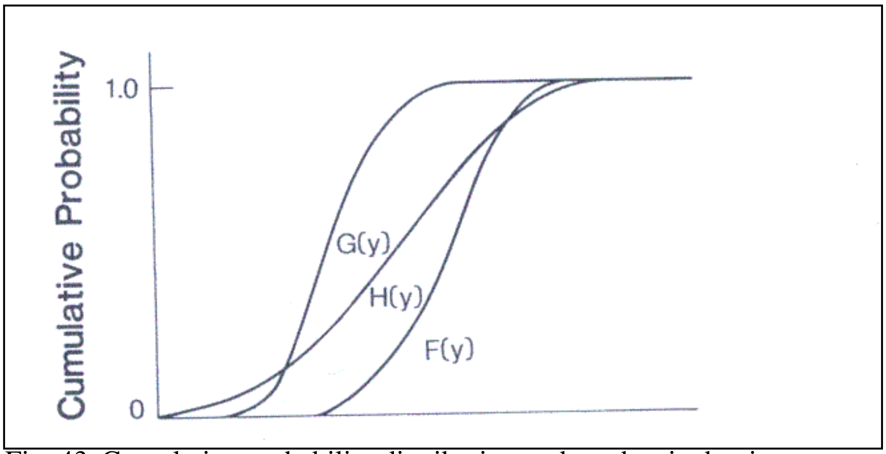

Fig. 43: Cumulative probability distribution and stochastic dominance
Source: King 1984: 70

In this case, this method could be used to make sensible, constant decisions.

A major problem with stochastic dominance is that it can often not be invoked unequivocally (Keeney and Raiffa 1993: 134-5). E.g. when, as done in figure 43, another distribution H(Y) is introduced, no dominating distribution can be established anymore as H(Y) lies both above and below the two other distributions. Another issue is the complexity involved in using the dominance methods.

For this thesis, where the focus is on establishing a framework to outline the costs and benefits of the management of natural disasters under risk rather than pretending to exactly determine these costs and benefits, the EV approximative method proves more useful due to its simpler arithmetics.

The **mean-variance (EV) method** is often used in portfolio analysis in finance theory and applications. While the stochastic dominance methods assess whole probability distributions, the EV method in essence relies on the mean and variance whereby the variance is used to measure volatility around the mean. The method allows to find risk-efficient solutions by defining an efficiency frontier that outlines those solutions that have the lowest risk in terms of variance for a given mean, or alternatively find the highest mean for a given variance. Markovitz (1959) introduced this method to analyze portfolios of stocks entirely based on the mean rate of return and the volatility around the mean (Selley 1984: 58). The EV method is the most popular method used in the expected utility framework (King 1984 and Robison: 72; Young 1984: 39; Kramer 1995: 74) mainly due to the practical ease with which it can be measured and applied. It allows to analyze the trade-off between return and stability and to assess whether volatility around expected value matters.

The EV method has to be understood as an approximative method. From a theoretical point of view this method is feasible when either the random variables X are normally distributed or the utility function is quadratic. These two assumptions are questionable, as extreme events usually do not follow normal distributions. Also, though the quadratic U function is often used for such analyses, this function has the undesirable property that risk aversion increases with increasing incomes which is counterintuitive.

In the cases where these conditions are not met, the EV method "falls short of being fully satisfying, but remains an eminently manageable approximation" (Hirshleifer 1992: 73).

9.3.2.4 Concept of certainty equivalence and risk premium

For deriving the EV method, it is necessary to introduce the certainty equivalent and the risk premium, and its mathematical formulations.

The certainty equivalent of a probabilistic income is defined as that level of certain income that renders an individual the same utility as a gamble with the same expected utility of income (Keeney and Raiffa 1993: 133). The certainty equivalent translates an uncertain value into a certain one. The uncertain value is discounted by the risk premium.

The concept of certainty equivalent and risk premium can be graphically analyzed (fig. 44). Project outcomes (and income for project beneficiaries) Y_2 and Y_1 are probabilistic, outcome may be as high as Y_2, but could also fall as low as Y_1. In the case of risk aversion (exhibited by utility curve U) there is decreasing marginal utility of wealth, and losses have higher value than gains. U[E(Y)] is larger than E[U(Y)].

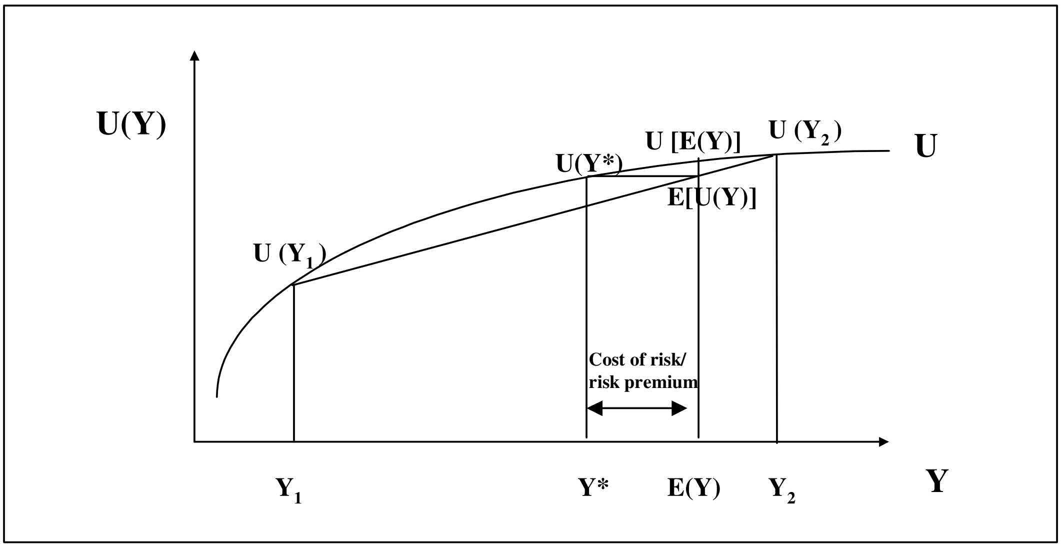

Fig. 44: Certainty equivalent and risk premium in the case of risk aversion

The certainty equivalent Y* is the deterministic, certain income with the same utility as the probabilistic value E[U(Y)]. This means that the decision-maker is willing to sacrifice E(Y)-Y* to gain the certainty equivalent income Y*. This difference is the (additional) willingness to pay for having a certain outcome, the risk premium RP (cost of risk, cost of risk bearing) and is the difference between the expected value of risky income E(Y) and its certainty-equivalent income Y*:

$$RP = E(Y) - Y^*$$

If risk aversion prevails, the risk premium is positive, if there is risk proneness, it is negative, in the case of risk neutrality it is zero. (Keeney and Raiffa 1993: 152). This means that a risk averse individual is willing to pay more than expected losses to gain a certain outcome (Y_2-Y*). Thus to summarize, fluctuations in benefits or costs create a cost of risk or risk premium as individuals are normally assumed to be risk averse[63]: They will value losses higher than gains. A sure outcome is preferred over uncertainty. "Individuals are averse to fluctuations in their income, the cost of bad outcomes is greater than the benefits from correspondingly good outcomes." (Dinwiddy and Teal 1996: 194). Risk aversion is dependent on income and magnitude of risk. This creates incentive to analyze risk transfer options, as e.g. insurance usually costs more than expected losses (refer to above discussion).

9.3.2.5 Calculation of EV method

For the calculation of the certainty equivalent the introduction of two risk aversion measures is helpful: The coefficients of absolute and relative risk aversion. These measures of risk aversion are defined by the curvature and steepness of the utility function (Layard and Walters 1978: 361). The negative of the quotient of these two variables is called the (Arrow-Pratt) *coefficient of absolute risk aversion denoted by* A(Y) or simply A:

[63] Individuals are usually assumed to be risk averse (due to financial limitations and coping mechanisms to deal with larger risks whereas, as discussed above, governments or large companies on the other hand are usually assumed to be risk neutral due to the possibility to pool or spread risks.

$$A = -\frac{U''(Y)}{U'(Y)}$$

Multiplying this by average income $\overline{Y}$ leads to the unit-free *coefficient of relative risk aversion,*

$$R = -\overline{Y}\frac{U''(Y)}{U'(Y)}$$

Relative risk aversion can also be interpreted as the elasticity of the marginal utility of income with respect to income (Layard and Walters 1978: 361):

$$R = \frac{dU'(Y)}{dY}\frac{\overline{y}}{U'(Y)}$$

With these measures the risk premium (RP) can be approximated by expanding the equation E[U(Y)] = U(Y*)[64] by means of a 2nd order Taylor series around average income $\overline{Y}$ (Dinwiddy and Teal 1996: 238-240):

(1) E [U(Y)] = U(Y*)

The left-hand side can be approximated by

(2) $$E[U(Y)] = E[U(\overline{Y}) + U'(\overline{Y})(Y - \overline{Y}) + \frac{U''(\overline{Y})}{2!}(Y - \overline{Y})^2 + ...]$$

as $E(Y - \overline{Y}) = 0$ this simplifies to

$$= U(\overline{Y}) + \frac{U''(\overline{Y})}{2}V(Y) + ...$$

The right-hand side is given by

(3) $$U(Y^*) = U(\overline{Y}) + U'(\overline{Y})(Y^* - \overline{Y}) + \frac{U''(\overline{Y})}{2!}(Y^* - \overline{Y})^2 + ...$$

equating (2) and (3) and solving for the RP = E(Y) - Y* leads to

(3) $$RP = \frac{A}{2} * V(Y)$$

where RP: risk premium, Y: Income, A: coefficient of absolute risk aversion.

Variance V(Y) is weighted by the risk aversion parameter A which theoretically is determined by the expected utility function. Thus, the risk premium is a function of the volatility of income measured by the variance and the risk preference as measured by the risk aversion parameter.

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[64] i.e. expected utility at Y is equal to the utility of the Certainty Equivalent Y.*

The risk premium is often expressed as a fraction of mean income:

(4) $\frac{RP}{\overline{Y}} = \frac{R}{2} * \frac{V(Y)}{\overline{Y}^2}$ where $\overline{Y}$ is average income

which can be rewritten as

$RP = \frac{R}{2} * \frac{V(Y)}{\overline{Y}}$ R : coefficient of relative risk aversion

Thus the certainty equivalent income can be calculated as follows:

$$Y^* = E(Y) - RP = E(Y) - \frac{R}{2} * \frac{V(Y)}{\overline{Y}}$$

This basically constitutes the EV method. The certainty equivalent income is derived by penalizing expected income by the risk premium consisting of the variance as a measure of volatility and the risk aversion parameter as a measure of the risk preference. For this analysis, the certainty equivalent income is the variable of interest.

As discussed above insuring against risk is interpreted as a secondary project that secures other projects income. If primary projects adding to existing income are regarded, the proper formula for calculating the certainty equivalent is as follows. The covariance of the project and national income has to be taken into account also, as

$Y = X+Z$

where Y is overall income, X: income without the project, Z: project income.

Then, the Risk Premium RP becomes (Dinwiddy and Teal 1996: 231):

$$RP = \frac{R}{2Y} * V(\overline{Z}) + \frac{R}{Y} * COV(Y, \overline{Z})$$

9.3.2.6 Empirical work on risk aversion

There is substantial research on empirical measures of risk aversion for developing and developed countries. Generally, risk aversion can be found in households and especially for poorer households (Dinwiddy and Teal 1996: 222). This also holds true for natural disaster risk. E.g. Brookshire et al. (1985) and Nakagawa et al. (2002) find aversion to earthquake risk for firms and households when analyzing land property prices in California and the Tokyo Metropolis. As well, both studies find the behavior of these agents in the property market as reflected by a risk premium for unsafer land to be consistent with the EU theory (Brookshire et al. 1985: 69; Nakagawa et al. 2002: 10). For very high values of relative risk aversion between 6 and 10 Nakagawa et al. (2002: 9) find their estimation results on the impact of earthquake risk on land pricing consistent with EU theory.

However, concerning the size of risk aversion and the issue whether relative or absolute risk aversion is constant or decreasing, evidence remains inconclusive. As well no study could be located that examined the risk preference for a representative government decision-maker - the approach chosen here. There are three major overview studies summarizing the research in this field (table 26).

Table 26: Empirical overview studies on relative risk aversion parameter

Study	Results
Newbery and Stiglitz 1981	Summary of studies. Relative risk aversion between 0 and 2.
Robison et al. 1984	Overview over farmer's risk attitudes. Found risk attitudes to vary considerably and influence behavior strongly.
Saha et al. 1994	Review of risk aversion and risk aversion parameters in general. Constant absolute risk aversion rejected in favor of decreasing absolute risk aversion, findings on relative risk aversion have been mixed. Values of absolute risk aversion are 0-14.75 with most values being lower than 0.5 for relative risk aversion 0 to 6.76 the main range being 0 to 4

Newbery and Stiglitz (1981: 100-108) provide a summary of studies. Relative risk aversion ranges between 0 and 2. *Robison et al.* (1984: 25-28) undertook an overview over empirical studies on farmer's risk preferences and found varying degrees of risk aversion while risk preferences ranked high and may strongly influence farmer's behavior. Robison concluded that risk attitudes need careful examination in economic analysis.

The most comprehensive review available is that of *Saha* (1994) summarizing empirical research on the kind of risk aversion as well as on the magnitude of risk aversion parameters. He states that while constant absolute risk aversion has generally been rejected in favor of decreasing absolute risk aversion, findings on the nature of relative risk aversion have been mixed. Summarizing studies on the values of risk aversion, the ranges for absolute risk aversion are 0-14.75 with most values being lower than 0.5, and for relative risk aversion 0 to 6.76 the main range being 0 to 4.

As there is considerable debate about the degree of risk aversion, applied developmental studies often resort to using a single value or a range of values for relative risk aversion. Little and Mirrlees (1974) suggest the value to be close to 2 with a range of 0 to 4, Anand and Nalebuff 1987 use a value of 2 for the analysis of energy projects in oil-exporting countries. Murdoch (1995: 105) suggests a value of 2 as well. Belli et al. state that "social risk aversion" falls in a range of 2 to 4 for developing countries (1998: 12). Hardaker et al. (1997: 102) for risk in agricultural decisions acknowledge the uncertainties involved in eliciting risk aversion parameters and state that it is often more realistic and sufficient to use a sensible number or range of values.

This approach will be taken here. Due to the considerable uncertainty about the modelling of risk aversion which cannot be resolved in this study and the fact that the empirical studies on the risk preference refer to individuals and households, not to representative government decision-makers, a sensitivity analysis approach will be used varying relative risk aversion values from 0 to 4 for an assumed representative individual as decision-maker. This is the range in which most of the empirical estimates fall. Also, for the empirical studies dealing with different per capita income countries (Argentina an upper middle income and Honduras a lower income country) varying risk aversion parameters seems a sensible approach. Using a range of 0 to 4 can be interpreted as using the following preferences to risk as displayed in table 27 (Hardaker et al. 1997: 102)

Table 27: Risk aversion parameters

Risk aversion	Associated risk preference
0	not risk averse
1	normally risk averse
2	rather risk averse
3	very risk averse
4	exceptionally risk averse

Source: Hardaker et al. 1997: 102.

In this fashion, appropriate risk aversion values can be chosen by decision-makers and thus the degree of the tradeoff between return (expected value) and volatility (in the form of variance) can be defined. Thus utility functions are used implicitly to discount expected value calculations. Results will still be explained in terms of income or fractions thereof.

9.4 Formula for calculation of social benefits under uncertainty

Now the formula derived before can be expanded to account for risk by replacing the deterministic arguments by their certainty equivalent.

The change of welfare was measured as

$$dW = \sum \frac{\Delta y_i}{(1+r)^i}$$

When using the certainty equivalent of the change in welfare, the formula is modified to:

$$CE(dW) = \text{CE}[\sum \frac{\Delta \text{y}}{(1+r)^i}] = E[\sum_{\text{i=1}}^{\text{t}} \frac{\Delta \text{y}_\text{i}}{(1+\text{r})^\text{i}}] - \frac{R * V(\sum_{\text{i=1}}^{t} \frac{\Delta \text{y}_\text{i}}{(1+\text{r})^\text{i}})}{2E[\sum_{\text{i=1}}^{\text{t}} \frac{\Delta \text{y}_\text{i}}{(1+\text{r})^\text{i}}]}$$

Thus, the change in welfare dW is calculated as the discounted sum of the expected values of aggregate income less the risk premium. This consists of the project variance weighted by the risk aversion parameter R. Whole GDP paths rather than effects in individual years need to be assessed, as there is temporal dependency of GDP in the modelling (investment in previous years affects current output). In the usual case, based on the Arrow and Lind theorem, when only the expected value is calculated in cost-benefit assessments, the term that accounts for volatility is considered insignificant and the variance V supposed to be small (Arrow and Lind 1970). This is the case of assumed risk-neutrality.

To assess the benefits due to insurance to the situation without insurance, the respective certainty equivalents need to be subtracted, net benefits are:

NB=CE(dWins)-CE(dW)

The benefits in the form of mitigated disaster costs are stochastic values, as they are potentially shocked by catastrophes, the costs are deterministic annual payments due to the premium payment. There is need to stress that benefits are the costs foregone due to risk management: Thus it is necessary to compare impacts with and without risk management and to take the difference in order to estimate the cost efficiency of risk management measures.

9.5 Conclusions modelling part

In order to study the costs and benefits of disaster risk management to be calculated with the macroeconomic modelling approach developed in chapter 7, chapters 8 and 9 outline a CBA method. The CBA method derived allows the calculation of the net benefits of risk management measures, in particular of insurance, in the context of risk. It is based on the expected utility (EU) framework. The EU framework is the standard method of dealing with risk in economics to account for CBA in stochastic context. As it was not feasible to establish a utility function representing the preferences of the representative decisionmaker, the mean-variance (EV) method was chosen as an approximation, which is a common procedure in decision-making in economics. The EV method basically relies on the mean and variance of the outcome variables and weights the variance by a risk aversion parameter. Thus, the method accounts for the average impacts of catastrophes as well as for the extremes and volatility. It also considers the ability to cope with disasters by including the risk aversion parameter. If there is (perceived) risk neutrality the analysis can be reduced to calculating averages. In this fashion the risk-return tradeoff involved in buying insurance can be modelled. Purchasing insurance is regarded as a tradeoff between stability and growth: Insuring provides more stability but less funds to be spent on an annual basis for important developmental objectives. Remaining uninsured means more funds available in case no disasters happens; in case of an event, however, there is high risk that infrastructure cannot be rebuild which will cause large aggregate effects. The magnitude of the trade-off can be influenced by decision-makers themselves by deciding upon a proper risk aversion parameter. The method chosen bears resemblance to the determination of the insurance premium by the insurance suppliers where in addition to the expected losses, insurance pricing includes a loading element accounting for the variability of risk (as well as for transaction costs and profit margin).

III CASE STUDIES: APPLICATION OF MODELLING FRAMEWORK

Part III will apply the modelling framework developed in section II to the analysis of two case studies. For two countries from Latin America - Honduras and Argentina - the costs of natural disasters as well as the costs and benefits of insurance of infrastructure assets will be investigated and effects contrasted. These two case studies cover a wide spectrum of characteristics and were chosen as the Latin American region is highly at risk to natural disasters, data and models were available, and interest in the research and policy community existed. Chapter 10 will shortly provide the general background on disaster risk in Latin America and the Caribbean, and chapters 11 and 12 will present the case studies.

10 LATIN AMERICA AND DISASTER RISK

Section 10.1 will discuss the situation with regard to natural disaster risk, 10.2 examines the issues of economic volatility and insurance markets, 10.3. outlines the general structure of the case studies and 10.4 discusses general caveats that need to be expressed concerning the case studies.

10.1 Natural disaster risk in Latin America and the Caribbean

The Latin America and Caribbean (LAC) region[65] is particularly prone to natural disasters. Next to Asia it is the second most disaster prone world region (EM-DAT 2002). 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. Total direct and indirect losses were estimated at more than 50 billion USD over this period. It is estimated that between 1990 and 1999 about 2.5 million people became homeless due to natural disasters. In addition, the number and the losses from natural disasters have been rising (fig. 45) (Charveriat 2000: 9-15; ECLAC and IDB 2000: 7).

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[65] Latin America and the Caribbean are usually examined as one region for purposes of policy analyses and project planning by multilateral finance institutions.

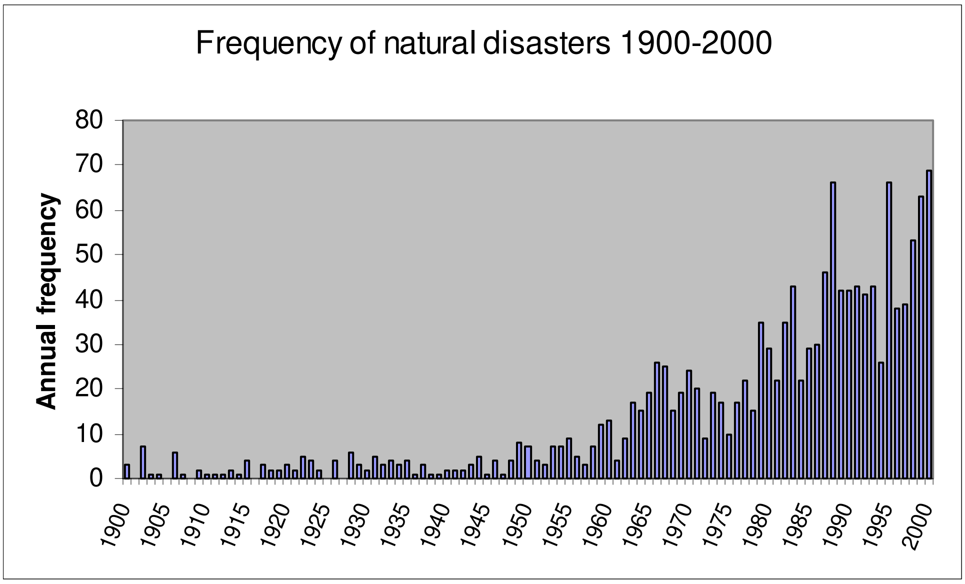


Fig. 45: The number of natural disaster events in the Latin American and Caribbean region is rising.
Data source: EM-DAT 2002.

Factors that are considered to having contributed to this increase indicated by figure 45 are rapid population growth coupled with migration to risky urban areas that are at risk due to proximity to coasts or seismic activity. Another important factor is widespread poverty in the region. Overall, 16% of the population in Latin America and the Caribbean is considered extremely poor. This results in people settling on marginal land and in make-shift housing (Charveriat 2000: 58-64)

The human loss due to natural disasters is relatively constant, but there has been recurrence of events with heavy human toll (fig. 46)

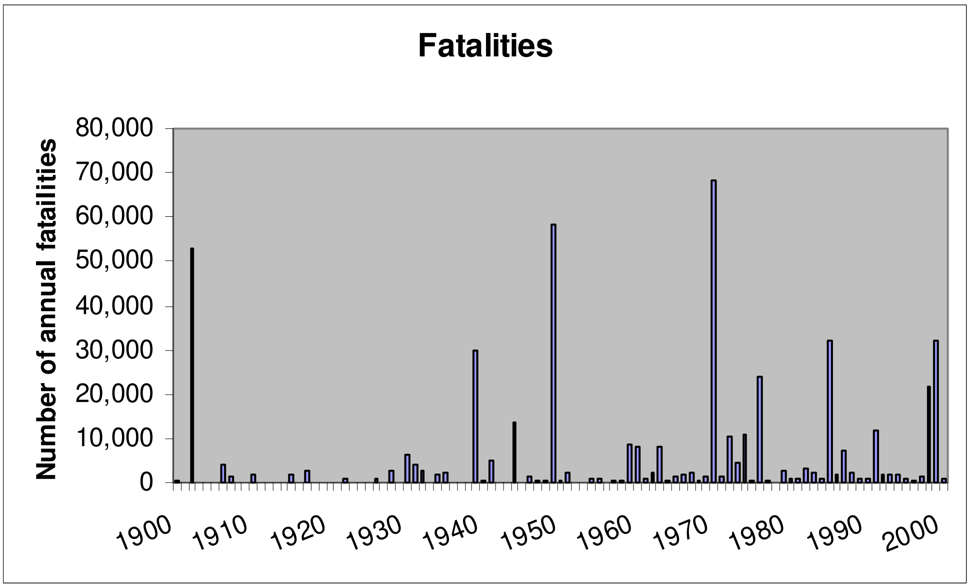


Fig. 46: Human toll due to natural disasters in the Latin American and Caribbean region 1900-2000.
Data source: EM-DAT 2002.

Direct disaster losses in individual years have been volatile, furthermore in the last years, an increase in losses seems to be occuring (fig. 47).

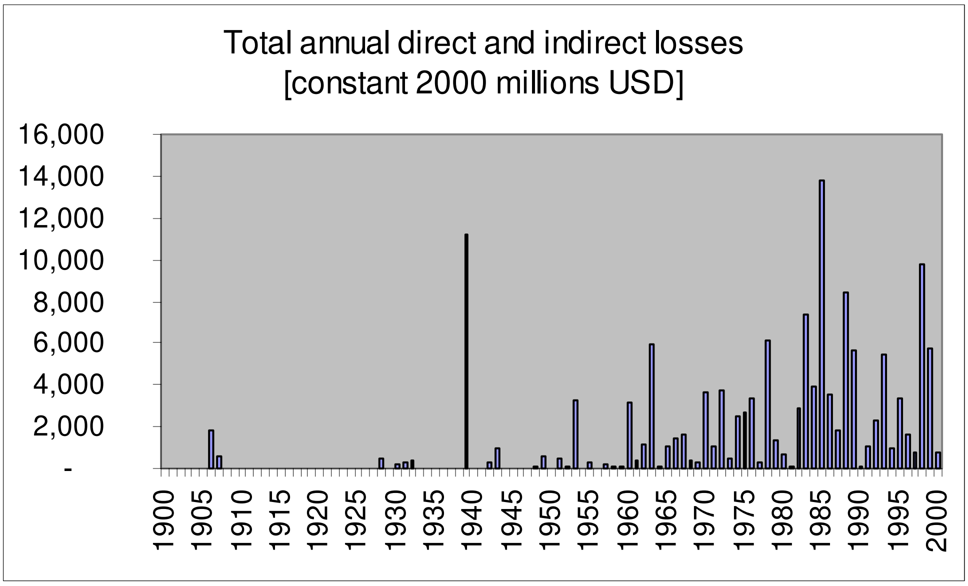


Fig. 47: Disaster losses are increasing in the Latin American and Caribbean region 1900-2000
Source: EM-DAT 2002.

10.2 Economic volatility and insurance markets

In addition to being exposed to high natural disaster risk, Latin America, like other developing regions, suffers from a high degree of aggregate economic volatility. Over the last four decades the volatility of real GDP has been twice as high as in industrial economies.[66] Reasons are large external disturbances from global goods and financial markets combined with shallow domestic financial and insurance markets and volatile monetary and fiscal policies. This translates into wage volatility and volatile unemployment rates that affect workers and households and particularly the poor who have lesser means to deal with income and employment fluctuations. However, in most countries of the region volatility today is lower than it was in the 1980s which are considered a particular turbulent decade (Ferranti 2000: 61).

In Latin America (and the Caribbean), insurance density is low, over the period 1985-2000 Munich Re lists that about 3.6% of total damages were insured.[67] Premium volume in the property and casualty insurance sector in 2000 were 3,446 million USD (Swiss Re 2002b: 37).

[66] Volatility measured as the standard deviation of the growth rate of real GDP exceeded four percent while it amounted to only two percent in industrial economies (Ferranti 2000: 15)..

67 When also taking small and medium-sized events into account, losses are supposed to roughly double (Munich Re 2000: 62). This probably does not apply for insured losses, as typically smaller events with higher return periods are proportionally less insured.

10.3 Case studies and structure

One case study deals with Honduras which is a low per capita income country and a natural disaster "hot spot". There is high hazard exposure and high vulnerability. In a global ex-post risk ranking for 1998, Honduras was listed as the most risky country (Wagner et al. 2001). Due to these reasons, there is large interest in Honduras in the research and development community. Argentina is an upper middle income country, which is however highly indebted with a currently ongoing severe external debt crisis; thus it is relatively vulnerable from an economic point of view. On the other hand, hazard exposure is small and the economy in absolute size considerably larger than the Honduran.

The structure of the case studies is as follows:

1. Analysis of socio-economic state of the country
2. Risk Identification
3. Risk Assessment:
   - 3.1 Direct costs, expected annual losses
   - 3.2 Analysis of economic vulnerability
   - 3.3 Macroeconomic costs
4. Risk management
   - 4.1 Costs of risk transfer
   - 4.2 Benefits of insurance
5. Conclusions

10.4 Caveats related to modelling results

Caveats have to be expressed related to the quantification of impacts and the underlying data used. As discussed, the input data on the direct losses have been provided by Swiss Re which used sophisticated loss modelling. Losses are expressed as a fraction of total capital stock in a country; thus the assumption is that the different kinds of elements of capital stock exhibit equal physical vulnerability. This has to be understood as a necessary approximation for this top-down analysis.

Furthermore, another caveat has to be expressed concerning the macroeconomic data. These data are projections of the future development as projected and planned in RMSM-X contingent on the respective base year economic structure. The original model developers collected data from different sources for the base year and complemented these by a number of assumptions of the future development of the sectors of the economy. Based on these input parameters, projections of the future economic development are derived. The base year for Honduras is 1997 and data were revised after Hurricane Mitch in 1999; for Argentina the base year is 1998. Some assumptions were updated, most notably assumptions about the stock of external debt, but updating the whole system was not feasible, as a mix of assumptions and input data has to be created by using country-specific information that is not available to the author. However, the focus of this report is on the relative benefits of risk management measures (in this case insurance strategies) rather than predicting the correct path of the economy (normally a very difficult exercise in itself!). For this purpose, the country-specific information on the economic relationships and trade-offs seems to be sufficient. Accordingly, results should be interpreted as approximative values and interpreted in orders of magnitude. For the most part, results will be expressed as percentage changes to the baseline without catastrophe impacts or the percentage changes of the cases with and without insurance.

11 HONDURAS CASE STUDY

11.1 Socioeconomic situation

Honduras is highly vulnerable in socioeconomic terms as well as heavily exposed to natural catastrophes. Honduras is an *IDA country*, i.e. due to its low per-capita income of USD 850 in 2000, it is eligible for practically zero percent interest loans from World Bank through the International Development Association (IDA).[68]

The prevalence of poverty is high with 53% of the population under the national poverty line. Infant mortality is very high at 34.4.%. Honduras is heavily dependent on outside aid. In 1997 aid constituted ca. 6.3% of GDP and after Hurricane Mitch struck the country it rose to 15.5% of GDP in 1999. The economy is heavily export-dependent with a share of exports in GDP of 42.4%. A major problem is the high external debt at a PV/exports ratio of currently 118% (table 28).

Table 28: Important socioeconomic indicators for Honduras (for the year 2000 unless noted otherwise)

Social
Population: 6.5 million
Surface area: 0.11 million sq. km
Population density/km^2: 59.1
Population growth: 3.2%
Life expectancy: 70 years
Infant mortality: 34%
Population below national poverty line (1999): 53%
Economic
GDP: 5.9 billion USD
GNP/capita[69] : 850 USD
GDP growth (post-Mitch): 3.2%
Exports/GDP: 42.4%
Aid/GDP: 9.5%
Inflation (consumer prices): 10.5%
Unemployment: 28%
PV debt/exports: 118.2%
Capital stock: 12.1 billion USD (2002)

Source: World Bank 2001a, World Bank 2002c; Freeman et al. 2002a

Since the 1980s, the economy has been subject to a combination of adverse internal and external influences causing stagnation, inflation and a large increase of external debt. Factors said to having contributed to this and having discouraged savings and

[68] The International Development Association, IDA, is the concessional lending branch of World Bank. It provides long-term loans at zero interest to the poorest developing countries, only an annual fee (0.75%) is charged. In 2000, the threshold for eligibility was set at a per capita income of less than $885.

[69] World Bank uses gross national product (GNP), or recently renamed to gross national income (GNI), to classify countries into income groups. GNP/GNI measures value added in an economy over a year by country residents living at home or abroad. Gross domestic product (GDP) measures value added within the borders of the country by residents and non-residents. In this thesis, GDP is used as the aggregate economic indicator as the focus is on the value added (and lost) domestically.

investment are the debt crisis in the early 80s, an extensive and inefficient public sector, tight administrative regulations discouraging private investment, a trade regime unfavorable to exports, inefficient financial intermediation, low investment in human capital, and insecure property rights. In the 1990s stabilization policies and structural reforms were implemented and achieved a turnaround. With the exception of 1994 when expansionary fiscal policy conducted before national elections had to be countered by drastic contractionary policies by the succeeding government, the economy grew until 1998. On average the economy grew by 3.25% over the 90s (World Bank 1999a: 1ff.). Manufacturing and construction sectors were booming, inflation was falling and the balance of payments deficit was kept within manageable bounds.

Then, in October 1998, Hurricane Mitch struck Central America and affected Honduras extensively by causing widespread flooding. 5,700 people were killed, and another 620,000 heavily affected. Total direct losses amounted to ca. 2 billion USD, approximately 18% of capital stock. Indirect damages were calculated at another 1.8 billion USD (ECLAC and IDB 2000: A 1-4-8; EM-DAT 2002). Total losses as measured in terms of GDP were in the range of 80%. 60% of transportation infrastructure of Honduras was destroyed (PAHO 1999) as well as 70% of the banana, coffee, and pineapple crop, which amounted to losses of more than 1 billion USD in the agricultural sector alone (CEPAL 1999). According to direct loss information from Swiss Re which, will be discussed and used in the following, Mitch was an event with a return period of less than once in 100 years.

The effects of this catastrophe were enormous and will have long-lasting impact on the economy. Before Mitch, the economy had performed well and GDP growth was projected to reach 3 percent in 1998 and 1999. Also, structural adjustment programs assisted by the multilateral finance institutions had advanced considerably. Post-Mitch GDP growth in 1998 still reached 3.3 percent, in 1999, however, there was a recession with -1.9% economic decline; preliminary figures for the year 2000 indicate a recovery with growth amounting to 4.0% helped by massive international assistance. Aid post-Mitch in 1999 rose by ca. 500 million USD, an increase of 146% when measured in relative terms as a fraction of GNP.

Also, exports were affected heavily: in 1999 they decreased by 6.6%, in 2000 they rebounded with an increase of 13.5%. With higher imports for rehabilitation and reconstruction purposes the trade balance worsened in 1999. Also, the large relief and rehabilitation effort increased public expenditures and increased the existing fiscal deficit in 1999 (World Bank 1999a; ECLAC 2001). On average, GDP growth from 1980-1999 has been 2.7%, the year after Mitch in 1999 it was negative at -1.9% (fig. 48).

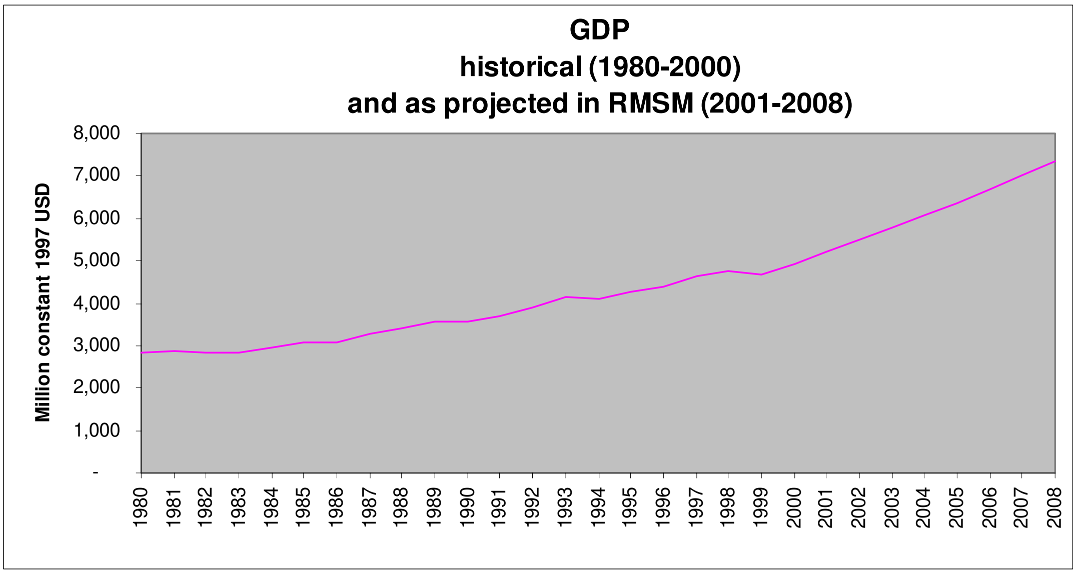


Fig. 48: GDP over the last 20 years (1980-2000) and as projected by RMSM-X (2000-2008)
Source:

The growth projections for the period 2003-2008, which is the relevant period for the model runs, used as the baseline projections in this work estimate the average growth rate at 5.2%, which seems optimistic, however, considering the substantial debt relief granted, maybe feasible. In any case, the concern of this work is not with the projections per se; they are used as a reference baseline. The actual comparison undertaken will be between projections in cases without and including insurance arrangements.

Until recently Honduras had faced an unsustainable external debt situation. In 1999 the present value of debt (PV) constituted ca. 142% of exports and more than 300% of central government revenue. Since then, Honduras has been granted debt relief under the *Highly Indebted Poor Countries Initiative* (HIPC) framework. In July 2000, Honduras passed the decision point in the initiative which makes it eligible for preliminary debt relief of more than 900 million USD over the next two decades. This will bring down the PV/X ratio to a projected value of about 61% in 2008 as projected in fig. 49 (IMF and IDA 2000: 33).

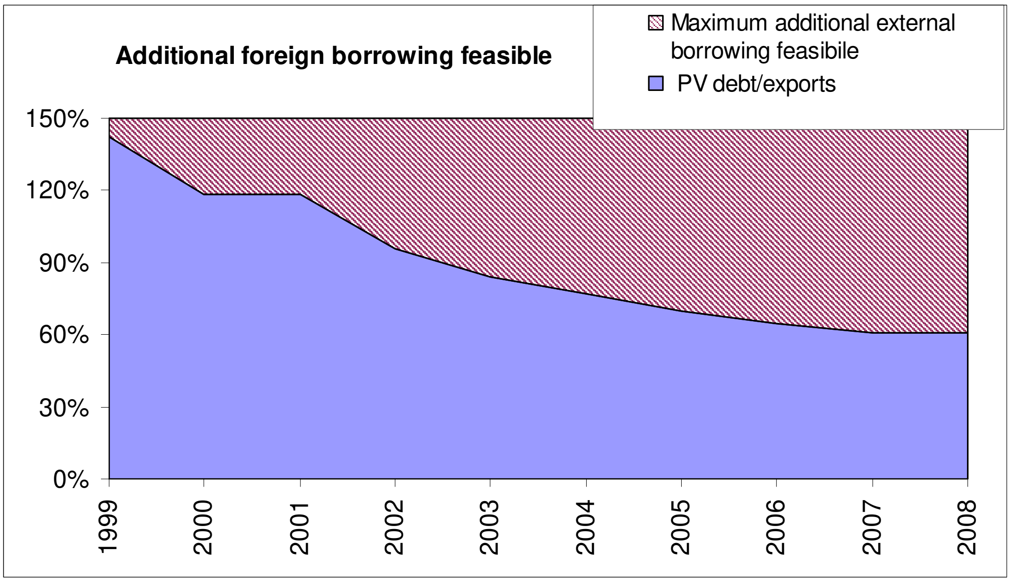


Fig. 49: Historical and projected external debt situation in Honduras and maximum additional external borrowing feasible
Source: IMF and IDA 2000: 33, own calculations.

When calculating maximum additional foreign borrowing as the difference of the sustainable limit of 150% of exports less the PV of debt/exports ratio, e.g. in 2002 another 1,200 million USD could have been borrowed externally while still maintaining external debt sustainability. In future years, with the debt relief granted, Honduras can be expected to be able to borrow higher amounts.[70]

Insurance density in Honduras is low. Domestic insurers standardly seek reinsurance internationally for the loss exposure. The standard reinsurance cover used by Honduran insurance companies is proportional reinsurance which as discussed is less common for natural disasters than buying XL coverage (Pollner et al. 2001: 4-5).

Private capital stock is partially insured against natural disasters in Honduras, including quasi-private public capital like airports, telecommunications and energy industry. Government infrastructure assets with truly public good characteristics such as roads, transport and water infrastructure are uninsured. An inventory undertaken by Pollner et al. of public assets arrived at a value of 1.6 billion USD of uninsured public assets in 2001, of which 1.1 billion USD is economic infrastructure (roads, transportation and water infrastructure) (Pollner et al. 2001: 17). This amount will consequently be assumed to used as the total value of the infrastructure assets to be protected by insurance. Total capital stock for 2001 was estimated at 11.3 billion USD (Freeman et al 200a). Thus 9.7% of total capital stock will be assumed to be insured on top of existing insurance arrangements. Existing insured capital stock will be broadly assumed to amount to 10% of capital stock. Furthermore, it is assumed that these assets are fully insured. This is based on information on Hurricane Mitch in which 0.3 billion of the total direct and indirect losses of 3.8 billion USD were insured damages (thus 7.9% of total losses were insured). Also, when assuming an average relation of infrastructure to total capital stock of 20% as estimated by World

[70] For the calculation of additional borrowing possible, the Special drawing rights (SDR) interest rate at end 2001 of 5.16% was used (see IMF and IDA 2002: 38)).

Bank (1994: 14), 10.3% of capital stock would be infrastructure held in private ownership which according to Pollner et al. is insured (2001: 17).

These broad assumptions do not diminish the value of the analysis. As outlined before, the aim of this study is to estimate the ranges of impacts and compare the effects in the situations with and without insurance in order to asses costs and benefits of engaging in risk transfer of infrastructure.

11.2 Risk Identification: Natural Hazards

The main risk in Honduras is due to Hurricane hazard causing flooding, mudslides and wind damage. It is in the following described as **storm and flood risk.** Hurricanes originate in the Caribbean sea to the North of the country (fig. 50). As Hurricanes loose in intensity once they hit landmass, wind hazard is highest in the sea-prone regions and decreases with distance to the sea.

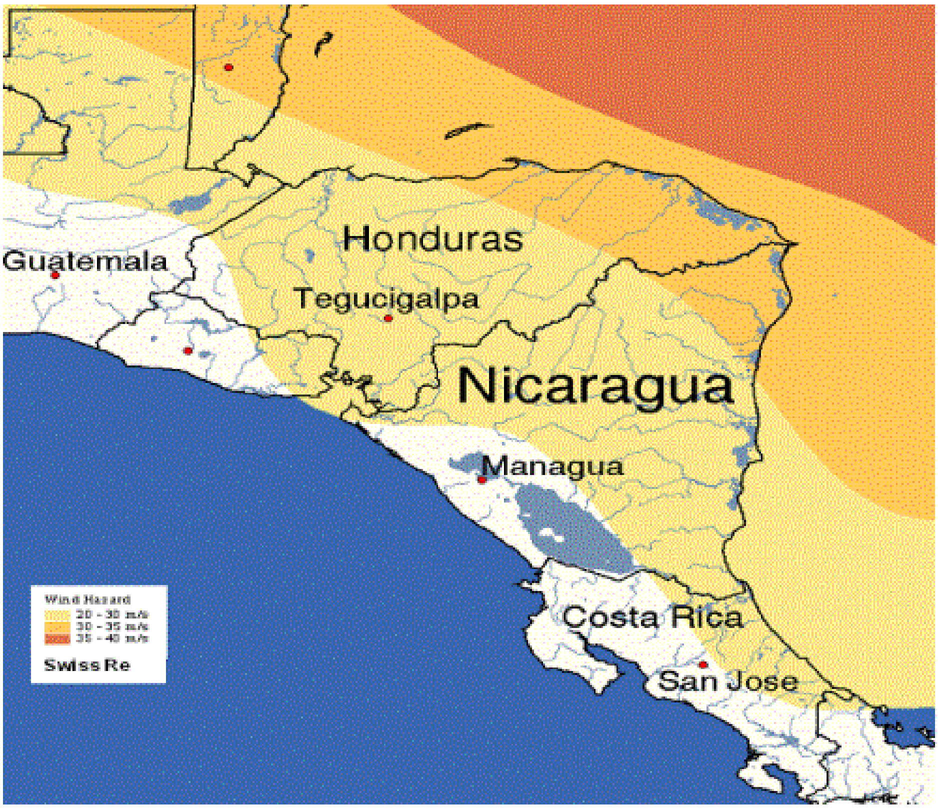


Fig. 50: Wind hazard in Honduras
Source: Swiss Re as described in Freeman et al. (2002a).

Seismic hazard in Honduras is moderate and increases from east to west. The area with the highest seismic hazard in the western part of the country is only sparsely populated (fig. 51).

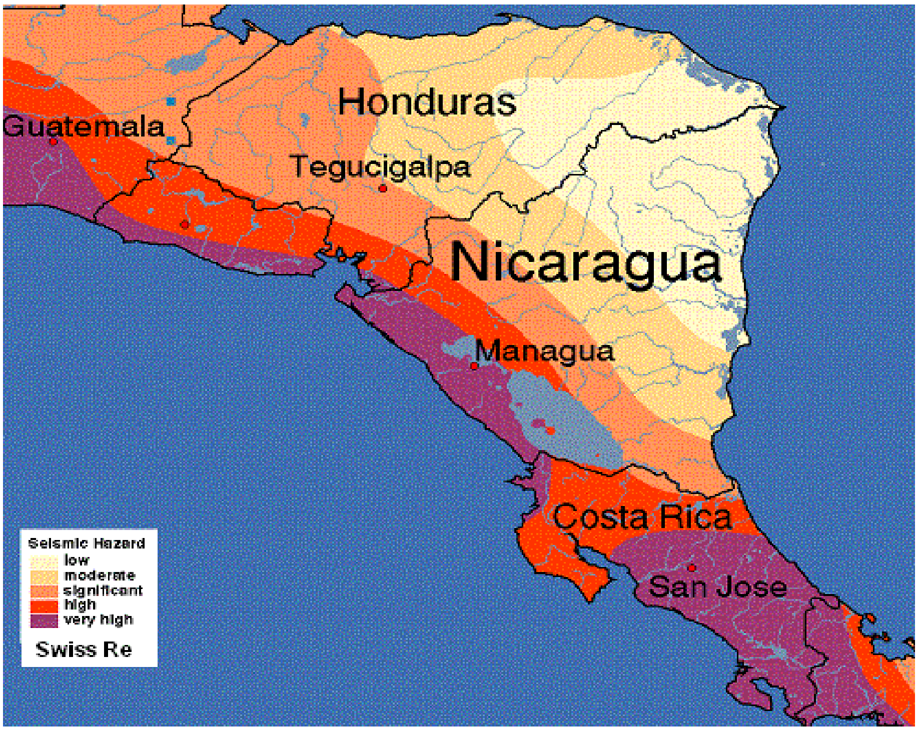


Fig. 51: Seismic hazard in Honduras
Source: Swiss Re as described in Freeman et al. (2002a).

Five major events have been recorded: A Hurricane in 1931 took 1500 lives, in 1973 another Hurricane caused a landslide killing 2,800. Hurricane Fifi in 1974 caused fatalities of 7,000, GDP fell 7% in this year. In 1993 a torrential rain killed 400 people. As outlined, the worst event so far was Hurricane Mitch in 1998 in terms of people affected and economic losses (table 29).

Table 29: Recorded impacts of major disaster events in Honduras

Events	*Fatalities*	*Affected*	*Losses (USD)*		*Insured losses*
			Direct	*Indirect*	
1931 Hurricane	1,500	-	-	-	-
1973 Landslide	2,800	-	-	-	-
1974 Hurricane	7,000	115,000	512	818	-
1993 Torrential rain	400	15,000		58	-
1998 Hurricane	5,700	618,000	2,005	1,789	300
2001 Drought	-	791,394	-	-	-

Sources: Munich Re 1998a: 39, ECLAC 2000 A 1-4-8. EM-DAT 2001.

When including also the smaller events, almost every second year there has been a catastrophe since the 1960s, with a few years where 2 or 3 catastrophes have happened (fig. 52).

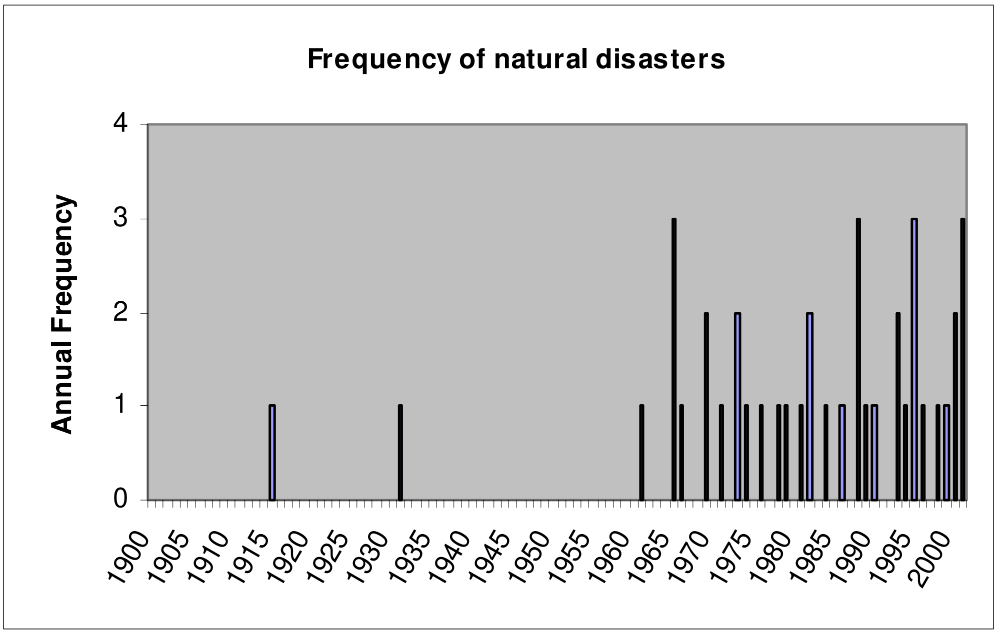


Fig. 52: Annual disaster frequency from 1900-2001
Source: EM-DAT 2002

Significant economic damages have been rarer, but in three recent years reached or exceeded 1 billion USD in constant prices.

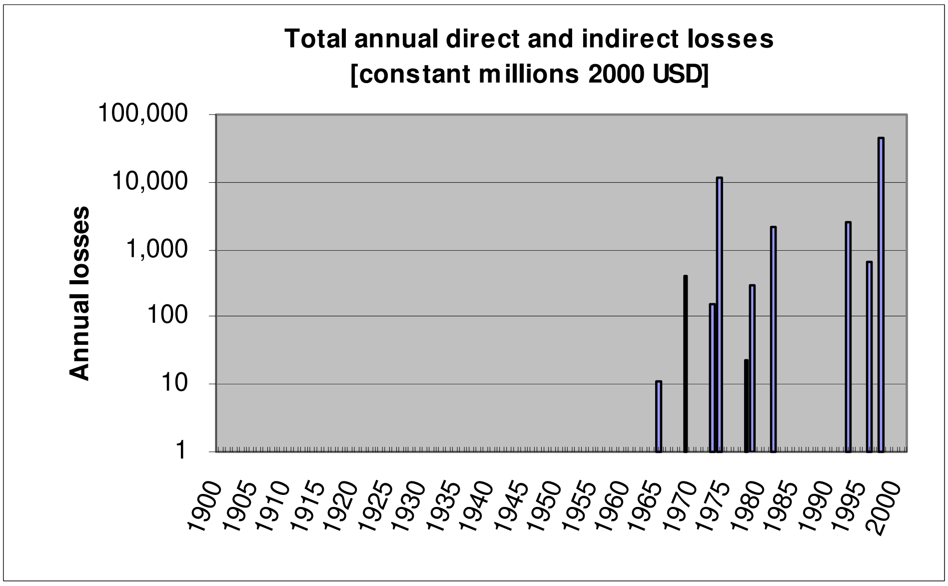


Fig. 53: Total direct and indirect losses from 1900-2001
Source: EM-DAT 2002

11.3 Risk Assessment

For the risk assessment, first the direct loss potential will be assessed. Subsequently this loss exposure will be incorporated into the macroeconomic modelling framework in order to estimate the macroeconomic costs.

11.3.1 Direct loss exposure

The current direct loss potential is assessed in building on hazard modelling as well as historical losses. Data for the losses as a percentage of capital stock were obtained from Swiss Reinsurance Company. Losses for four potential disaster events with return periods of 10, 50, 100 and 500 years for both storm and flood and earthquake risk were estimated (table 30).

Table 30: Earthquake and flood exposure in Honduras

		Storm/flood		Earthquake	
Event (year)	**Annual probability**	**Loss in % Capital stock**	**Annual loss in 2003 Mill. USD**	**Loss in % Capital stock**	**Annual loss in 2003 Mill. USD**
10	10%	0.77%	93	0.11%	13
50	2%	5.00%	605	0.77%	93
100	1%	12.31%	1490	1.38%	167
500	0.2%	30.77%	3723	4.23%	512
E(X)		**0.06%**	**7.3**	**0.43%**	**52.0**
E(X) combined		**0.49%**	**59.3**		

Source: Fractional losses from Swiss Re as described in Freeman et al. (2002a). Absolute losses adapted to 2003.

These events indicate disasters that will occur on average every 10, 50, 100 and 500 years. Thus the annual probability of their occurrence is 10%, 2%, 1% and 0.2%. For example, it is estimated that a 10 year storm and flood event will cause a 0.77% capital stock loss. Capital stock was estimated at 12.8 billion USD in 2003, this will mean a loss of 93 million USD, of which 9.7% equaling 9.1 million USD will be public infrastructure losses. Annual expected losses due to storm and flood and earthquake risk are estimated to be 0.49% of capital stock, thus in 2003 59.3 million USD total capital stock and 5.8 million USD infrastructure losses can be expected.

With this information loss-frequency curves for the relative losses to capital stock can be estimated by using available software packages. Here, RISK was used to fit the following distributions. Using the OLS estimation procedure of RISK, the Pearson 5 (also known as inverse gamma distribution) showed the best approximation to the empirical distributions. The Pearson 5 density function has the following functional form.

$$f(x;\alpha,\beta) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{-(\alpha+1)} e^{-1/\beta x}$$

For earthquake direct loss exposure, the Pearson 5 with the parameters for alpha of 2.1796 and for beta of 0.32510 and a shift of -.40966 was derived; for the more severe flood and storm loss exposure the parameters 2.0958 (alpha) and 2.0077 (beta) and a shift of –2.7027 were determined (Freeman et al. 2002a: 82). Figs. 54 and 55 show the corresponding cumulative probability curves.

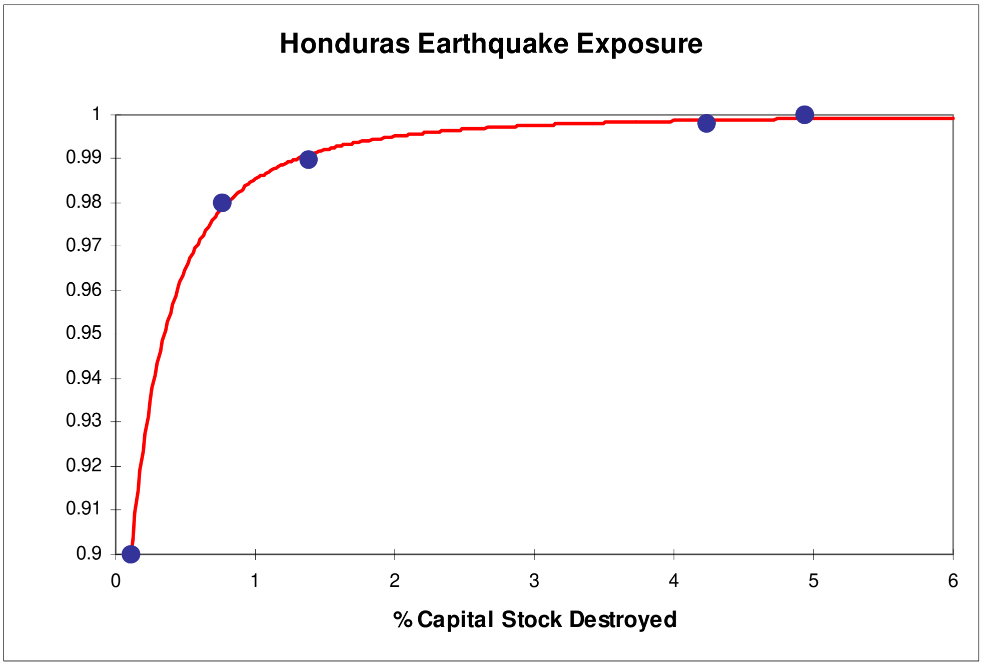


Fig. 54: Cumulative probability curve for earthquake risk in Honduras
Source: Freeman et al. (2002a: 49) based on data from Swiss Re.

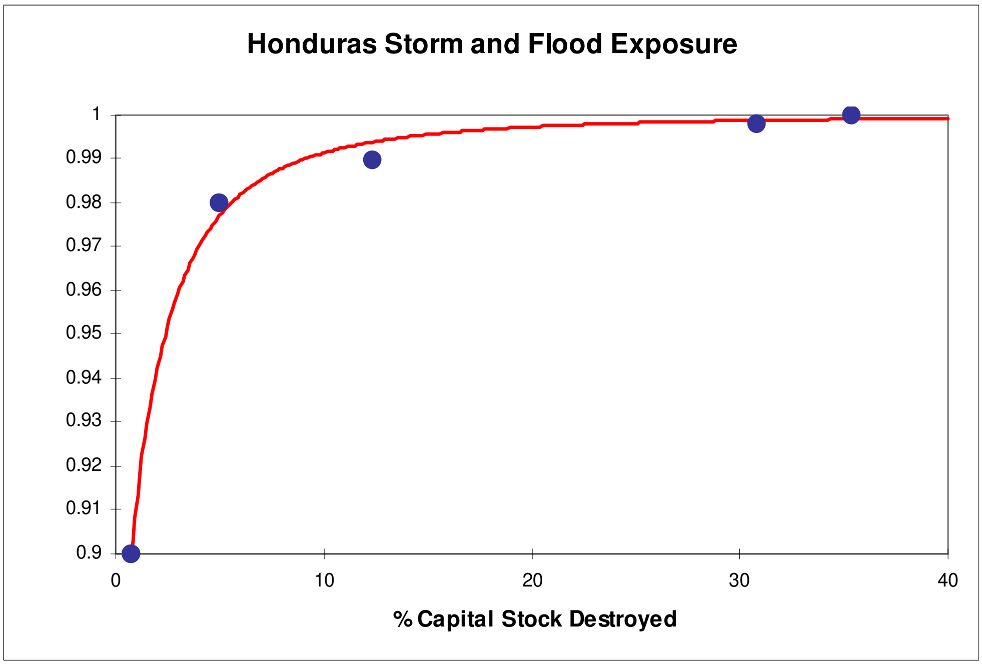


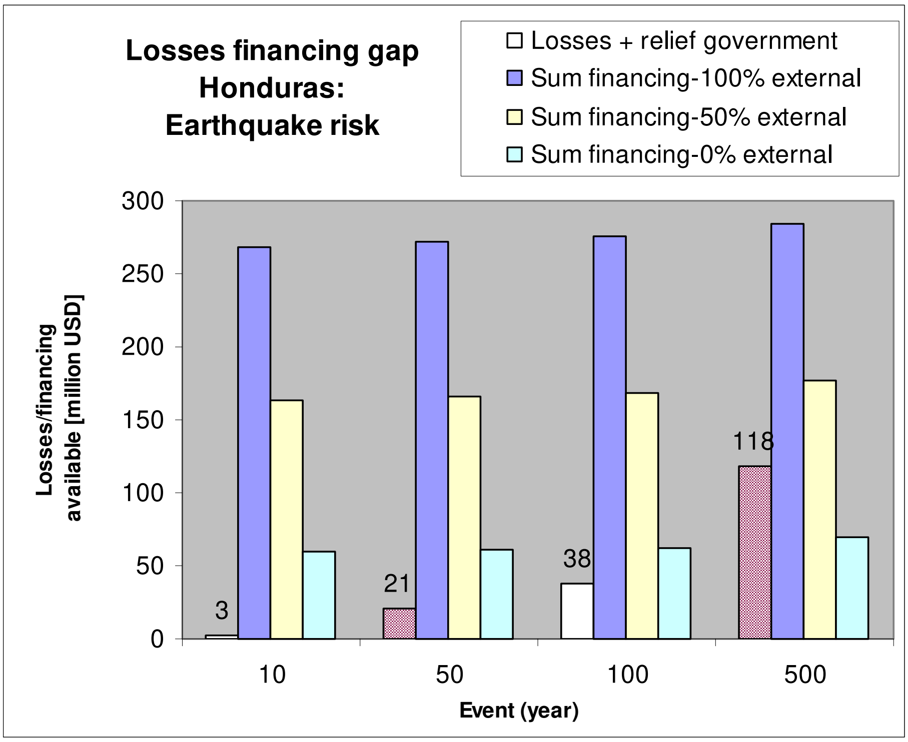
Fig. 55: Cumulative probability curve for storm and flood risk in Honduras
Source: Freeman et al. (2002a: 49) based on data from Swiss Re.

Based on this information, the annual expected direct losses due to earthquake and storm and flood hazard can be estimated by integrating the area above the cumulative probability curves. For earthquake risk, the expected annual loss is estimated at 0.06% of capital stock, for storm and flood risk at 0.43% of capital stock, or 7.3 million USD respectively 52.0 million USD. As these hazards are uncorrelated, the total expected loss can be derived as the sum of the individual expected losses. Thus it is 0.49% of capital stock or 59.3 million USD in 2003. As discussed, these expected losses are also the basis for the insurance premium calculations.

11.3.2 Economic vulnerability

Using the approach developed in chapter 7 to estimate economic vulnerability, financing necessary and available can be estimated. Fig. 56 a,b show the government's financing requirements and maximum financing available for potential losses due to storm and flood and earthquake events. The government has to finance relief for the private sector and reconstruction of infrastructure. E.g. for the worst event considered here, the 500 year hurricane, according to this analysis 846 milllion USD would be necessary in total. Of this amount 347 million USD would be necessary to provide relief to the private sector in order to stabilize its consumption and 499 million USD to replace lost infrastructure.

The financing sources aid, budget diversion and foreign borrowing are considered. Foreign borrowing makes up the major part of the financing available. However, the availability of this source is unclear. Therefore, again three external financing scenarios are displayed: 0%, 50% and 100% external financing available



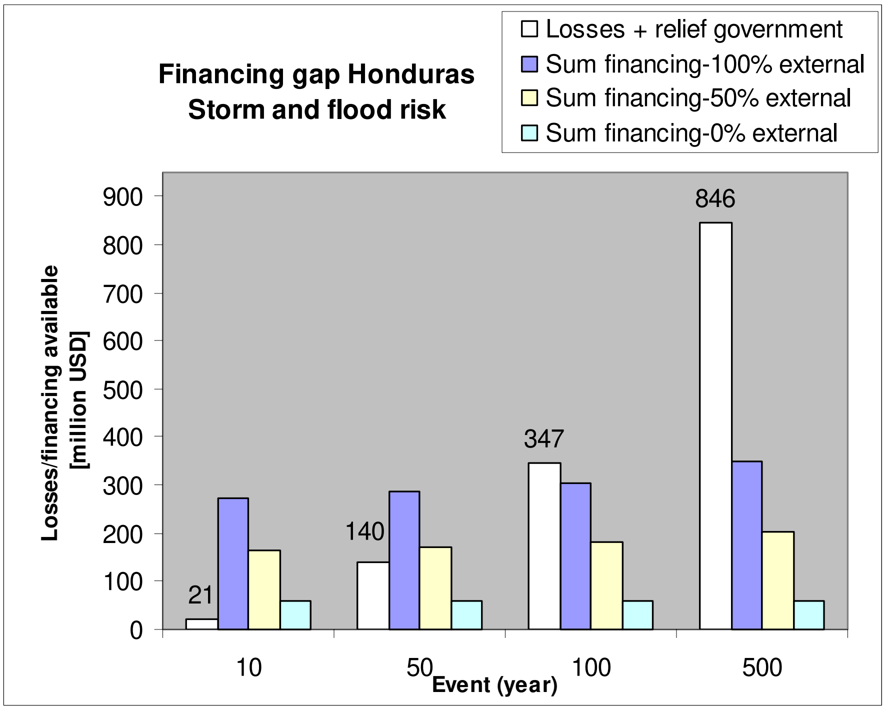


Fig. 56: a,b: Government reconstruction and relief needs, and maximum financing available for storm/flood and earthquake risk in Honduras as projected for 2003 (million USD)

According to this analysis, for all potential earthquake events considered sufficient financing seems to be available except for the 500 year event and the 0% external financing scenario. However, for storm and flood loss events, a financing gap may already occur for the 50 year event if external financing is assumed to be zero. For the more infrequent 100 and 500 year events, financing gaps become substantial for all financing scenarios. For the 100 year event, even in the full financing 100% scenario, a financing gap will occur. For such rarer events, it may be important to engage in insurance transactions to avoid large financing shortfalls and the associated macroeconomic impacts.

This analysis examined the ocurrence of one event in a given year. Of course, two disaster events could occur in the same year and create even larger financing gaps. The modeling accounts for such a possibility.

11.3.3 Macroeconomic costs of disasters

When incorporating catastrophe risk into the model as described, the originally deterministic projections are replaced by stochastic values. Fig. 57 a,b show the stocks of infrastructure in each year of the analyzed time period from 2003-2008 for the different scenarios on 0% and 100% external financing received. The dots represent the expected values, the vertical line the volatility around it.

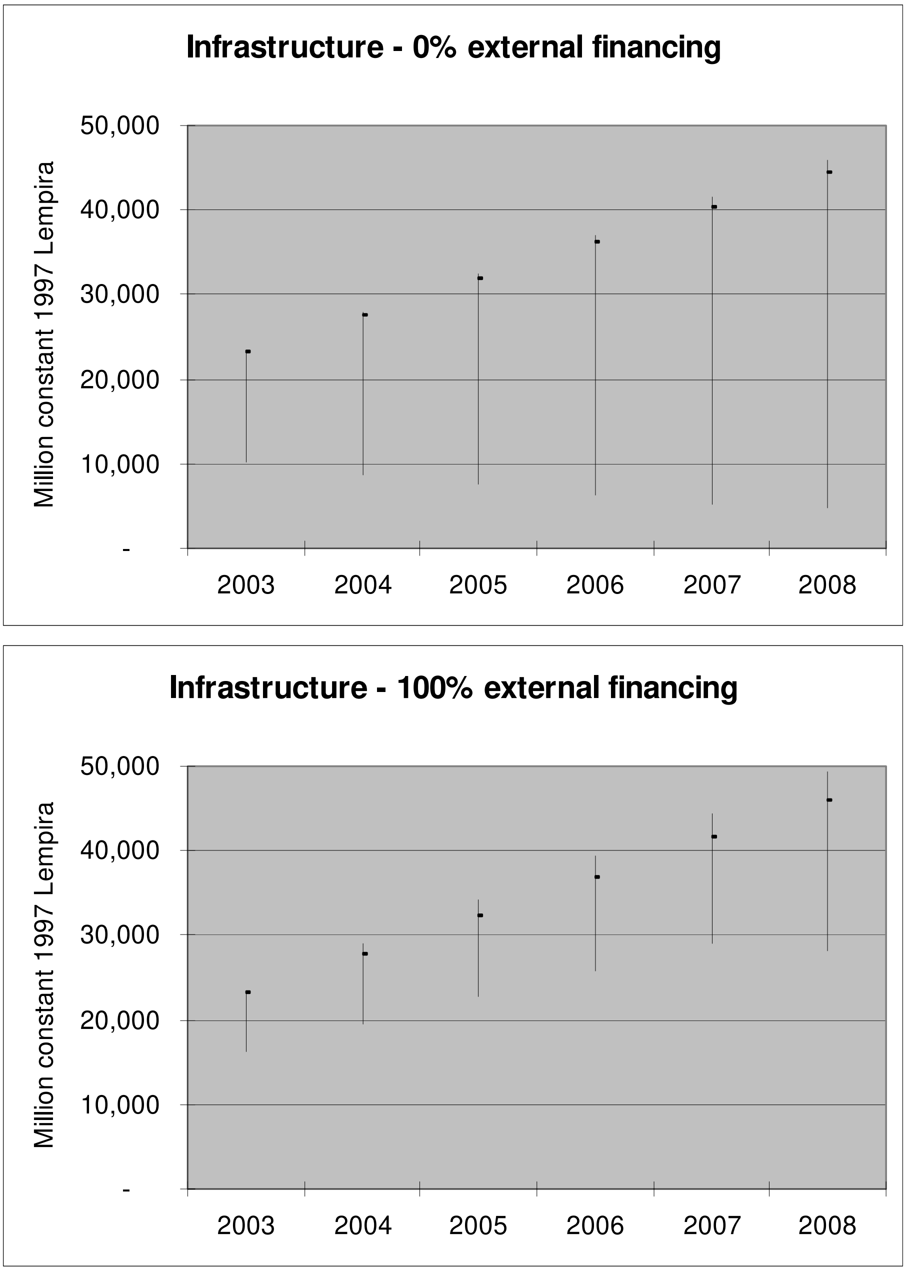


Fig. 57: a,b Volatility of infrastructure stock for 0% and 100% external financing scenarios

For both scenarios, there is large variation around the expected values. However, volatility is substantially larger for the 0% financing scenario. E.g. according to this analysis, infrastructure stock in 2008 could fall as low as 6,000 million Lempira for the 0% scenario, whereas in the full financing scenario the worst outcome does not approach 30,000 million Lempira. The fact that the mean values (represented by the dots are almost identical to the maxima for the 0% financing scenario demonstrates that these extreme shortfalls are rare. However, they remain a possibility. This is the characteristic of catastrophe risk.

These effects on infrastructure (as part of the effects on total capital stock that are not displayed here), translate into GDP impacts as shown in fig. 58 a,b for non-discounted GDP over the time horizon from 2003-2008 and table 31 that lists the effects of the different scenarios on the sum of discounted GDP.

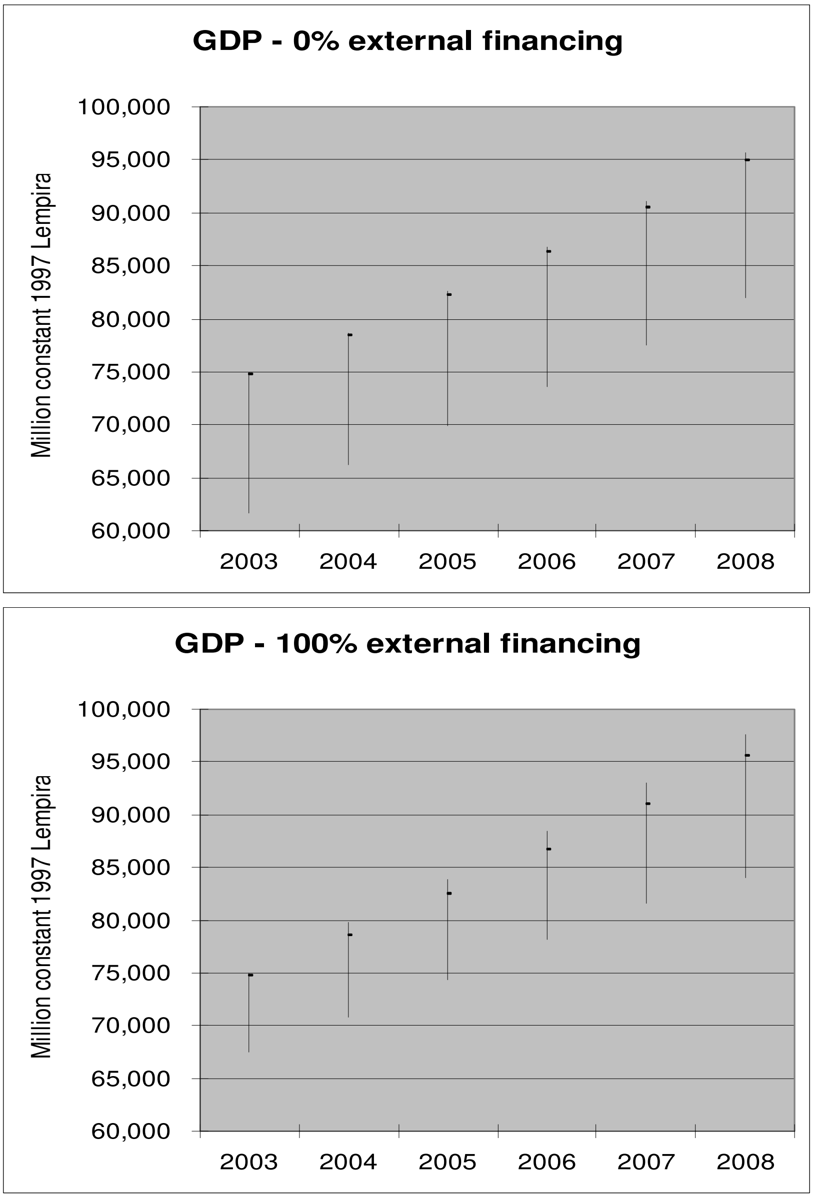


Fig. 58: a,b Volatility of GDP for 0% and 100% external financing scenarios

As for infrastructure, volatility is high for both scenarios. However, in the more favorable external financing scenario, there is less volatility and the potential maxima are higher.

When examining these effects over the course of entire GDP paths from 2003-2008 by summing up and discounting GDP in the individual years for each of the GDP paths, the following values are derived (table 31).

For the 0% scenario, the minimum of the discounted sum of GDP over the period 2003-2008 could fall as low as 84.3% of baseline GDP, thus amounting to a 15.7% loss. Of course, such large losses are not very likely as the small standard deviation, which measures the dispersion around the mean, of 3,175 million USD shows, but they remain a possibility. The average change to the discounted sum of GDP over the period 2003-2008 is small at -0.5% of baseline GDP.

Table 31: Change of projections of the sum of discounted GDP from 2003-2008 for 0% and 100% external financing scenarios

	0% external financing		**100% external financing**	
	Absolute Million constant 1997 Lempira	As a fraction of baseline %	Absolute Million constant 1997 Lempira	As a fraction of baseline %
Minimum	289,861	84.3%	324,143	94.3%
Maximum	343,866	100.0%	344,985	100.3%
Mean	342,167	99.5%	343,258	99.8%
Std Deviation	3,175		1,594	

Note: Sum of discounted baseline GDP is 343,866 Million Lempira.

For the 100% scenario, the worst case is less severe than the 0% scenario with a loss of about 5.7% only. The average outcome is slightly higher with 99.8% of baseline GDP. Volatility as measured by the standard deviation is substantially smaller than in the 0% scenario (1,594 vs. 3,175 million Lempira).

These two external financing scenarios outline the possible range of impacts. In reality, external financing received will normally neither approach 100% or 0%, but rather lie in between these two scenarios as discussed. Therefore, also a 50% scenario will be analyzed in the following.

11.4 Risk Management

11.4.1 Costs of risk transfer

Based on this analysis and the available event data, several insurance strategies were evaluated. In general both risks for Honduras were considered as insured at the same time, as combining risks has the cost-saving advantage that, as demonstrated in chapter 6, the combined variance is lower and thus the loading element of the premium will be smaller.

Four possible insurance arrangements were studied with a focus on XL insurance options:

- XL 0-500: XL insurance for all events up the maximum credible 500 year event. Though insuring by means of XL insurance from the bottom upwards is unusual, this strategy was chosen to demonstrate the case of buying full insurance up to the highest event considered possible.[71]
- XL 50-100: XL insurance for events from the 50 year to the 100 year event. This is a more typical XL insurance strategy. The financial vulnerability analysis demonstrated that the 50 year event for both earthquake and flood and storm risk can just be borne by the government under all external financing assumptions.[72]

[71] In the stochastic modelling, events less frequent than the 500 year event can also be generated. These extremely rare losses will thus not be covered by insurance.

[72] Assuming that no large events occured prior which will impact economic vulnerability adversely. Again, this is a possibility in the stochastic simulation.

- XL 100-500: XL insurance for events from the 100 year up the 500 year event. This layer will only indemnify against the relative rare events less frequent than 100 years and more frequent than 500 years.
- QS 0-500: Quota share insurance for all events up to the 500 year event with loss and premium splitting of 50%/50% between government and insurer. This arrangement was chosen to model the effects of proportional insurance where losses are split between risk cedent and insurer.

Other risk transfer strategies could be analyzed, however the above options seem to represent a fair range of possible strategies. These strategies and the associated results should be understood as an illustration of the costs and benefits of insurance, not as a prescription for actual policy implementation for which a more bottom-up analysis and discussions with potential reinsurers are required.

The following financial costs for the chosen insurance options were determined and are listed in table 32 as a fraction of infrastructure stock. The costs are highest if all the risks up to the 500 year event are insured (XL 0-500) and decrease for smaller XL-layers or when only proportional insurance is bought (QS 0-500). Also, the loading components increase substantially when the events are getting more infrequent. The cheapest option is the XL 50-100 option with protection only for events between the 50 and 100 year events.

Table 32: Financial cost of different insurance options for Honduras case study

	XL 0-500 % infrastructure	XL 50-100 % infrastructure	XL 100-500 % infrastructure	QS 0-500 % infrastructure
Total premium	1.15%	0.36%	0.79%	0.57%
Expected loss	0.55%	0.11%	0.06%	0.27%
Loading element	0.60%	0.24%	0.73%	0.30%

These financial costs create opportunity costs when the government diverts the premium amounts annually from the budget. Assuming no catastrophe takes place over the whole time horizon studied, the following changes in the GDP trajectories due to the premium payments can be determined (fig. 59).

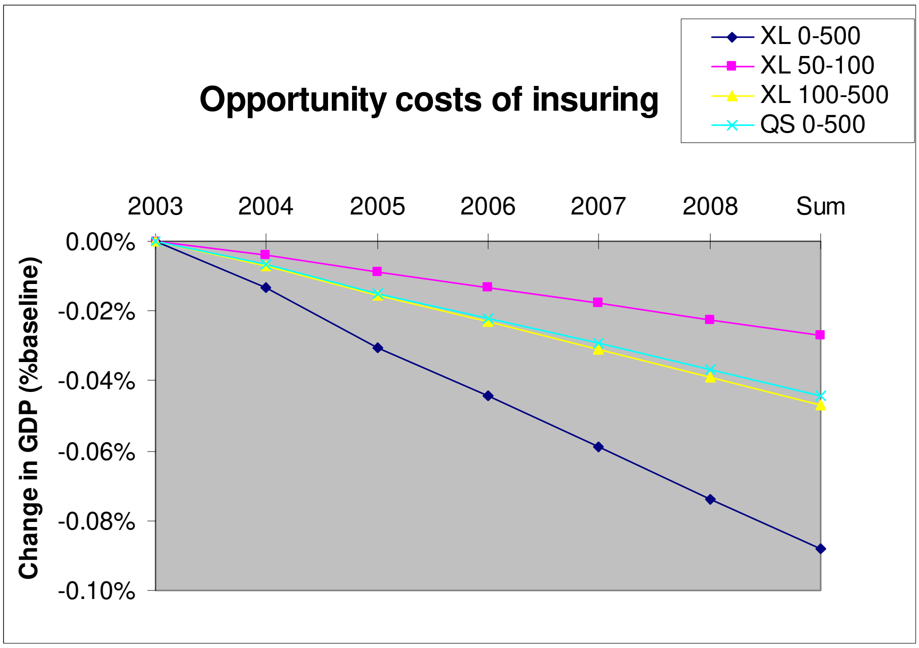


Fig. 59: Change in GDP trajectories due to annual insurance premium payment for infrastructure 2003-2008 for different insurance strategies (assuming no catastrophe event)

In general, the opportunity costs are relatively small. For the most expensive XL 0-500 option, they remain below 0.1% of baseline GDP in 2008. The opportunity costs are proportional to the financial cost, i.e. highest for the XL 0-500 option and lowest for XL 50-100 with the other options falling in between.

11.4.2 Benefits of Insurance

The main financial benefit of insuring is the inflow of indemnity payments in case of events and the reduction in the financing gaps in the insurance cases as compared to the cases without buying insurance. Table 33 lists the accumulated reduction in the financing gaps for the different strategies for the period 2003-2008 under the assumptions of 0%, 50% and 100% supply of required and fiscally sustainable inflow of external borrowing.

Table 33: Change in the sum of the financing gap due to insurance

External financing scenario	XL 0-500	XL 50-100	XL 100-500	QS 0-500
0%	-35.9%	-13.2%	-9.8%	-23.1%
50%	-65.3%	-34.3%	-27.0%	-51.3%
100%	-3.8%	-26.0%	-20.5%	-31.0%

Generally, the financing gap is reduced for all external financing scenarios. The largest reductions occur for the XL 0-500 and QS 0-500 options. This is explained by the comprehensive cover these options provide: XL 0-500 indemnifies against all loss events, QS 0-500 will provide 50% of that cover.[73]

[73] The size of the change in the financing gaps cannot just be compared between the different financing scenarios, as the values are indicated as fractions of no insurance financing gaps, which differ for these scenarios.

These effects in terms of financial costs translate to effects on infrastructure and capital stock and finally GDP. For example, for the XL 0-500 option the following effects arise. Figures 60 a,b display the stocks of infrastructure with 0% and 100% external financing.

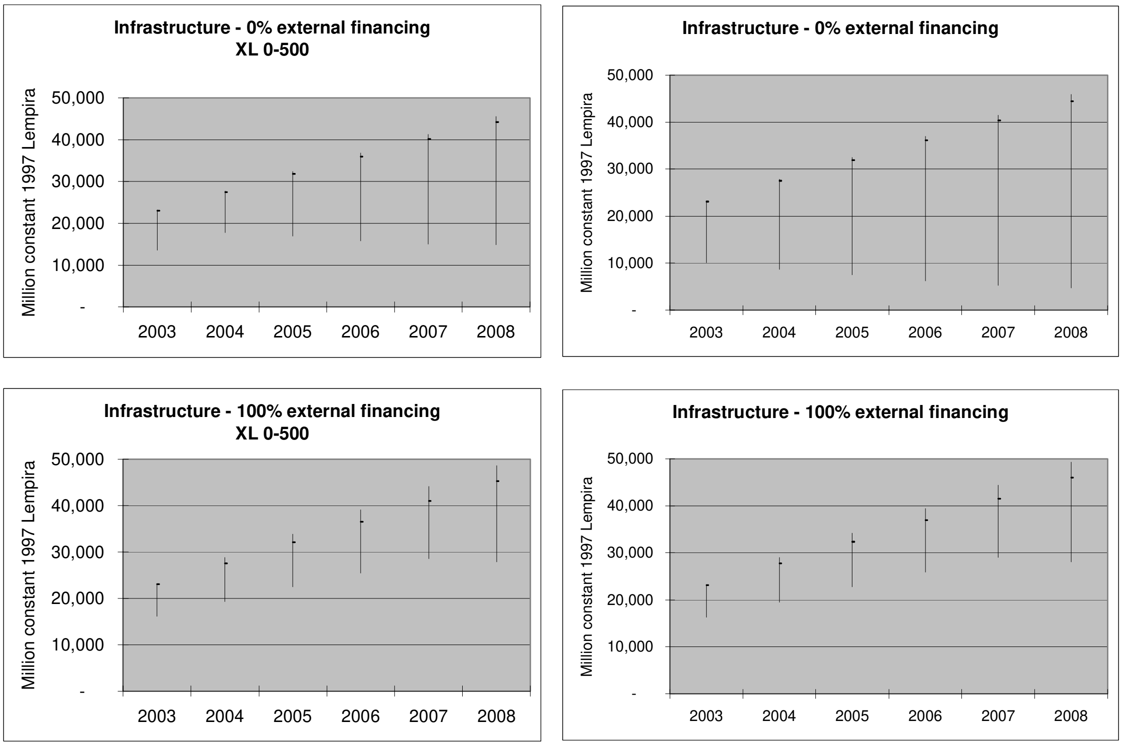


Fig. 60: a ,b: Volatility of infrastructure with XL insurance for 0-500 layer and no insurance for 0% and 100% external financing scenarios

It can be discerned that in the 0% scenario volatility is substantially decreased by this insurance arrangement. E.g. in 2008, the worst outcome with insurance is about 15,000 million Lempira worth of infrastructure, which exemplifies the hedging effect of insuring. However, for the 100% financing scenario, no benefit in terms of reduced volatility is discernible. The strong inflow of funds helps in hedging against volatility already. Thus, insurance can be considered a substitute to uncertain external financing. If enough external financing is available, the benefits of undertaking insurance are diminished

Of final interest is to analyze the social costs and net benefits as exhibited by the change in GDP. Figures 61 a,b show the GDP effects for the XL 0-500 strategy and 0% and 100% external financing.

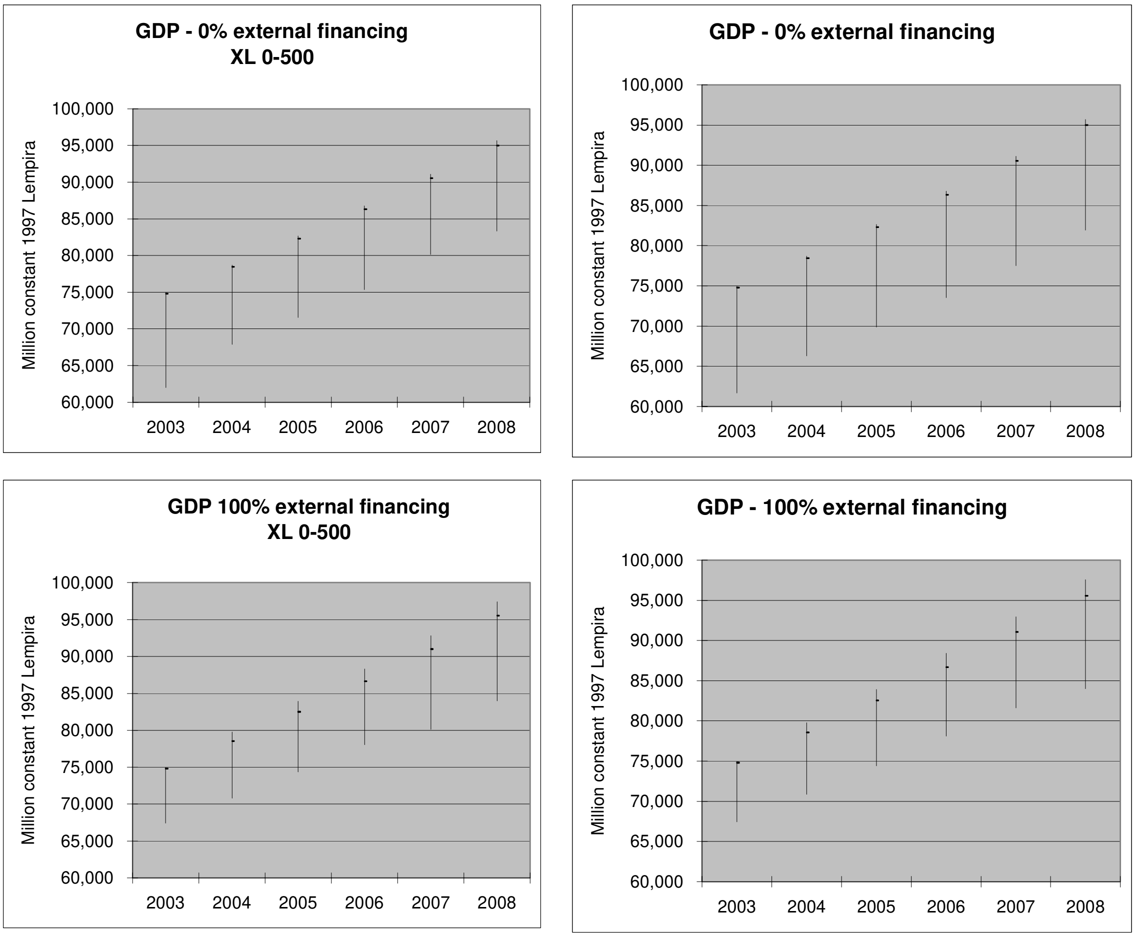


Fig. 61: a ,b: Volatility of GDP with XL insurance for 0-500 layer and without insurance for 0% and 100% external financing scenarios

As can be seen, the effects on GDP are similar, but less pronounced than for infrastructure. Table 34 summarizes the GDP impacts as measured by the sum of discounted GDP for 2003-2008 for one insurance case (XL 0-500) and compares impacts to the no insurance case.

Table 34: Comparison of XL 0-500 option with no insurance case for 0% and 100% external financing scenarios

	0% external financing		**100%external financing**	
	Absolute	Change compared to no insurance	Absolute	Change compared to no insurance
	Million constant 1997 Lempira	% baseline GDP	Million constant 1997 Lempira	% baseline GDP
Minimum	295,767	2.0%	325,184	0.3%
Maximum	343,757	-0.03%	344,886	-0.03%
Mean	342,129	-0.01%	343,126	-0.04%
Std. deviation	2,907	-8.4%	1,534	-3.8%

In the 0% external financing scenario, the worst case, minimum outcome for the discounted sum of GDP amounts to 295,767. This value is 2.0% percentage points higher than the no insurance case (it amounts to 86.3% of the baseline projections). The maximum outcome is a bit lower than without insuring (-0.03%). The mean, expected value is also lower, but slightly so with 0.01% percentage points less. On the other hand the standard deviation with 2,907 million USD is 8.4% lower than without insuring.

In the 100% scenario, these effects are similar, but smaller: the worst outcome is only 0.3% higher, the change in the maximum outcome is the same. The change in the mean outcome is in the same small range. The reduction in volatility is smaller than in the 0% scenario.

These figures well describe the tradeoff of growth vs. stability and the benefits insurance brings about in terms of volatility reduction: The worst outcomes are reduced by insurance; however, the annual premia payments cause opportunity costs reducing the maximum outcome (when no or only small disaster events occur) and the expected outcomes. The trade-off is relatively small when looking at GDP due to the fact that only a part of capital stock is assumed as insured in this analysis.

In order to compound the trade-off to a single indicator and examine the efficiency of the different risk transfer strategies, the change in GDP will be investigated by means of the EV-method as laid out in chapters 7 and 8. Calculating the NPV of the losses while accounting for volatility, the **relative benefits of different insurance options** can be calculated. When applying the formula of the certainty equivalent derived earlier, the following relative benefits of insurance can be derived. Table 35 and figures 62 a,b,c lists and display the results as a ratio of the losses of discounted GDP without insurance to baseline GDP.[74]

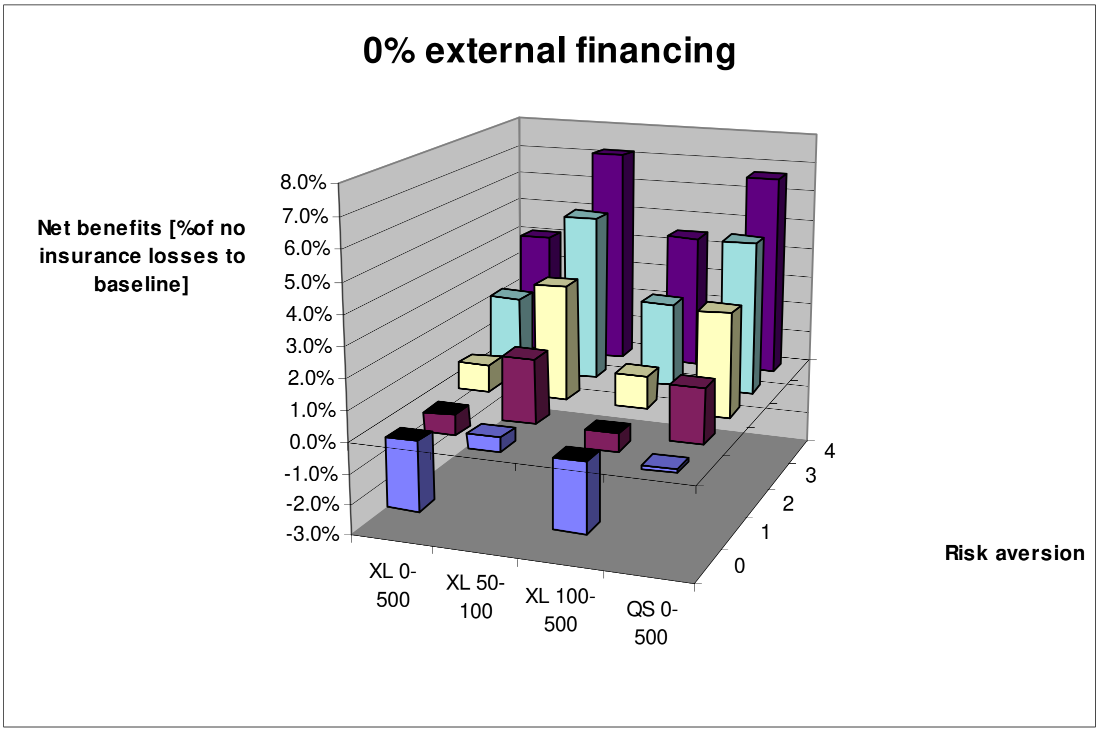
Table 35: Relative Benefits of insurance as a function of risk aversion, premium and availability of external financing (% of losses of discounted non-insurance GDP to baseline)

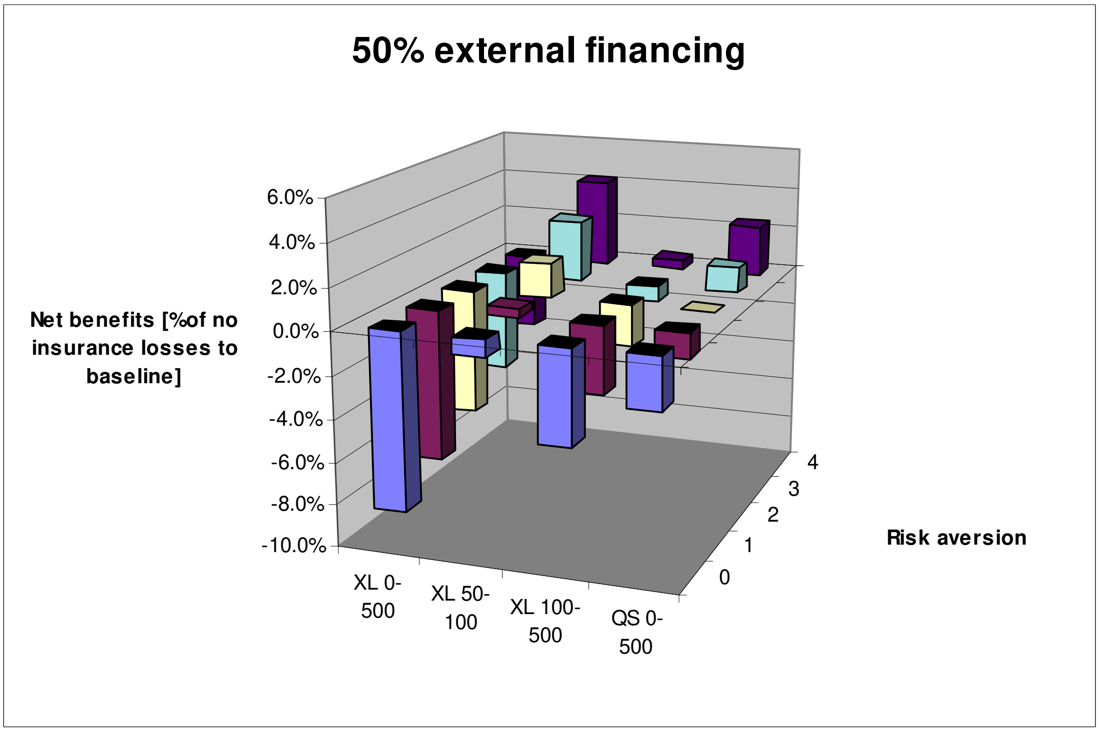
0% external financing				
Risk aversion	XL 0-500	XL 50-100	XL 100-500	QS 0-500
0	-2.3%	0.4%	-2.3%	0.1%
1	-0.7%	2.1%	-0.6%	1.8%
2	0.9%	3.8%	1.1%	3.4%
3	2.5%	5.5%	2.8%	5.1%
4	4.1%	7.2%	4.5%	6.7%
50% external financing				
Risk aversion	XL 0-500	XL 50-100	XL 100-500	QS 0-500
0	-8.4%	-0.8%	-4.5%	-2.4%
1	-7.2%	0.4%	-3.2%	-1.2%
2	-6.0%	1.7%	-2.0%	0.0%
3	-4.8%	2.9%	-0.8%	1.2%
4	-3.6%	4.1%	0.5%	2.4%

[74] The sensitivity of results to changes in the discount rate was assessed for the Honduras as well as the Argentina case study. In total, the sensitivity was small and did not change results profoundly.

100% external financing				
Risk aversion	XL 0-500	XL 50-100	XL 100-500	QS 0-500
0	-21.7%	-5.2%	-11.7%	-10.1%
1	-20.5%	-4.1%	-10.5%	-8.9%
2	-19.4%	-2.9%	-9.3%	-7.8%
3	-18.2%	-1.7%	-8.1%	-6.6%
4	-17.0%	-0.5%	-6.9%	-5.4%

E.g. for the XL 50-100 option, no risk aversion (risk parameter equals 0) and 0% external financing there is net benefit to insuring as calculated by the EV method: The NPV hedges against 0.4% of the losses of the insurance case compared to the deterministic baseline. With risk aversion, net benefits increase (as volatility, which is weighted by the risk aversion parameter, is lower for the insurance cases). For extreme risk aversion (parameter of 4), net benefits amount to 7.2%.





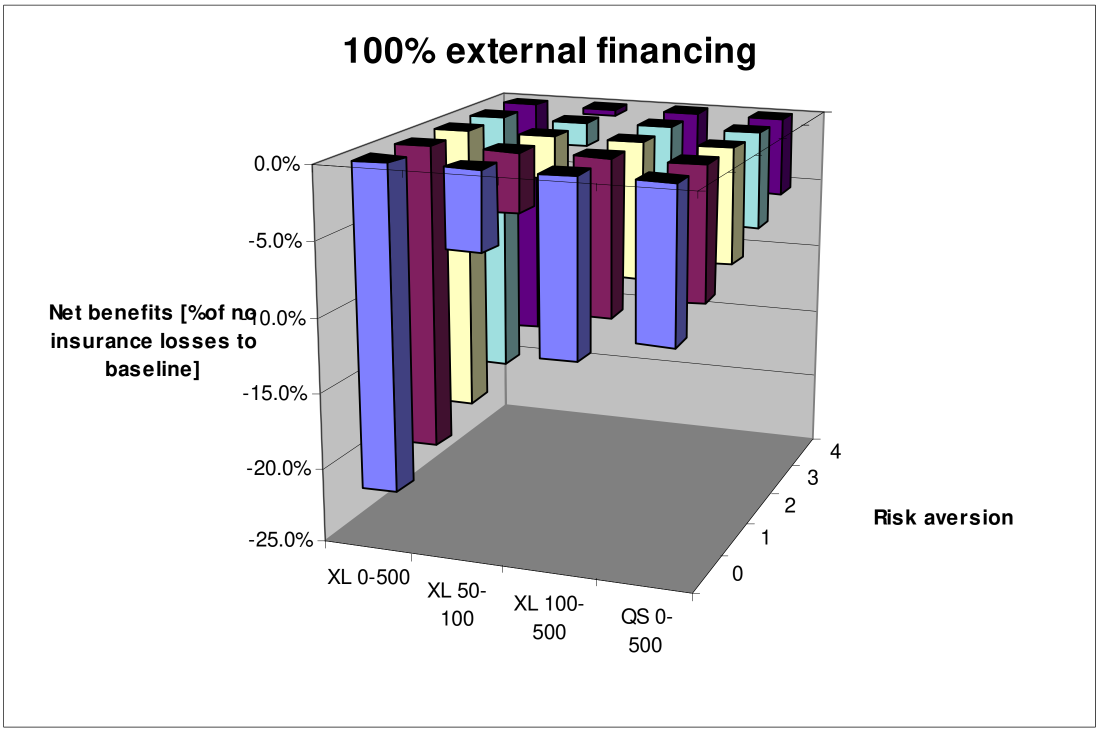


Fig. 62: a,b,c Relative Benefits of insurance as a function of risk aversion, premium and availability of external financing (% of losses of discounted non-insurance GDP to baseline)

As to be expected, net benefits of insuring were highest for the 0% external financing scenario. However, in case of risk neutrality (expected value analysis) they are only positive for XL 50-100 and QS 0-500. For the other options, opportunity costs due annual premia were higher than the benefits received from indemnity payments in case of a catastrophe. However, if some risk aversion is assumed (and variance is included in the calculations), all options become efficient. XL 50-100 and QS 0-500 maintain highest benefits

If some external financing is made available (50% scenario), the insurance options lose in desirability and benefits are only estimated for risk averse attitudes. XL 0-500 does not show any benefits for this financing scenario.

For the 100% external financing scenario, where all needed financing is granted although with a time lag of one year, all insurance options exhibit net costs.

In total, the efficiency of undertaking certain insurance arrangements for public infrastructure depends on the inflows of foreign financing. Insurance options and external financing flows are substitutes. The less “reinsurance of last resort” is provided by the MFIs the more desirable it becomes to seek protection in the private insurance market. For small inflows of external financing insurance provides net benefits as measured by GDP, for more substantial inflows, benefits become negative, there are welfare losses. The amount of risk aversion influences results considerably.

In addition to GDP other indicators may be of interest for decision-making. Table 36 lists a selection of the comparison of the different insurance options to the no insurance case for important indicators: Infrastructure stock, government deficit, and government debt in 2008. Here, expected values only are indicated.

Table 36: Sum of important indicators compared to the no insurance case (non-discounted values)

0% external financing	XL 0-500	XL 50-100	XL 100-500	QS 0-500
Infrastructure in 2008	-0.5%	-0.1%	-0.5%	-0.1%
Government debt in 2008	-9.4%	-6.4%	-5.3%	-7.0%
Deficit in 2008	-7.8%	-4.2%	-3.9%	-5.5%
50% external financing				
Infrastructure in 2008	-0.9%	-0.1%	-0.5%	-0.3%
Government debt in 2008	-7.7%	-6.1%	-3.8%	-6.9%
Deficit in 2008	-9.7%	-3.9%	-3.0%	-5.5%
100% external financing				
Infrastructure in 2008	-1.4%	-0.3%	-0.6%	-0.5%
Government debt in 2008	-7.3%	-5.4%	-3.7%	-5.6%
Deficit in 2008	-8.8%	-2.4%	-1.4%	-0.8%

Generally, the deficit and debt situation in 2008 is better in the cases where insurance was purchased. E.g. for XL 0-500 the deficit will be decreased on average by ca. 8%, 10% and 9% for the 0%, 50% and 100% external financing scenarios. Similarly, government debt will on average be reduced by 9%, 8% and 7% for the 0%, 50% and 100% external financing scenarios. On the other hand, infrastructure stock will be lower with insurance when looking at the averages: For the 0% and XL 0-500 case, there will be 0.5% less, for 50% and 100% external financing scenarios 0.9% and 1.4% less. Again, this demonstrates the trade-off financing stability (less deficit and debt) vs. return (more infrastructure stock and GDP).

11.5 Summary Honduras

In Honduras natural hazards are severe, particularly hurricane hazards. Hurricane Mitch in 1998 demonstrated the dramatic consequences. This event that destroyed ca. 18% of capital stock is considered an event less frequent than 100 years.

In the simulations, hurricane risk as well as less severe earthquake risk were considered. Events up to the 500 year events were included in the simulations. For such events, the ability of the government to finance losses to its infrastructure while providing relief to the poor was estimated. While losses due to earthquakes up to the maximum 500 year event considered here were assessed to be financeable (with one exception for the 0% financing scenario), for hurricane risk a financing gap could already occur for the 50 year event, i.e. events with an annual probability of 2%.

When incorporating risk probabilistically into economic projections for Honduras, the maximum shortfall of the sum of discounted GDP over a time horizon of 2003-2008 was substantially different from baseline GDP. It was highest for the 0% external financing scenario. If more external financing was obtained, this maximum shortfall was less severe and the volatility of GDP was decreased.

Insuring infrastructure by means of XL and QS insurance had the major benefits of reducing the financing gap. Consequently, the volatility of GDP and maximum shortfalls were reduced. On the other hand, the trade-off in terms of a loss of mean and maximum income was relatively small.

In total, Honduras is a country that is highly at risk due to natural disasters. Thus, a risk averse attitude to natural disaster risk is called for. In Honduras, this attitude already prevails as exemplified by the fact that the Honduran government is currently involved in discussions with donor organization to undertake risk transfer for public assets. In Honduras benefits to insuring infrastructure against disaster risk were found. The volatility of economic development was reduced while average losses to GDP due to opportunity costs of premium payment were relatively low.

12 ARGENTINA CASE STUDY

12.1 Socioeconomic situation

Argentina is an upper middle income country with a per-capita income of ca. 7,500 USD in 2000. Though it is a relatively rich country, there is unequal distribution of wealth and a relatively high incidence of poverty.

Table 37: Important socioeconomic indicators for Argentina (for the year 2000 unless noted otherwise)

Social
Population: 37.0 million
Surface area: 2.8 million sq. km
Population density/km^2: 13.2
Population growth: 1.1 %
Life expectancy: 74 years
Infant mortality: 18%
Urban population: 90%
Population below national poverty line: 18%
Economic
GDP: 285.0 billion USD
GNP per capita: 7,470 USD
GDP growth: -0.5%
Exports/GDP: 10.9%
Aid/GDP: 0.05%
Inflation (consumer prices): -0.8%
Unemployment: 21.5%
Present value of debt/exports: 555.1%
Capital stock: 1,300 billion USD (2002)

Source: World Bank 2000b; Freeman et al. 2002a; World Bank 2002c.

Once among the wealthiest economies worldwide during in the middle of the last century, Argentina has grown slowly since then until the 1990s and in the 1980s even suffered a period of stagnation. The 1990s were marked by adjustment and liberalization programs with privatization of state-owned industries and the opening of markets to foreign commerce in order to counter chronic public sector deficits and high levels of inflation. In 1991 the *Convertibility Plan* introduced a currency board arrangement that pegged the Argentine Peso to the US Dollar in a relationship of 1:1. On the one hand these measures have led to a sharp drop in the rate of inflation (in 1999 negative) and a stimulation of economic growth, on the other hand it has affected the poor adversely mainly via effects on labor demand when employees of state enterprises were laid off in large numbers. In 1999 18% of the population were estimated to be under the national poverty line. Also, there have been economic crises in 1995 and 1998 that have been large sources of instability and slowed economic growth. (World Bank 2000c).

Finally, the unsustainable external debt situation in 2002 culminated in another severe crisis when Argentina declared itself unable to service its external debt obligations anymore and also had given up its currency board arrangement causing a large devaluation of the Peso.

Looking at the development of GDP from the 1980s, several bumps can be detected (fig. 63).

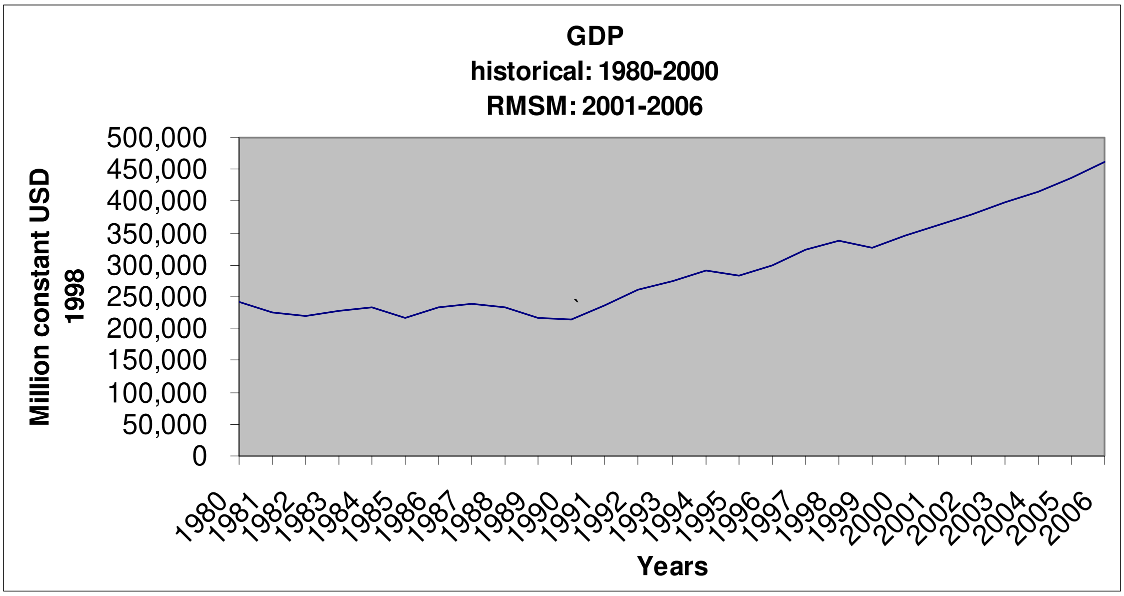


Fig. 63: GDP over last 20 years
Source: IDB/IDA 2000, World Bank 2001c.

Argentina had an average growth rate of 1.8% from 1980-1999 including several recessions over this period. The projections set the average growth rate for 2000-2006 at 5.0%, which is probably not achievable given the current crisis. The data used for the modelling are mostly from the base year 1998 and thus do not incorporate the recent dramatic social and economic events in Argentina. But, as for Honduras, the focus of this analysis is on the benefits of insurance, not on the projections per se.

The debt situation is very severe as the latest crisis is mainly an **external debt** crisis and occurred when Argentina was not able to service its enormous debt anymore. On average, the present value of debt for the period 1998-2000 was 425% of exports, clearly an unsustainable level (GDF 2002: 125). For this reason, no extra foreign borrowing for reconstruction after disasters was assumed feasible for the modelling.

In the past, the Argentine **insurance market** has been severely affected by inflation, overregulation, protectionism and mismanagement by the state reinsurance monopoly. Since the reforms administered in the early 1990s that deregulated and opened the market and brought tighter solvency requirements about, the market has become more robust and financially sound. The other side to that is however that many domestic Argentine companies went bankrupt or had to merge with other companies, and foreign companies went into the market. The market share of foreign insurers in Argentina has grown drastically. For non-life insurance it rose from about 1-2% in the beginning of the 1990s to ca. 45% in 2000 (Swiss Re 2002b: 19). Total revenues in the insurance market summed up to 6.45 billion USD representing 2.2% of GDP in 1999 (Keller 2001: 2-4). In 1999, there were about 100 reinsurers in Argentina, of which only three had active local operations. The other represented international reinsurers (Keller 2001: 7).

For Argentina, no inventory of public infrastructure assets was at hand. Therefore, top-down assumptions were used. These assumptions were based on the Honduras information in order to estimate a reasonable value for unprotected public infrastructure. Thus, a value of 9.7% of capital stock is used as infrastructure that will be insured in the model runs whereas 10% of total losses are considered already insured. Given a capital stock estimate of 1,300 billion USD for 2003 (Freeman et al. 2002a), public infrastructure in absolute terms is thus estimated at 126 billion USD. While these assumptions are debatable, the same holds true what was discussed for the Honduras case study: the focus of this analysis is on the relative costs and benefits of insuring infrastructure and the efficiency of such risk management measures. Furthermore, as will be discussed below, aggregate natural disaster risk is rather unimportant in Argentina and very small effects are calculated.

12.2 Risk Identification

Argentina is at moderate risk from natural disasters. There have been large earthquakes in the past with up to 18,000 fatalities, but today seismic risk mainly exists in sparsely inhabited regions. The main risk is flood risk in the regions of Rio Parana and Rio Uruguay of the Great La Plata basin in the north-eastern and central parts of the country. In addition, flood risk in Argentina appears to be rising with increasingly frequent and severe flood events (Penning-Rowsell 1996: 87). Major cities such as the political and economic capital Buenos Aires and the cities of Santa Fe and Resistencia are at risk of riverine floods. Fig. 64 shows a hazard map for flooding in the riverbasins of the Rio Parana and Rio Paraguay for 10, 1,000 and 10,000 year events.

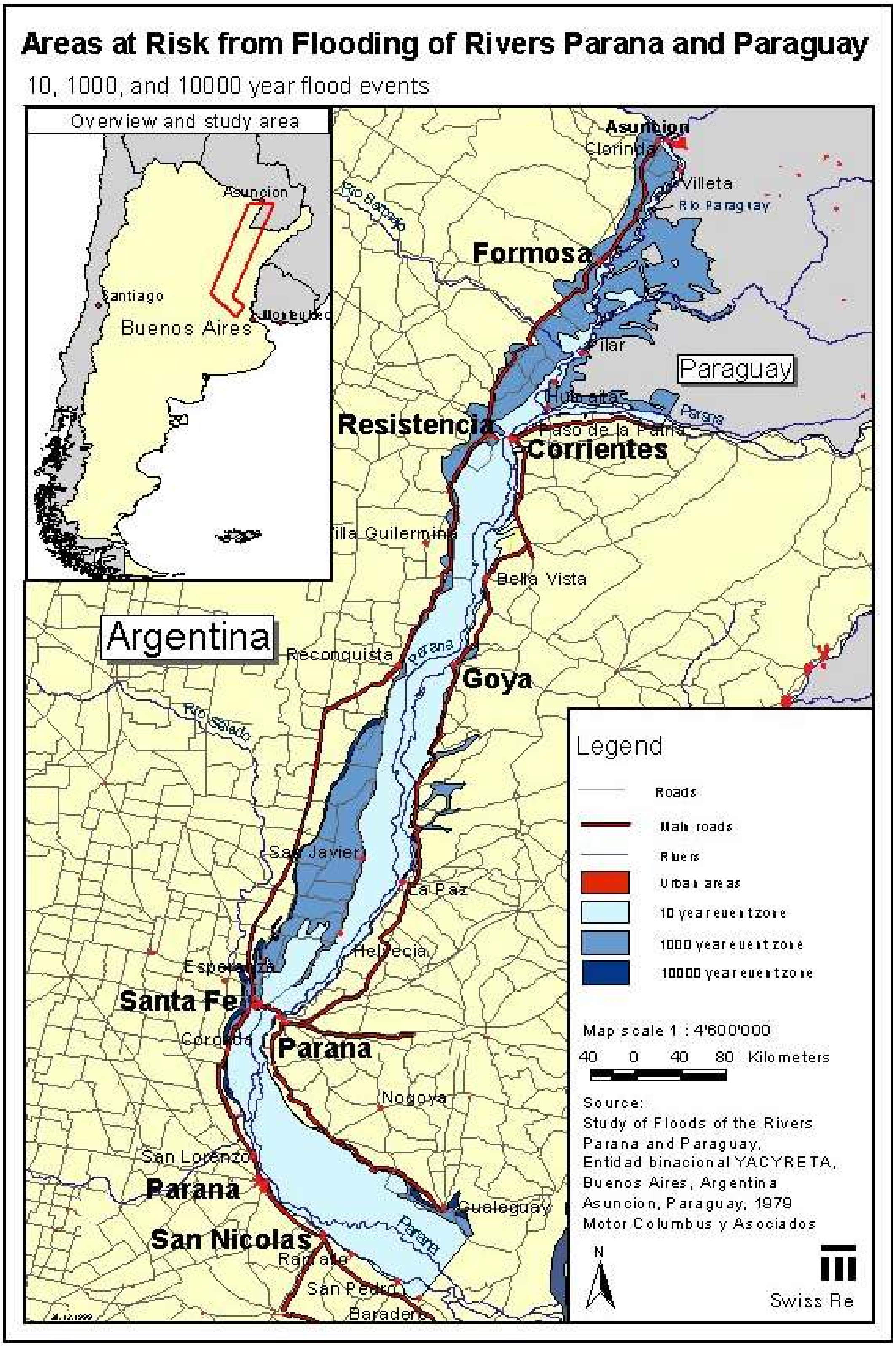


Fig. 64: Flood risk in Argentina to 10, 1,000 and 10,000 year flood events
Source: Swiss Re as described in Freeman et al. (2002a)

As many as 5 million people have been affected by these flood events in the past (flood in 1983) and losses have been up to 2.5 billion USD. The loss of life due to the flooding on the other hand has been comparatively low. Insurance density is low, and no sizeable insured losses have been reported for the major disasters (table 38).

Table 38: Major disaster events and associated impacts in Argentina

Events	Fatalities	Affected	Economic losses (Million USD)	Insured losses
Earthquake 1861	18,000	-	-	-
Earthquake 1944	10,000	120,000	100	-
Earthquake 1949	10,000	5,000	-	-
Earthquake 1977	65	-	80	-
Flood 1983	-	5,580,000	1,000	-
Flood 1983	-	250,000	800	-
Flood 1985	360	150,000	1,300	-
Floods 1998	19	360,000	2,500	-

Sources: Munich Re 1998a: 39.

Based on data from the EM-DAT data base, the next two figures show that there is also a risk of smaller events. Almost every year, an event has happened with several years having had more than one event (fig. 65).

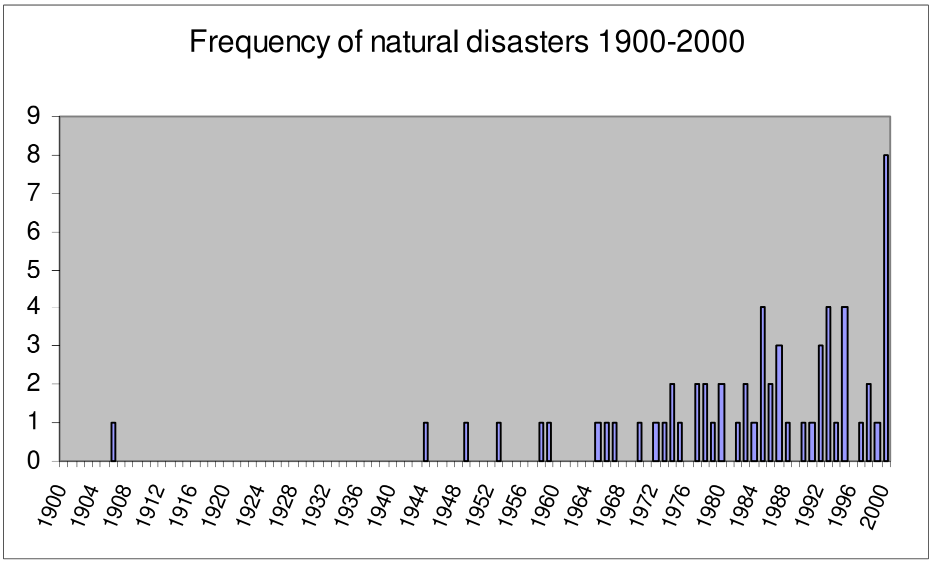


Fig. 65: Annual disaster frequency over last 100 years
Source: EM-DAT 2002

Significant economic damages have been rarer, but in a number of recent years reached or exceeded 1 billion USD (fig. 66).

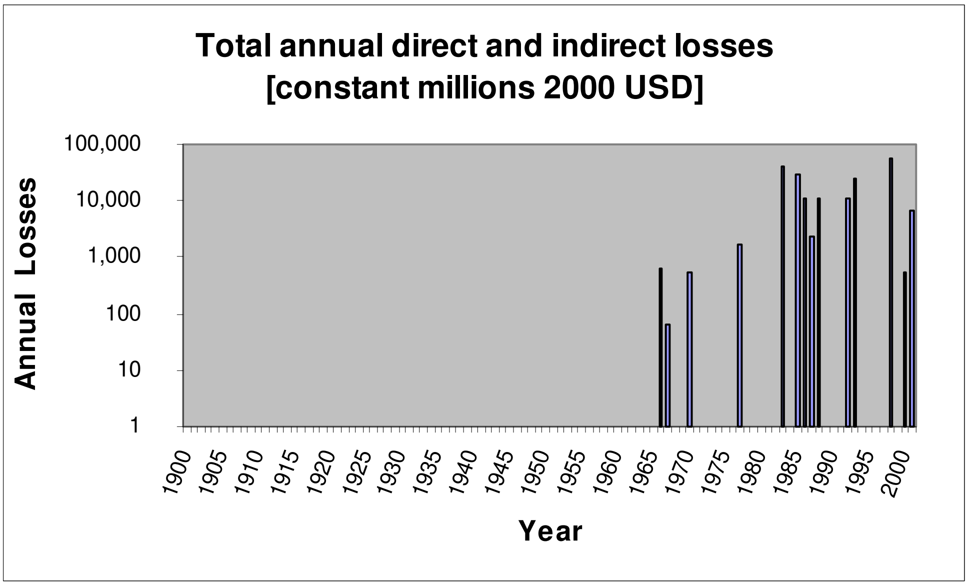


Fig. 66: Total direct and indirect losses over last 100 years
Source: EM-DAT 2002

12.3 Risk assessment

12.3.1 Direct loss exposure

As for Honduras, the risk assessment for the direct losses relies on input data from Swiss Reinsurance Company. The major source of risk identified by Swiss Re was flood risk in the La Plata river basin. Based on this information, the following direct loss estimates for disaster events with a return period of 10, 100 and 1,000 years can be established (table 39).

Table 39: Estimates of direct losses in Argentina due to flood hazard

Event (year)	Probability	% Capital stock	Mill.USD in 2003
10	0.1	0.10%	1,300
100	0.01	0.45%	5,850
1000	0.001	0.60%	7,800
E(X)		**0.025%**	**325**

Source: Fractional losses from Swiss Re as described in Freeman et al. (2002a). Absolute losses adapted to 2003.

At 0.025%, the direct loss potential for Argentina as a ratio of capital stock is twenty times smaller than for Honduras. Capital stock for 2003 was estimated at 1,300 billion USD (Freeman et al. 2002a). Thus, in dollar terms, the expected annual loss is estimated at 325 million USD. Assuming unprotected public infrastructure equals 9.7%, an annual infrastructure loss amount of 32 million is arrived at.

Using these data, a loss-frequency distribution can be fitted. Fig. 67 shows the corresponding cumulative probability curve.

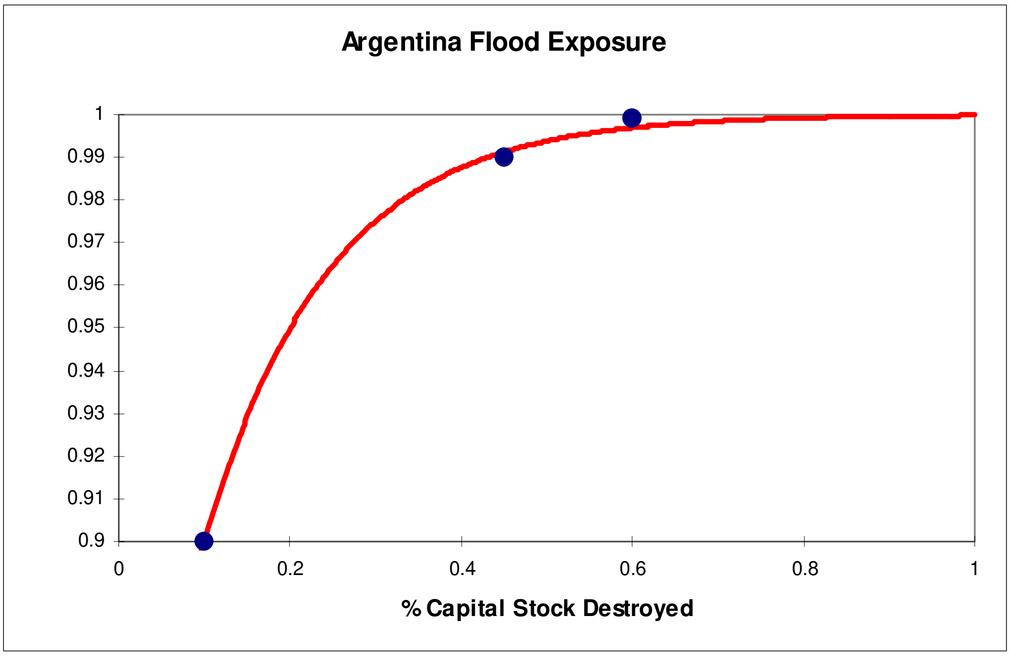


Fig. 67: Cumulative probability curve for flood risk in Argentina
Source: Freeman et al. (2002a: 49) based on data from Swiss Re.

For Argentina and direct flood risk, the Weibull distribution showed the best results in the OLS regression. The Weibull density function has the following functional form.

$$f(x;\alpha,\beta) = \frac{\alpha}{\beta^{\alpha}} x^{\alpha-1} e^{-\left(\frac{x}{\beta}\right)^{\alpha}} \quad \text{where } \alpha,\beta > 0$$

The parameters alpha and beta were estimated at 1.0122 and 0.14753 (Freeman et al. (2002a: 82).

12.3.2 Economic vulnerability

When calculating reconstruction and relief requirements due to the events assessed and financing available, no financing gaps occur for the listed events, even though external borrowing is not considered a source for additional reconstruction finance due to the debt crisis (fig. 68). Thus, the scenarios on external financing are in effect scenarios on external aid and differ only marginally between the 0%, 50% and 100% assumptions. Mainly diversion will be sufficient to finance the loss events. However, in the model runs also higher events could occur potentially causing a financing gap.

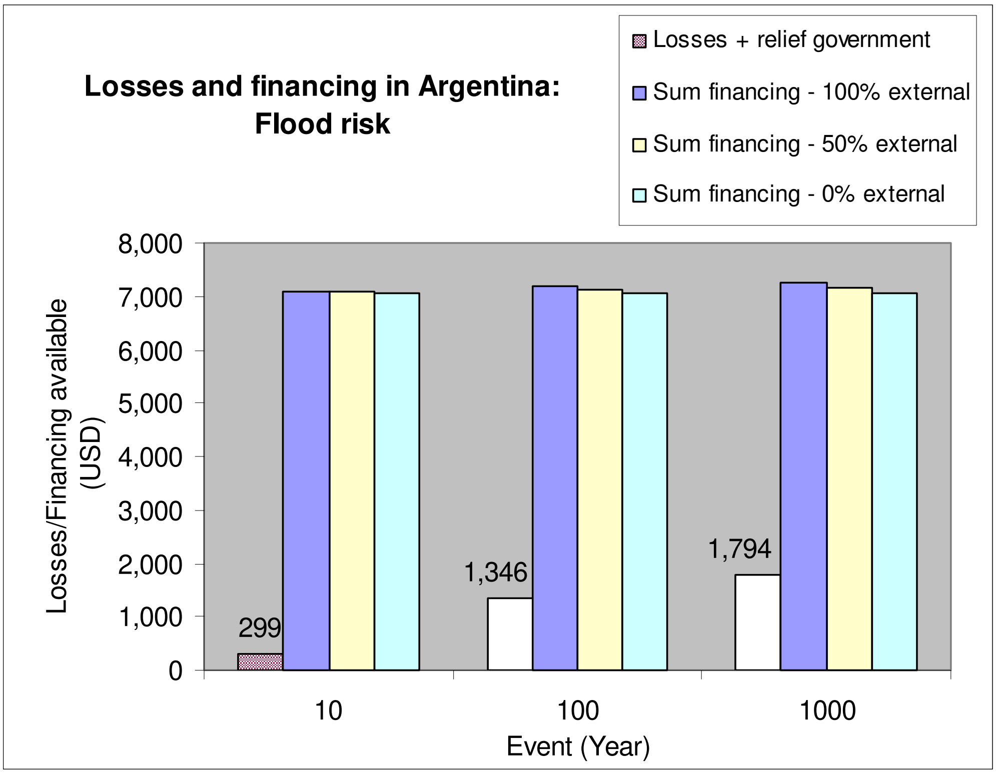
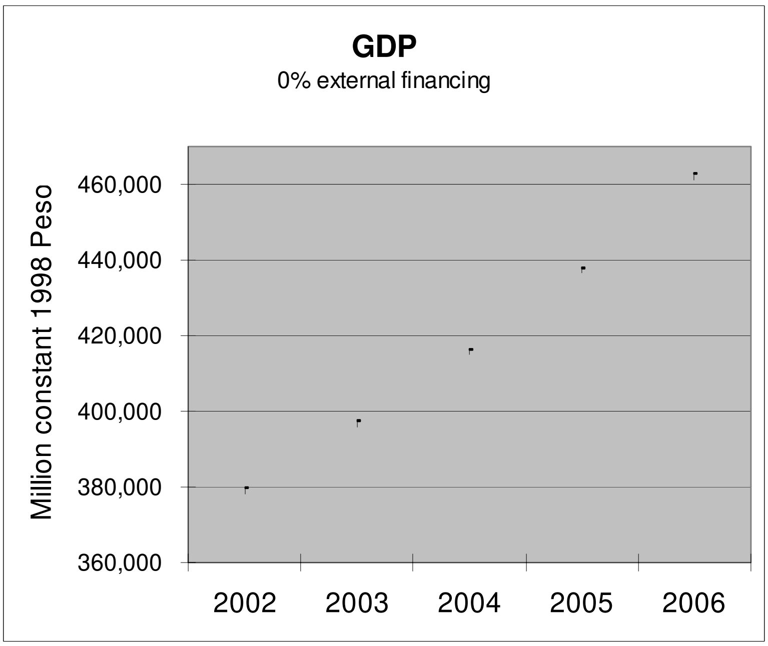


Fig. 68: Government reconstruction and relief needs, and maximum financing available for flood risk in Argentina as projected for 2003 (million USD).

12.3.3 Macroeconomic costs of disasters

Due to the considerably smaller direct loss exposure, macroeconomic effects in Argentina are largely smaller compared to Honduras. Incorporating natural disaster exposure into macroeconomic projections changes outcomes for Argentina only slightly; as well the trajectory of the worst case is almost identical to the baseline scenario that does not account for disasters (fig 69 a,b)



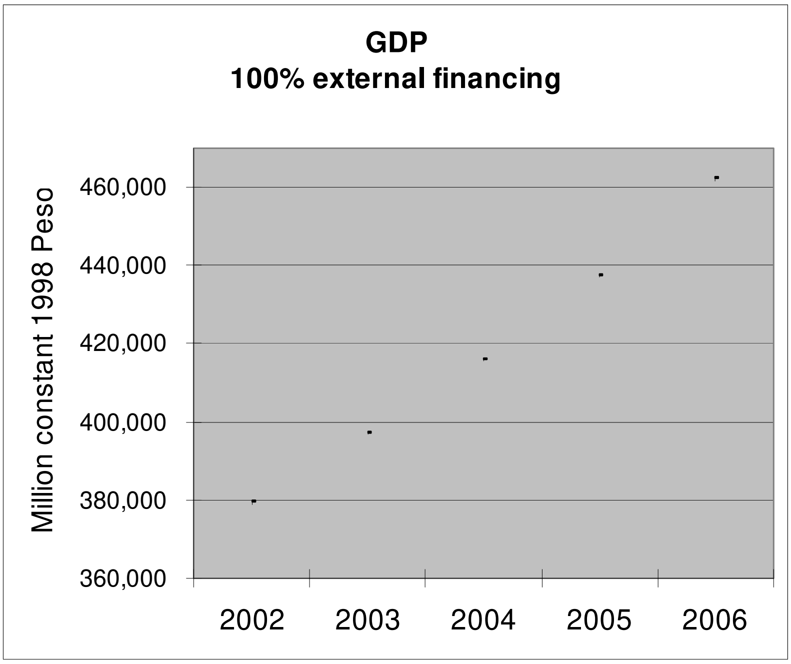


Fig. 69: a, b Volatility of GDP after including catastrophe exposure for 0% and 100% external financing scenarios

As impacts are so small, in the following, only the extreme scenarios of 0% and 100% external financing will be displayed to avoid redundancy. Table 40 summarizes the GDP effects for the sum of discounted GDP over 2003-2006.

Table 40: Change of projections of the discounted sum of GDP from 2003-2006 (million constant Peso) for 0% and 100% external financing scenarios

	0% external financing		**100% external financing**	
	Million constant 1998 Pesos	% baseline	Million constant 1998 Pesos	% baseline
Minimum	1,667,204	99.73%	1,667,344	99.74%
Maximum	1,671,721	100.00%	1,671,721	100.00%
Mean	1,671,283	99.97%	1,671,386	99.98%
Std. Deviation	653		496	

In the worst cases, due to disaster impacts, the sum of GDP could only fall as low as 99.73% and 99.74% for the 0% and 100% external financing scenarios. The mean values are almost identical to the deterministic value with 99.97% and 99.98% for 0% and 100% external financing. Also volatility as measured by the standard deviation is negligible. Thus the potential losses in terms of GDP are very small.

12.4 Risk Management

12.4.1 Costs of Insurance Strategies

Four insurance strategies are evaluated. Again the focus was on the XL options.

- XL 0-1000: Insuring all of infrastructure up to maximum credible 1000 year event.
- XL 100-1000: Insuring infrastructure layer from 100-1000 year events.
- XL 0-100: Insuring infrastructure layer from 0-100 year events.
- QS 0-1000: Insuring all proportionally for 0-1000 year events and splitting premium and claims 50%/50% between government and insurer.

Table 41: Financial costs of different insurance options for Argentina case study

	XL 0-1000 % infrastr.	XL 0-100 % infrastr.	XL 100-1000 % infrastr.	QS 0-1000 % infrastr.
Premium	0.0347%	0.0290%	0.0053%	0.0174%
Pure premium	0.0151%	0.0145%	0.0006%	0.0076%
Loading element	0.0196%	0.0145%	0.0047%	0.0098%

Also, the opportunity costs of the premium payments are rather insignificant in relation to the development of GDP (fig. 70).

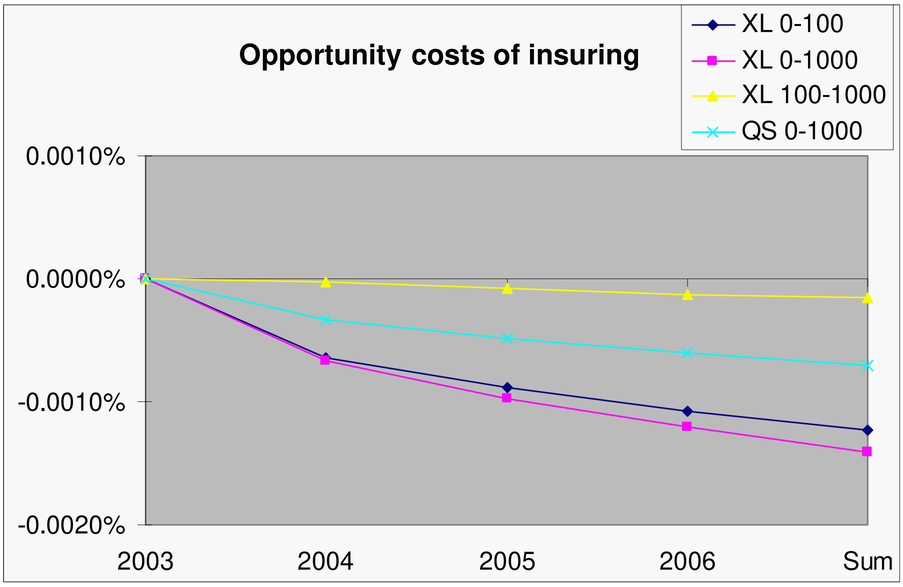


Fig. 70: Change in GDP trajectories in Argentina due to annual insurance premium payment for infrastructure 2003-2006 for different insurance strategies (assuming no catastrophe event)

12.4.2 Benefits of Insurance

Due to the small size of potential losses compared to the size of the economy and available tax revenue, no financing gap occurs for either of the 0% and 100% external financing scenarios. This already shows that there is little benefit to insuring. The change of the projections of the discounted sum of GDP from 2003-2006 (million constant Peso) for the 0% and 100% external financing assumptions for the XL 0-1000 option differs negligibly from the no insurance case as table 42 shows.

Table 42: Comparison of XL 0-1000 option with no insurance case for 0% and 100% external financing scenarios

	0% external financing		**100% external financing**	
	Million constant Pesos	Change to no insurance	Million constant Pesos	Change to no insurance
Minimum	1,667,403	0.012%	1,667,380	0.002%
Maximum	1,671,693	-0.002%	1,671,703	-0.001%
Mean	1,671,269	-0.001%	1,671,368	-0.001%
Std Deviation	628	-3.834%	478	-3.603%

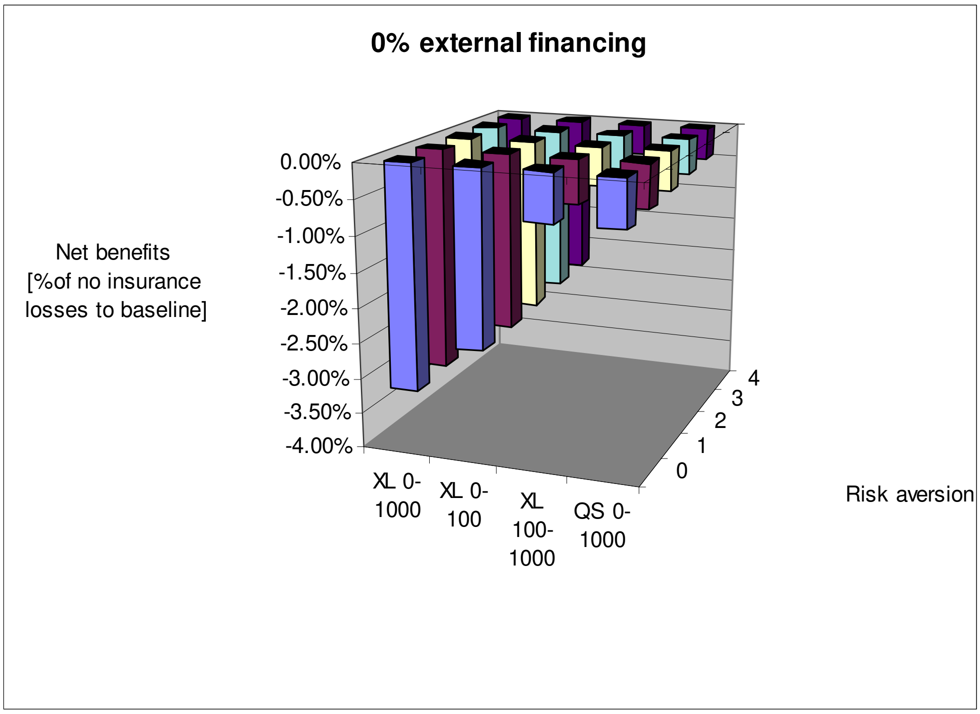
The minimal outcomes for the insurance case are only 0.012% resp. 0.002% higher for the 0% resp. 100% external financing cases than for the no insurance case. On the other hand the shortfall in the maximum and means is very low at about 0.002-0.001%. The reduction in volatility as measured by the standard deviation is higher and amounts to ca. 3.8% and 3.6% for 0% and 100% scenarios.

Relative benefits of insurance strategies

Graphically, the differences between the insurance and no insurance scenarios cannot be distinguished due to the small effects. Numerically, there is a small change with insurance as shown in table 43 and figures 71 a,b. The table lists the results for 0% and 100% scenarios for the comparison between XL 0-1000 and no insurance cases.

Table 43: Relative Benefits of insurance as a function of risk aversion and premium (% of discounted non-insurance GDP)

0%				
Risk aversion	0-1000	0-100	100-1000	QS 0-1000
0	-3.19%	-2.51%	-0.68%	-0.68%
1	-3.14%	-2.45%	-0.63%	-0.63%
2	-3.08%	-2.40%	-0.57%	-0.57%
3	-3.03%	-2.34%	-0.51%	-0.51%
4	-2.97%	-2.29%	-0.45%	-0.45%
100%				
Risk aversion	0-1000	0-100	100-1000	QS 0-1000
0	-5.37%	-4.18%	-0.89%	-0.89%
1	-5.33%	-4.13%	-0.85%	-0.85%
2	-5.28%	-4.09%	-0.81%	-0.81%
3	-5.24%	-4.05%	-0.76%	-0.76%
4	-5.20%	-4.01%	-0.72%	-0.72%



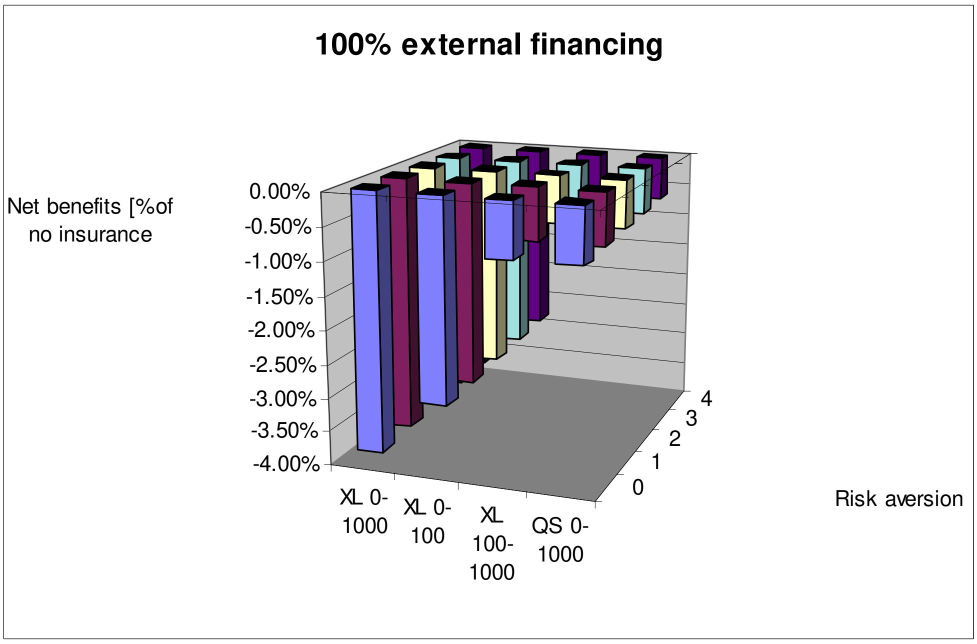


Fig. 71: a, b: Relative Benefits of insurance as a function of risk aversion and premium (% of discounted non-insurance GDP) for 0% and 100% external financing scenarios

For both external financing scenarios, no net benefit of insuring is derived for the whole range of risk aversion. The 0% scenario is better than the 100% scenario, but net benefits remain negative. The best outcomes are achieved for the insurance strategies with smaller premium payments (XL 100-500, QS 0-1000). XL 0-1000 and XL 0–100 are worse, with XL 0-1000 being the least efficient option.

Thus for Argentina, insuring infrastructure in the manner described does not produce net benefits, as the direct risk is so small and internal sources suffice to finance the losses.

12.5 Summary Argentina

In contrast to Honduras, aggregate natural disaster risk in Argentina is rather unimportant due to low natural hazard exposure, but despite moderate vulnerability. External economic vulnerability is high due to the currently ongoing external debt crisis. Consequently, no external borrowing was assumed to be feasible for the model runs. However, budget diversion and aid seem to suffice in Argentina for the government to finance its potential losses due to disasters. No financing gap will occur for the events considered feasible (up to the 1000 year event).

In the stochastic simulation the potential economic effects and volatility due to disasters were small. No financing gap occurred, and consequently no net benefit was found for the analyzed insurance strategies. Though buying insurance helps in decreasing this volatility, the necessity for reduction is less so in Argentina than in Honduras as the volatility is rather small and thus the opportunity costs in terms of investment and GDP foregone may be larger than the benefits created by the government purchasing insurance for its infrastructure.

13 OVERALL RESULTS

13.1 General conclusions

The thesis analyzed the significant economic impacts natural disasters may exert on developing countries and the viability of ex-ante disaster management, commonly termed risk management, undertaken by national governments in reducing those impacts. In particular, the viability of risk transfer by national governments of disaster risk to its infrastructure by means of reinsurance was discussed analytically as well as by developing a modelling framework.

The thesis focused on the sudden-onset events. A natural disaster was defined as an event concentrated in time and space whose occurrence is triggered by natural causes, which is referred to as hazard. The extent of damages is influenced to a high degree by anthropogenic factors that were grouped into elements exposed to risk and vulnerability of these elements. Accordingly, risk, the probability of losses occurring, was defined as a function of hazard, vulnerability and elements at risk. Furthermore, the thesis focused on the macroeconomic costs due to natural disasters: The macroeconomic costs comprise the aggregate impacts on economic variables like gross domestic product (GDP), investment and government deficit and arise due to the losses incurred by disasters as well as due to the reallocation of government resources to relief and reconstruction efforts post-disaster.

Currently risk transfer instruments are not used frequently by national governments due to the conscious or unconscious assumption of disaster risk by governments. In economic theory assuming risk by governments is suggested if risk can be shared or pooled without major difficulty. For disaster risk this applies generally to the more developed countries. On the contrary, developing countries are often not able to finance the losses, relief and reconstruction by their own means. The international donor community in their role as "reinsurer of last resort" is assisting in such cases. Even then, however, some losses will remain unfinanced and a financing gap - an inability to finance the reconstruction of losses - will occur, which creates significant developmental losses, if e.g. important infrastructure elements like roads and bridges cannot be repaired and put into use again. Also, concessional international assistance payments have been declining and the willingness of donors to finance disasters retroactively has clearly been diminishing.

In order to tackle those problems and reduce potential impacts, disaster risk management undertaken by the government was analyzed. Risk management entails planning for disasters ex-ante, i.e. before the actual occurrence of disaster events. Risk management comprises three elements:

- risk identification and assessment of potential impacts,

and two options concerned with risk control:

- mitigation, the reduction of risks by e.g. building dams or improving early warning systems,

- and ex-ante risk financing, the arrangement of risk financing measures before actual events. The most common form of risk financing is risk transfer where risk is transferred to other parties willing to share risks in exchange for a fee. Most common forms of risk transfer are insurance or reinsurance.

What concerns the risk control options, mitigation and risk transfer, mitigation has received the major share of attention and is increasingly being done today. Risk transfer by governments has rarely been done so far, but has currently become a policy issue and forms an important component of disaster management strategies particularly in Latin America and the Caribbean. The thesis analyzed the transfer of risk to public infrastructure (roads, bridges, water and sewage systems) to international reinsurance market. Because governments quasi act as insurers already as they pool risk, it is considered important to transfer risk out of the country so that the so-called covariance problem associated with natural disasters affecting entire regions at the same time is reduced. The pros and cons and costs and benefits of such a risk transfer strategy were analyzed.

Insurance premia can be substantial, generally premia will cost more than expected losses, i.e. the losses that can be expected to accrue over one year. Furthermore, these financial costs can translate into high opportunity costs if there is a lack of government funds for essential social spending or infrastructure investment; in this case the gains foregone due to paying the premium can be substantial.

The benefits of conducting risk transfer consist in the stabilization of financing flows and the reduction of the financing gap post-disaster due to the indemnity payments received from foreign insurance companies post-disaster. This allows to rebuild a larger portion of the damaged infrastructure and to rebuild more quickly as insurance payments usually arrive soon after a disaster hits whereas loan disbursements from international donors do not normally materialize before one year later.

An associated benefit of undertaking risk transfer is the transfer of covariant risk out of the country. Natural disasters can affect whole regions or even entire smaller countries (geographic covariance). As well developing countries often exhibit less redundancy what concerns important assets for producing income, such as infrastructure. Losing important elements will affect economic performance throughout the whole country (economic covariance).

Another benefit of insurance arrangements is that, as insurance premia are usually tied to the degree of mitigation measures undertaken by the risk cedent, incentives are provided to increase mitigation efforts. This is an important argument for the multilateral finance institutions which are concerned with the current degree of mitigation efforts in borrowing countries.

13.2 Methodological approach developed to analyze economic costs of natural disasters and benefits of risk management

In order to study these issues properly and compare the costs with the benefits, a stochastic simulation approach was developed in addition to the analytical discussion of the relevant issues. The basis for the modelling approach used in the thesis was developed at IIASA in collaboration with World Bank and Swiss Reinsurance Company in which the author participated. The modelling combined probabilistic information on the direct losses of natural disasters with a macroeconomic projections model, the Revised Minimum Standard Model (RMSM-X) of World Bank. RMSM-X is a flow-of funds model and is standardly used to establish macroeconomic projections for World Bank client countries.

The methodology integrated probabilistic future disaster losses into a macroeconomic projection model. Expected severity and frequency of catastrophic events were combined with prevalent macroeconomic conditions and vulnerability. There are two steps to the estimation process. The first one entails the estimation of the direct, stock losses of a country by combining information on natural hazards with physical vulnerability data on a country's capital stock. This information came to a large degree from Swiss Re and was used to derive loss-frequency distributions. Based on this information, random catastrophe shocks were generated via Monte-Carlo simulation. The second step involved integrating these stock loss estimates with the macroeconomic model representing the economy and inherent vulnerability. Outputs are macroeconomic flow impacts. While the direct losses give account of the magnitude of potential catastrophes, the macroeconomic costs represent the full consequences that catastrophes may cause to an economy.

This modelling approach was revised and extended for the thesis. One major extension was the explicit accounting for economic vulnerability which was defined for the present purposes as the ability to finance relief and reconstruction post-disaster; furthermore an *insurance module* to analyze the costs and benefits of undertaking risk transfer was developed. Proportional (*excess of loss*) and non-proportional (*quota-share*) reinsurance arrangements for infrastructure were studied in a simplified form. Also, a Cost-Benefit analysis (CBA) approach was used to systematically compare the costs and benefits in order to derive the net benefits of engaging in risk management.

In the modelling approach, risk transfer was characterized as a tradeoff: volatile, but potentially higher economic growth is traded-off against more stable but lower growth as resources are used for paying the insurance premium. More concretely, in the case of insuring less government funds for investment and government spending are available annually, thus GDP is decreased constantly while on the other hand cover against natural disasters losses has been secured. In the case of an event, losses can be financed to the extent insurance has been bought, indemnity payments arrive generally quickly and the reconstruction of important assets can be undertaken thus reducing developmental impacts.

In order to analyze this trade-off systematically, a CBA approach was employed. In this macroeconomic analysis, GDP was used as the main welfare indicator to estimate potential net benefits arising due to risk management measures. Risk was accounted for by using an *Expected utility* approach which is the standard approach used in economics for decision-making under risk. In this framework, a *Mean Variance* (EV) approximation was employed that basically relies on the mean and variance weighted by a parameter representing the decision-maker’s risk preference.

The main objective of the thesis was to establish a platform to provide such information on the costs due to disasters and the costs and benefits of disaster risk management. The focus was particularly on determining the kind and magnitudes of the costs and benefits of ex-ante risk financing by means of risk transfer (particularly insurance) by governments in developing countries. The final objective was to provide insight into the specific conditions where risk transfer may constitute an option that provides net benefits and increases social welfare.

13.3 Case studies

In order to apply the developed modelling framework and analyze the usefulness of risk transfer strategies for public infrastructure in developing countries, two case studies were conducted on countries with a different record of disasters events as well as of different economic capability: Honduras, a low income country, and Argentina, an upper middle income country. Three different excess of loss (XL) options and one quota share (QS) arrangement were studied for each of the case studies.

It was shown that under certain conditions, risk transfer could be welfare enhancing and provide positive net benefits. A major parameter of importance for the simulation was the availability of financial assistance of the international donors. As the willingness of the donors has been decreasing and unstable over the past, this parameter was varied from 0% to 100% foreign financing disbursed of what would be necessary for complete rehabilitation of lost capital stock. Another parameter that was varied was the assumed risk aversion parameter for which a range between 0 (risk neutral) and 4 (extremely risk averse) was used.

In **Honduras,** natural hazards are severe, particularly due to hurricane hazards. Hurricane Mitch in 1998 demonstrated the dramatic consequences. This event that destroyed ca. 18% of capital stock is considered an event less frequent than 100 years. In the simulations, hurricane risk as well as less severe earthquake risk were considered. Events up to the 500 year events were included in the simulations. For such events, the ability of the government to finance losses to its infrastructure while providing relief to the poor was estimated. While losses due to earthquakes up to the maximum 500 year event considered here were assessed to be financeable with one exception only, for hurricane risk a financing gap could already occur for the 50 year event, i.e. events with an annual probability of 2%.

When incorporating risk probabilistically into economic projections for Honduras, the maximum shortfall of the sum of discounted GDP over a time horizon of 2003-2008 was substantially different from baseline GDP. It was highest for the 0% external financing scenario. If more external financing was obtained, this maximum shortfall was less severe and the volatility of GDP was generally decreased.

Insuring infrastructure by means of XL and QS reinsurance had the major benefits that the financing gap was reduced for all financing scenarios. Consequently, the volatility of GDP and the maximum shortfall were reduced. Furthermore, the maximum shortfall of GDP was less severe. On the other hand, the trade-off in terms of a loss of mean and maximum income was relatively small.

When assessing the benefits of the different insurance options, positive net benefits were calculated for the 0% external financing scenario already for risk neutrality or moderate risk aversion. For the 50% scenario, higher degrees of risk aversion were necessary to derive net benefits, whereas for the 100% scenario insurance brought about negative benefits irrespective of the exhibited risk preference.

In total, Honduras has to be considered a country that is highly at risk due to natural disasters. Thus, a risk averse attitude to natural disaster risk is called for. In Honduras, this attitude already prevails as exemplified by the fact that the Honduran government, among other risk management measures, is currently involved in discussions with donor organization to undertake risk transfer for public assets. In Honduras benefits to insuring infrastructure against disaster risk were estimated. The volatility of economic development was reduced while average losses to GDP due to opportunity costs of premium payment were relatively low.

In **Argentina**, natural hazards are less severe, although the floods in the past have affected a large fraction of the population; economic losses however were rather small compared to overall economic output. Economic vulnerability in Argentina is moderate but increasing, as the ongoing debt crisis demonstrates. As Argentina is heavily indebted, it was assumed that no external borrowing would be feasible. Thus the external financing scenarios for Argentina reduced to scenarios about external aid.

Only flood risk was incorporated into the modelling. Though there have been earthquakes in the past, earthquake risk predominantly endangers sparsely inhabitated regions today. For flood risk, events up to the 1000 year event were considered. Potential direct losses were small in relation to capital stock. No financing gap was found for the events up to this worst case.

Consequently, when incorporating risk probabilistically into economic projections for Argentina, potential macroeconomic impacts and the volatility around the mean were small. The maximum shortfall of the sum of discounted GDP over a time horizon of 2003-2008 did not significantly differ from baseline GDP.

No benefit was found for the different insurance options for the different external financing scenarios and varying risk aversion parameter owing to the fact that the ability to finance disaster losses in Argentina seems to suffice and no financing gap occurred.

13.4 Insights and recommendations gained from case studies

A number of insights were derived from the case studies: Disasters can cause large economic impacts and hamper socioeconomic development in some developing countries considerably. The losses as e.g. measured by GDP can be substantial. depending on the degree of the hazard and vulnerability and on the elements at risk. External financing in the form of aid and concessional and market rate borrowing were identified as major variables of importance.

Due to the low-probability-high consequence characteristics of natural disasters, the average impacts (as measured by expected values) due to disasters are small compared to the baseline projections without accounting for natural disaster risk. The extremes need to be assessed as natural disasters are extreme events by nature. Particularly for some countries that are or should be risk averse to natural disaster risk, volatility as e.g. measured by variance needs to be factored in in decision-making.

Insurance can be a viable risk management tool to decrease the risk to an economy. Reinsurance hedges against the extreme outcomes and volatility. The risk is not reduced, but rather transferred to the insurance sector, which causes important costs triggering opportunity costs in the economy. These can be substantial in poorer developing countries where there is a general lack of financing for important development projects. Thus, there is a trade-off between growth and stability: Lower growth and less funds for developmental objectives are traded-off for more robustness of development when extremes are hedged. In total, such risk transfer arrangements may help in achieving a more robust development pathway for an economy and in decreasing economic volatility.

Insurance is a substitute to uncertain external financing. Both sources of financing help in reducing the macroeconomic impacts to be suffered post-disaster. If enough external financing is available, the benefits of undertaking insurance are decreased. However, today external financing for regular development efforts and post-catastrophe efforts is often insufficient. Thus, it is necessary to plan for the cases when not all external financing necessary to continue growth as planned can be obtained.

In total, the modelling approach is meant to provide insight into the costs of disasters on economies and the costs and benefits derived from risk management measures, in particular insurance. In a stylized manner, the costs and benefits of transferring all risk to public assets to foreign insurers was studied. In the present form, the modelling approach should no be interpreted as a decision tool that can be used for actual policy implementation, e.g. like answering the more realistic question which specific assets to insure.

13.5 Detailed chapter summary

13.5.1 Part I: Analytical section

In **Chapter 2** the characteristics of natural disasters were discussed and a natural disaster was defined as an event highly concentrated in time and space whose occurrence is triggered by natural causes, but the extent of damages influenced to a high degree by anthropogenic factors. The focus on the sudden-onset events was established due to the very substantial political interaction component involved in the slow-onset events like droughts and famines. The main determining factors of disaster risk were listed. These were natural hazard, vulnerability and elements exposed to the specific hazards. It was shown that there has been an increase of events and risk attributable to an extent to increases in the value of the exposed elements mainly through population growth and increases in welfare. Also, vulnerability has increased and climate change is forecasted to increase severity and frequency of hazards occurring.

Next, the differential impacts of disasters on developed and developing countries were examined in **chapter 3**. Whereas the more developed countries are usually able to cope with disasters, less developed countries – when development was measured by GDP – showed significant impacts. In general, fatalities due to natural disasters are significantly higher in these countries than in the more developed ones. Concerning the economic impacts, the empirical evidence on the different kinds of impacts was presented. What distinguishes developing countries from the more developed ones, is the fact that in these countries macroeconomic effects occur whereas there usually are no macroeconomic effects in the industrialized economies.

In **chapter 4**, the terms disaster management and risk management were introduced. Disaster management encompasses a variety of measures taken before, during and after disasters; it denotes the management of disaster risks as well as the consequences of disasters. Three phases can be distinguished in disaster management: the pre-disaster phase, the disaster phase and the post-disaster phase. Accordingly, efforts to deal with disaster risk and the impacts can be separated into the categories risk management (ex-ante), relief (during) and rehabilitation and reconstruction (ex-post). The focus of the thesis was on ex-ante risk management. Risk management analyzes the risk situation ex-ante and aims at reducing the risk and potential losses before events. There are four areas that can be distinguished: Risk identification and assessment where the risk situation and potential impacts are assessed, risk mitigation is concerned with risk reduction and risk financing dealing with the ex-ante financing of risk. Furthermore, it was considered necessary to evaluate risk mitigation and risk transfer measures e.g. by means of Cost-Benefit analysis.

It was outlined that traditionally the main effort in the disaster management field has been on ex-post approaches, but currently a shift in paradigm is being advocated towards more emphasis on ex-ante risk management measures due to growing awareness that disasters are not mere "acts of God" beyond human influence.

Chapter 5 dealt with risk financing and the issue of risk aversion: The prevailing attitude – implicitly or explicitly - towards natural disasters in developing countries is one of risk-neutrality, i.e. the attitude that this kind of risk can be borne without major difficulties. The theoretical underpinning for this attitude was provided by Arrow and Lind in 1970 however referring mainly to larger developed countries. Most developed countries assume (disaster) risk, for them the Arrow and Lind theorem seems to be valid. These countries are able to pool or spread risk so that individual risk is negligible. However, the Arrow and Lind theorem may not apply for a number of developing countries subject to high natural disaster risk and with lesser means at disposal of spreading or pooling the risks they are exposed to. Especially the second argument of the risk spreading capacity of governments and the resulting individual cost being negligible was debated. Three countries' ability to assume and spread natural disaster risk was compared: The USA, and the two case study countries Honduras and Argentina. It was shown that whereas the USA and Argentina were able to bear risk by their own economic means, for Honduras this ability was very limited. This was also exemplified for Honduras after Hurricane Mitch when aid measured in terms of GDP almost tripled from 6% to 15%.

Furthermore, it was shown that rather than being able to finance disaster losses by their own means, in reality, a number of developing countries post-disaster have to rely on external aid or loans from the international donor community, which thus acts as *reinsurer of last resort.* However, this kind of financing is volatile and decreasing, and increasingly the Multilateral Finance Institutions are promoting the management of disasters *before* the occurrence of actual events (*ex-ante* instead of *ex-post* approach). For disaster loss financing, this implies arranging the financing of risk before actual events occur instead of waiting for losses to occur and then trying to obtain the necessary financing resources.

Ex-ante risk financing instruments were discussed in **chapter 6.** The chapter focused on the role of risk transfer, in particular insurance and reinsurance, for reducing the burden due to natural disasters in general and as an option for governments. First a number of risk financing instruments were discussed and compared: These were contingent credit, the creation of a fund and risk transfer by means of insurance and reinsurance. These ex-ante risk financing instruments may be arranged before a catastrophe providing needed liquidity for relief and reconstruction after a disaster. Insurance and reinsurance are by far the most common instruments and were focussed on in the following.

The mechanism of insurance and reinsurance is the same and consists of a risk cedent receiving indemnification from another agent in exchange for a fixed payment by the risk cedent. Whereas households and firms insure with an insurer, insurer reinsure their portfolio of risks with a reinsurer and reinsurer share risks with other reinsurers, so that risks are spread as widely as possible. The insurance market is based upon the *Law of Large Numbers* which states that the variance of average claim payments to the insured decreases as the number of policies increases. Thus, premiums become calculable with an increasing degree of confidence and risks can be transferred.

For the purpose of the thesis and the modelling in the following, insurance and reinsurance were both referred to as insurance due to the same underlying principle.

Concerning the sharing of disaster losses, risk transfer arrangements - although rarely used by governments today - are currently under investigation for transferring the risk to public assets. Particularly in Latin America and the Caribbean, some countries are currently deliberating whether to insure their infrastructure, hospitals and schools. In such an arrangement a government would take the place of an insurer, while pooling the large number of public assets it owns. Consequently, the further cession of this risk would occur to the international reinsurance market that generally tries to spread risk as widely as possible. Public assets are "special" in that they have high significance for socioeconomic development and are owned by the government.

On the other hand, while insuring hedges against shortfalls in loss financing post-disaster, there are considerable costs associated with paying insurance premia on an annual basis. Insuring was defined as a trade-off between economic growth and stability of growth. Paying insurance premia on an annual basis causes opportunity costs, e.g. in terms of GDP as these funds have to be diverted from important developmental projects. On the other hand, stability is granted to the government in case of actual disaster events and the risk of financing gaps occurring is kept low as indemnity payments arrive immediately post-disaster; thus reconstruction and relief are not delayed and economic development will be more stable than without insurance arrangements.

The magnitude of this trade-off was discussed as being largely dependent on the existing economic vulnerability of a country which was here measured by the concept of the disaster loss financing gap. The financing gap was defined as that amount of losses that remains unfinanced post-disaster due to the lack of financial resources. The greater the probability of such a gap and the associated economic costs, the higher the benefits due to engaging in insuring arrangements.

13.5.2 Part II: Modelling framework

In order to analyze this trade-off and the magnitudes in a dynamic manner, a modelling approach was developed in the second part of the thesis. The first part of **Chapter 7** discussed the small literature on the existing modelling approaches and the shortcomings of this modelling. Generally, the existing models are rudimentary, use ex-post information on disasters, do not examine vulnerability and hazard independently and do not account for external and internal resources for reconstruction financing in isolation.

Responding to these shortcomings, the following issues were addressed in the modelling approach developed:

- The macroeconomic modelling approach was based on a functional model that is standardly employed in policy analysis for developing countries. This model allows to make use of best available and detailed data on the analyzed individual economies.
- For assessing direct disaster risk, which serves as an input to the modelling, information on the current direct risk exposure was used. This information is based on state-of-the-art hazard modelling, and gives adequate account of the direct disaster risk that the case studies countries are currently exposed to.
- Economic vulnerability was isolated and assessed on a country-specific basis.
- Data from empirical studies were used to derive important assumptions for the model.

Overall, the modelling approach differs from existing research in that it models hazard and vulnerability in a dynamic fashion, assesses the current disaster risk the respective countries are exposed to, uses an operational macroeconomic model as a platform and allows to study several risk transfer options for ceding infrastructure risk to the insurance markets.

In more detail, the approach comprised the following features:

- An analysis of the costs of disasters on the economy using the RMSM-X macroeconomic projections model of World Bank. The foundation for this work was laid at IIASA, where the author was a co-author. Based on stochastic disaster shocks the impacts on macroeconomic variables are examined. This approach has been extended for a fuller analysis of vulnerability as well as for the representation of the insurance purchase. The approach measures flow impacts resulting from stock losses.

- The modelling of the kind and degree of potential macroeconomic impacts as depending on hazard as well as on prevalent economic vulnerability.
- For the hazard side, information from Swiss Reinsurance Company was relied upon, which measured important hazards in the respective countries and allowed to estimate loss-frequency distributions for the direct loss exposure. Direct loss exposure served as the input to the model and to a degree determined the macroeconomic impacts suffered.
- Economic vulnerability was measured as the ability to finance the reconstruction of lost capital stock. The term financing gap was introduced which indicates the lack of financing available to completely rebuild lost capital stock.
- The estimation of the financial and opportunity costs and benefits of disaster risk management, particularly as they relate to insurance.
- Specific analysis of insurance options of undertaking risk transfer by means of proportional quota-share (QS) and non-proportional, excess of loss (XL) reinsurance. In QS reinsurance risk cedent and reinsurer split premia and claims according to a contractually-defined ratio. In the dissertation, it was assumed that this ratio was 50%. XL reinsurance is more typical for natural disaster risk and was considered more extensively in the thesis. In XL reinsurance, certain layers of risk stretching from a lower limit (*attachment point*) to an upper threshold (*exhaustion point*) are insured.

In order to systematically study the costs and benefits calculated by the macroeconomic model and finally evaluate its cost-efficiency, a Cost-Benefit method was adapted. This thesis outlined a method for analyzing the efficiency of investments into risk transfer and risk mitigation for natural disaster risk. Risk transfer was defined and analyzed as a secondary project that secures the outcomes of the primary, main investment projects. **Chapter 8** laid out the general features and theory behind Cost-Benefit Analysis. CBA is standardly used by governments or public institutions to analyze the cost-efficiency of new investments. Usually, CBA is done for the analysis of individual projects, often infrastructure projects, on the microlevel, as e.g. assessing the economic viability of building a new highway. In this thesis, a project was defined in a more aggregate way as the transfer of risk to all of public economic infrastructure. Consequently macroeconomic indicators were used to evaluate the cost-efficiency of such a project.

Chapter 9 discussed the adaptation of CBA in the context of risk. It was proposed that if sufficient data on disaster risk are available, a probabilistic rather than a sensitivity or ad-hoc approach to measuring the impacts should be chosen. Thus a CBA method was elaborated in the context of risk. The chosen approach is based on the *Expected Utility* (EU) framework. The EU framework is the standard method of dealing with risk in economics. As it was not feasible to establish a utility function representing the preferences of the representative decisionmaker, the *Mean-Variance* (EV) method was chosen as an approximation, which is a common procedure in decision-making in economics. The EV method basically relies on the mean and variance of the outcome variables and weights the variance by a risk aversion parameter. Thus, the method accounts for the average impacts of catastrophes as well as for the extremes and volatility. It also considers the ability to cope with disasters by including the risk aversion parameter. If there is (perceived) risk neutrality, the analysis can be reduced to calculating averages. In this fashion the risk-return tradeoff involved in buying insurance can be modelled. The magnitude of the trade-off can be influenced by decision-makers themselves by deciding upon a proper risk aversion parameter. Thus, the method chosen bears resemblance to the determination of the insurance premium by the insurance suppliers where in addition to the expected losses, insurance pricing includes a loading element accounting for the variability of risk (as well as for transaction costs and profit margin).

Specific about this analysis is:

- It is based on the macroeconomic level evaluating the aggregate economic impacts. Usually, CBA is undertaken on the microeconomic level, examining the impacts on consumers and producers in specific markets.
- Usually primary projects, typically investments into infrastructure, are evaluated in CBA. This analysis focuses on secondary projects, which secure the benefits of primary projects. Secondary projects can be prevention or risk transfer measures, here risk transfer measures were analyzed.
- It accounts explicitly for risk and risk aversion.
- CBA was applied to insurance for infrastructure against natural disasters on a macroeconomic level. This kind of application has not been done yet to the knowledge of the author.

In total, the modelling framework developed allows to analyze the costs and benefits of undertaking risk management, in particular of buying insurance. The approach developed is not meant to be used as a decision-making tool for which more micro linkage would be necessary, but may help in informing about the trade-offs and magnitudes involved in disaster risk management.

13.5.3 Part III: Case studies

In the case studies part, the methodology was applied to assess the potential macroeconomic costs due to natural disasters and the benefits due to insuring public assets for two case study countries in Latin America: Honduras and Argentina.

In **chapter 10** a short summary of the situation with respect to natural disaster risk was given. The Latin America and Caribbean (LAC) region is very prone to natural disasters, it is the second most risky world region. In addition, the economies in the LAC region are highly volatile. Over the last four decades the volatility of real GDP has been twice as high in the LAC region as in industrial economies due to large external disturbances from global goods and financial markets combined with shallow domestic financial and insurance markets and volatile monetary and fiscal policies.

Chapters 11 and 12 analyzed the potential economic impacts of natural disaster and the benefits of risk management in Honduras and Argentina.

Both countries are economically vulnerable. Honduras is highly vulnerable. It is classified as a highly indebted poor income (HIPC) country with a per-capita income of 850 USD in 1999 and an incidence of poverty of 53% of its population below the national poverty line. Argentina is moderately, but increasingly vulnerable. It is a middle income country with a per capita income of ca. nine times that of Honduras at ca. 7,600 USD. 18% of the population live in poverty. However, Argentina's debt situation has to be considered probably even more severe than Honduras', as Argentina as of the time of writing was unable to service its foreign debt.

Natural hazard exposure in the two countries is very different: In Honduras with expected annual losses of ca. 0.5% of capital stock it is about twenty times higher than in Argentina where this figure amounts to 0.025% of capital stock; extreme events in Honduras are projected to destroy as much as 31% of capital stock (500 year storm and flood event) whereas in Argentina the maximum feasible loss considered is considerably smaller with a loss of 0.6% of capital stock (1000 year earthquake event).

When combining direct loss exposure and economic vulnerability, for Argentina natural disaster risk is not significant while Honduras faces a very difficult situation as relates to natural disasters. This was also demonstrated by the impacts of Hurricane Mitch in 1998 that was considered a 100 year event, destroying about 18% of capital stock and causing large impacts that still remain a heavy burden for the country.

Accordingly, the stochastic model simulation projected large potential impacts for Honduras with high volatility. For the 0% external financing scenario, the minimum of the discounted sum of GDP over the period 2003-2008 could fall as low as 84.3% of baseline GDP, thus amounting to a 15.7% loss. However, such large losses were considered rare as the standard deviation of 3,175 million Lempira showed, but they remain a possibility. The average change to the discounted sum of GDP over the period 2003-2008 was small at -0.5% of baseline GDP. For the 100% scenario, where all necessary external financing was assumed to be available, the worst case for the sum of GDP was less severe than in the 0% scenario with a loss of about 7% only compared to baseline GDP over the period 2003-2008. The average outcome was a bit higher than the 0% scenario with 99.8% of baseline GDP. Volatility as measured by the standard deviation was substantially smaller and reduced by about 50% compared to the 0% scenario. These two scenarios outlined the possible range of impacts in Honduras. Actual financing can be expected to fall in between these two extremes.

A number of non-proportional excess of loss and proportional quota share reinsurance options were assessed for Honduras in terms of their efficiency for reducing the impacts of disasters: These were the *excess of loss* (XL) options with covers for the 0-500, 50-100 and 100-500 loss layers. Also, one proportional *quota share* (QS) option, where claims and premium were assumed to be split between risk cedent and reinsurer equally for all losses, was studied. These insurance instruments generally achieved a reduction in the financing gap compared to the no insurance case.

Accordingly, these instruments helped in reducing disaster impacts on infrastructure and capital stock. Of final interest was to analyze the social costs and net benefits as exhibited by the change in GDP with and without insurance. The sum of GDP over the studied time horizon was 2.0 percentage points higher for the 0% financing scenario. For the 100% scenario, this benefit was lower at 0.3 percentage points.

Net benefits as calculated by the formula based on the EV method, were mostly positive for the 0% external financing scenario. For risk neutrality (risk aversion parameter of 0), the XL 50-100 and QS 0-500 options showed net benefits. These benefits increased with increasing risk aversion because volatility as measured by variance was generally lower for the insurance options. With non-zero values for the risk aversion parameter, the variance discounted the expected values. Also, the other options XL 0-500 and XL 100-500 achieved net benefits with increasing risk aversion.

For the 50% external financing scenario only the XL 50-100 and QS 0-500 options were estimated to have net benefits for risk aversion. For risk neutrality (without accounting for volatility), there were no net benefits. For the other options, the opportunity costs coupled with sufficient financing inflows from abroad made risk transfer less cost-efficient. Even with rising risk aversion, these options did not provide positive net benefits. For the 100% external financing scenario, all options were assessed to incur negative benefits as measured by the formula based on the EV method. Benefit was only derived what concerned the speed of inflows of insurance payments as foreign financing was assumed to be disbursed with a one year time lag.

It was concluded that insurance options and external financing flows are substitutes. The less "reinsurance of last resort" is provided by the MFIs, the more desirable it becomes to seek protection in the private insurance market. For small inflows of external financing, insurance provides net benefits as measured by GDP, for more substantial inflows, benefits could become negative. The amount of risk aversion influenced results considerably.

In contrast to Honduras, aggregate natural disaster risk in Argentina was found to be rather unimportant due to low natural hazard exposure, but despite moderate vulnerability. External economic vulnerability was assessed as high due to the currently ongoing external debt crisis. Consequently, no external borrowing was assumed to be feasible for the model runs. However, budget diversion and aid seemed to suffice in Argentina for the government to finance its potential losses due to disasters. No financing gap occurred for the events considered feasible (up to the 1000 year event).

In the stochastic simulations, the potential economic effects and volatility due to disasters were small for Argentina. No financing gap occurred, and consequently no net benefit was found for the analyzed insurance strategies.

Again four insurance options were studied: Three XL options with covers for the 0-1000, 0-100 and 100-1000 loss layers were examined as well as one proportional *quota share* (QS) option with equal claim and premium splitting for all losses. Though buying insurance helped in decreasing volatility, the necessity for purchasing risk transfer instruments for the reduction of disaster impacts was less so in Argentina than in Honduras: the volatility was rather small and thus the opportunity costs in terms of investment and GDP foregone were larger than the benefits created by insurance.

13.6 Caveats and areas for future work

Several caveats and areas for future work can be outlined.

Better representation of role of infrastructure in aggregate production function
In order to better capture the specific characteristics of infrastructure, it would be desirable to represent aggregate production by a function of the CES or translog type allowing to specify infrastructure stock as a complement to private capital or/and labor. This would allow to better demonstrate the potential "bottleneck effects" of losing infrastructure that are outlined in micro studies. Probably, this would increase the value of insurance options as they hedge against the losses to infrastructure and allow a quicker rehabilitation of important assets such as bridges, roads and water and sanitation lifelines. As discussed, for Honduras, an effort to estimate a CES function was undertaken; the results however were not fully significant and satisfactory.

Bottom-up foundation of physical vulnerability of infrastructure and other capital stock
The assumption of equal vulnerability of infrastructure and other capital stock is an approximation. In reality, infrastructure assets will exhibit differing vulnerabilities to extreme events; as well, the vulnerability of infrastructure assets will differ from that of private capital stock. For such information, a bottom-up analysis of vulnerabilities would need to be undertaken rather than the top-down approach chosen here.

Insurance and mitigation nexus
As discussed, an important benefit of undertaking risk transfer measures is the risk-transfer mitigation-nexus, i.e. the fact that insurers tie premia to the degree of mitigation undertaken by the risk cedent. Engaging in mitigation is commonly rewarded by lower premia. This nexus is of major interest for the MFIs, which are concerned with the level of mitigation efforts undertaken today. Establishing and incorporating such a relationship in the modelling framework would allow to quantify this additional benefit of undertaking risk transfer. As for assessing physical vulnerabilities more exactly, such an extension would require more bottom-up analysis.

Thus, further research is necessary to extend the approach of this study. However, it is hoped for that this thesis has provided some insights into the economic impacts of natural disasters and risk management measures to keep those impacts in check and further reduce them. After all, the thesis has dealt with an area of not purely theoretical concern, but of rather high importance for basic development as succinctly expressed in the following final quote:

> Development efforts have focused on helping the poor deal with many of the risks they face in daily life, such as in employment, health care, transport, water and sanitation, education, etc. Perhaps it is the "natural" character of hazard events that have helped to perpetuate the myth that disasters are a "whim of the gods" and kept disaster risk from becoming a priority issue in development. But we must remember that these events are recurrent phenomena of our physical environment, and it is the sum of human actions leading up to and immediately following that makes them disasters. In the end, it is an issue of basic development. It is an issue of doing development right, and making sure that activities contribute to reducing disasters rather than exacerbating them (Wolfensohn and Cerpitel 2002).

14 REFERENCES

ADB (2001). Guidelines for the Economic Analysis of Projects. Manila, Asian Development Bank.

ADPC (2000a). Terms and Definitions. Course materials, Workshop "Urban Disaster Mitigation." 23-27 October 2000. University of Karlsruhe.

ADPC (2000b). Glossary. Course materials, Workshop "Urban Disaster Mitigation." 23-27 October 2000. University of Karlsruhe.

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

Amendola, A., Y. M. Ermoliev, et al. (2000). A Systems Approach to Modeling Catastrophe Risk and Insurability. RR-00-25. Laxenburg, IIASA.

Anand, S. and B. Nalebuff (1987). "Issues in the application of cost-benefit analysis to energy projects in developing countries." Oxford Economic Papers **39**(1987): 190-222.

Andersen, T. J. (2001). Managing Economic Exposures of Natural Disasters. Exploring Alternative Financial Risk Management Opportunities and Instruments. Washington DC, IDB.

Anderson, M. (1991). Which costs more: prevention or recovery? In A. Kreimer and M. Munasinghe (eds.). Managing Natural Disasters and the Environment. Washington DC, World Bank**:** 17-27.

Anderson, M. (1995). Vulnerability to Disaster and Sustainable Development: A General Framework for Assessing Vulnerability. In M. Munasinghe and C. Clarke (eds.). Disaster Prevention for Sustainable Development: Economic and Policy Issues. Washington DC, World Bank**:** 41-59.

Anderson, M. and P. Woodrow (1998). Rising from the Ashes: Development Strategies in Times of Disaster. Boulder, Colorado, Westview Press.

Arrow, K. J. and R. C. Lind (1970). "Uncertainty and the Evaluation of Public Investment Decisions." The American Economic Review **60**: 364-378.

Arrow, K. J. (1992). Insurance, Risk and Resource Allocation. In G. Dionne and S. E. Harrington. Foundations of Insurance Economics: Readings in Economic and Finance. Boston, Kluwer Academic Publishers.

Barham, C., F. Krimgold, et al. (1999). Managing Disaster Risk in Mexico: Market Incentives for Mitigation Investment. Washington DC, World Bank.

Barry, P. J. (ed.) (1984). Risk management in agriculture. Ames, Iowa, Iowa State University Press.

Benson, C. (1997a). The Economic Impact of Natural Disasters in Fiji. London, UK, Overseas Development Institute.

Benson, C. (1997b). The Economic Impact of Natural Disasters in Viet Nam. London, UK, Overseas Development Institute.

Benson, C. (1997c). The Economic Impact of Natural Disasters in the Philippines. London, UK, Overseas Development Institute.

Benson, C. (1998). The cost of disasters. In J. Twigg (ed.). Development at Risk? Natural Disasters and the Third World. Oxford, Oxford Centre for Disaster Studies, UK National Coordinated Committee for the International Decade for Natural Disaster Reduction (IDNDR)**:** 8-13.

Benson, C. and E. Clay (1998). The Impact of Drought on Sub-Saharan African Economies. Washington DC, World Bank.

Benson, C. and E. Clay (2000). Developing Countries and the Economic Impacts of Catastrophes. In A. Kreimer and M. Arnold. Managing Disaster Risk in Emerging Economies. Washington DC, World Bank**:** 11-21.
Benson, C. and E. Clay (2001). Dominica: Natural Disasters and Economic Development in a Small Island State. Washington DC, World Bank.
Bentkover, J. D., V. T. Covello, et al. (eds.) (1986). Benefits Assessment. The State of the Art. Dordrecht, Holland, D. Reidel Publishing Company.
Brent, R. J. (1998). Cost-Benefit Analysis for Developing Countries. Cheltenham, Edward Elgar.
Briguglio, L. (1995). "Small Island Developing States and Their Economic Vulnerabilities." World Development **23**(9): 1615-1632.
Brookshire, D. S., S. E. Chang, et al. (1997). "Direct and Indirect Economic Losses from Earthquake Damage." Earthquake Spectra **13**(November): 683-701.
Brookshire, D. S., M. A. Thayer, et al. (1985). "A Test of the Expected Utility Model: Evidence From Earthquake Risks." Journal of Political Economy(93): 369-389.
Burby, R., Ed. (1991). Sharing Environmental Risks. How to control Governments' Losses in Natural Disasters. Boulder, Colorado, Westview Press.
CACND (1999). The Impacts of Natural Disasters: A Framework for Loss Estimation. Washington DC, Committee on Assessing the Costs of Natural Disasters, Board on Natural Disasters, Commission on Geosciences, Environment and Resources, National Research Council, National Academy Press.
Canning, D. and E. Bennathan (2000). The Social Rate of Return on Infrastructure Investments, Public Economics Division, World Bank.
Canning, D., M. Fay, et al. (1994). Infrastructure and growth. In M. Baldassarri and E. S. Phelps (eds.). International Differences in Growth Rates: Market Globalization and Economic Areas. New York, St. Martin's Press.
Cannon, T. (1994). Vulnerability Analysis and the Explanation of 'Natural Disasters'. Disasters, Development and Environment. A. Varley. Chichester, John Wiley and Sons.
CEPAL (1999). Evaluacion de los danos ocasionados por el Huracan Mitch. Mexico City.
CGCED (2002). Natural hazard risk management in the Caribbean: revisiting the challenge. Washington DC, Caribbean Group for Cooperation in Economic Development, World Bank.
Chang, S., A. Rose, et al. (1997). Infrastructure Life Cycle Cost Analysis: Direct and Indirect User Costs of Natural Hazards. U.S.-Japan Joint Seminar on Civil Infrastructure Systems Research, August 28-30, 1997, Honolulu, Hawaii, Multidisciplinary Center for Earthquake Engineering Research, University at Buffalo, State University of New York.
Charveriat, C. (2000). Natural Disasters in Latin America and the Caribbean: An Overview of Risk. Working Paper 434. Washington DC, Inter-American Development Bank.
Cochrane, H. (1992). Overview of Economic Research on Earthquake Consequences. The Economic Consequences of a Catastrophic Earthquake: Proceedings of a Forum, The National Academy Press.
Commonwealth Secretariat (2000). Small States: Meeting Challenges in the Global Economy. Washington, DC and London, Commonwealth Secretariat, World Bank Joint Task Force on Small States.
CRED (2003). EM-DAT: International Disaster Database. Brussels, Belgium, Centre for Research on the Epidemiology of Disasters, Université Catholique de Louvain.

Croson, D. and H. C. Kunreuther (1999). Customizing Reinsurance and Cat Bonds for Natural Hazard Risks. First EuroConference on Global Change and Catastrophe Risk Management: Flood Risks in Europe, 6–9 June 1999, Laxenburg, Austria, IIASA.

Croson, D. and A. Richter (1999). Sovereign Cat Bonds and Infrastructure Project Financing. First EuroConference on Global Change and Catastrophe Risk Management: Flood Risks in Europe, 6–9 June 1999, Laxenburg, Austria, IIASA.

Crowards, T. (2000). Comparative Vulnerability to Natural Disasters in the Caribean. Charleston, South Carolina, Caribbean Development Bank**.**

Cuny, F. C. (1983). Disasters and Development. New York, Oxford University Press.

Dacy, D. C. and H. Kunreuther (1969). The Economics of Natural Disasters: Implications for Federal Policy. New Yok, Free Press.

Dasgupta, A. K. and D. W. Pearce (1978). Cost-Benefit Analysis: Theory and Practice. London, Macmillan.

Dedeurwaerdere, A. (1998). Cost-benefit Analysis for Natural Disaster Management - A Case-study in the Phillipines. Brussels, Belgium, CRED.

DeFerranti, D., G. E. Perry, et al. (2000). Securing Our Future in a Global Economy. Washington DC, Worldbank.

Devarajan, S., L. Squire, et al. (1995). Reviving Project Appraisal at the World Bank. Washington DC, Policy Research Department, World Bank.

Devarajan, S. and J. S. Hammer (1997). Public Expenditures and Risk Reduction. Washington DC, Policy Research Department, World Bank.

Dinwiddy, C. and F. Teal (1996). Principles of cost-benefit analysis for developing countries. Cambridge, Cambridge University Press.

Dionne, G. and S. E. Harrington, Eds. (1992). Foundations of Insurance Economics. Readings in Economics and Finance. Boston, Kluwer.

Dionne, G. and S. E. Harrington (1992). An Introduction to Insurance Economics. In G. Dionne and S. E. Harrington (eds.). Foundations of Insurance Economics. Readings in Economics and Finance. Boston, Kluwer**:** 1-48.

Doherty, N. A. (2000). Integrated Risk Management: Techniques and Strategies for Reducing Risk. New York, McGraw-Hill.

Downing, T. E., A. A. Olsthoorn, et al. (eds.) (1999). Climate, Change and Risk. London, Routledge.

Easterly, W. and S. Rebelo (1993). "Fiscal policy and economic growth." Journal of Monetary Economics **32**: 417-458.

ECLAC (1982). Nicaragua: Las inundaciones de mayo de 1982 y sus repercusiones sobre el desarrollo economico y social del pais. New York, Economic Commission for Latin American Countries, United Nations.

ECLAC (1985). Damage caused by the Mexican Earthquake and its repercussions upon the country's economy. Santiago de Chile, Economic Commission for Latin America and the Caribbean.

ECLAC (1988). Damage caused by Hurricane Joan in Nicaragua. Its effects on economic development and living conditions, and requirements for rehabilitation and reconstruction. New York, Economic Commission for Latin American Countries, United Nations.

ECLAC (1999). Manual for estimating the socio-economic effects of natural disasters. New York City, United Nations Economic Commission for Latin America and the Caribbean, International Decade for Natural Disaster Reduction.

ECLAC and IDB (2000). A matter of development: how to reduce vulnerability in the face of natural disasters. Seminar "Confronting Natural Disasters: A Matter of Development", New Orleans, 25-26.3.2000.
ECLAC (2001). Current conditions and outlook. Economic Survey of Latin America and the Caribbean 2000-2001. Santiago de Chile.
ECLAC (2002). Handbook for estimating socio-economic and environment effects of disasters. Mexico City.
EFTEC (2001). Review of Technical Guidance on Environmental Appraisal. London, Department of the Environment, Transport and the Regions, UK.
Eikenberg, C. (1998). Journalisten-Handbuch zum Katastrophenmanagement. Deutsches Komitee für Katastrophenvorsorge e.V., Bonn.
Ellson, R. W., J. W. Milliman, et al. (1984). "Measuring the Regional Economic Effects of Earthquakes and Earthquake Predictions." Journal of Regional Science **24**(4): 559-579.
Ermoliev, Y. M., T. Y. Ermolieva, et al. (2000). A System Approach to Management of Catastrophe Risk. RR-00-08. Laxenburg, IIASA.
Faber, M., G. Stephan, et al. (1989). Umdenken in der Abfallwirtschaft. Vermeiden, Verwerten, Beseitigen. Heidelberg, Springer Verlag.
FEMA, J. W. Milliman, et al. (1999). Indirect Economic Consequences of a Catastrophic Earthquake. USA, National Earthquake Hazards Reduction Program (NEHRP), Federal Emergency Management Agency (FEMA).
Ferranti, D. d., G. E. Perry, et al. (2000). Securing Our Future in a Global Economy. Washington DC, World Bank.
Fischer, S. and W. Easterly (1990). "The economics of the government budget constraint." The World Bank Research Observer **5**(2 (July): 127-42.
Freeman, P. K. and H. Kunreuther (1997). Managing Environmental Risk through Insurance. Boston, Kluwer Academic Publishers.
Freeman, P. (2000a). Catastrophe Risk: A Model to Evaluate the Decision Process for Developing Countries. Fakultät für Wirtschaftswissenschaften und Informatik. Wien, Universität Wien.
Freeman, P. K. (2000b). Infrastructure, Natural Disasters, and Poverty. Managing Disaster Risk in Emerging Economies. A. Kreimer and M. Arnold. Washington DC, World Bank.
Freeman, P. K. (2000c). Estimating chronic risk from natural disasters in developing countries: A case study on Honduras. Annual Bank Conference on Development Economics-Europe: Development Thinking at the Millennium, Paris, France.
Freeman, P. K., L. McKellar, et al. (2000a). Integrating Natural Catastrophe Exposure into Development Planning: Case study of natural catastrophe risk in Honduras. Laxenburg, IIASA.
Freeman, P. K., L. MacKellar, et al. (2000b). Integrating Natural Catastrophe Exposure into Development Planning: Case study of flood risk in Argentina. Laxenburg, IIASA.
Freeman, P. and R. Mechler (2001). Public Sector Risk Management in Mexico for Natural Disaster Losses. Workshop "Innovations in Managing Catastrophic Risks: How Can They Help The Poor?" January 8-10, 2001, World Bank, Washington DC.
Freeman, P. K., L. Martin, et al. (2001). National systems and institutional mechanisms for the comprehensive management of disaster risk: Phase I. Regional Policy Dialogue, Natural Disasters Dialogue First Meeting, Washington, DC, Inter-American Development Bank.

Freeman, P. K., L. A. Martin, R. Mechler, K. Warner with P. Hausmann (2002a). Catastrophes and Development. Integrating Natural Catastrophes into Development Planning. Washington DC, World Bank.
Freeman, P. K., Leslie A. Martin, Joanne Linnerooth-Bayer, Reinhard Mechler, Sergio Saldana, Koko Warner and Georg Pflug (2002b). Financing Reconstruction. Phase II Background Study for the Inter-American Development Bank Regional Policy Dialogue on National Systems for Comprehensive Disaster Management. Washington DC, Inter-American Development Bank.
Freeman, P. K. and G. Pflug (2003). "Infrastructure in Developing Countries: Risk and Protection." Risk Analysis, forthcoming.
Froot, K. (1998). The evolving market for catastrophic event risk. Cambridge, Harvard Business School and Marsh and McLennan Securities.
Froot, K. (ed.) (1999). The Financing of Catastrophe Risk. Chicago, The University of Chicago Press.
Froot, K. A. and P. G. J. O'Connell (1999). The Pricing of U.S. Catastrophe Reinsurance. In K. Froot (ed.). The Financing of Catastrophe Risk. Chicago, The University of Chicago Press**:** 195-232.
IMF (1999). Honduras: Initiative for Heavily Indebted Poor Countries-Preliminary Document. Washington D.C., International Monetary Fund and International Development Association.
Gilbert, R. and A. Kreimer (1999). Learning from the World Bank's Experience of Natural Disaster Related Assistance. Washington DC, World Bank.
Gramlich, E. M. (1981). Benefit-Cost Analysis of Government Programs. Englewood Cliffs, Prentice-Hall.
Green, A. (1992). Planning human resources: An Introduction to Health Planning in Developing Countries. Oxford, Oxford University Press.
Guimaraes, P., F. L. Hefner, et al. (1993). "Wealth and Income Effects of Natural Disasters: An Econometric Analysis of Hurricane Hugo." Review of Regional Studies **23**: 97-114.
Gurenko, E. (2001). The Role of World Bank in Supporting Turkish Catastrophe Insurance Pool. Workshop "Innovations in Managing Catastrophic Risks: How Can They Help The Poor?" January 8-10, 2001, World Bank, Washington DC.
Guy Carpenter (1999). The World Catastrophe Reinsurance Market 1999. New York, Guy Carpenter.
Guy Carpenter (2001). The World Catastrophe Reinsurance Market 2000. New York, Guy Carpenter.
Guy Carpenter (2002). The World Catastrophe Reinsurance Market 2001. New York, Guy Carpenter.
Guy Carpenter in asociation with EQECAT with contributions from IIASA(2000). Managing the financial impacts of natural disaster losses in Mexico: Government options for risk financing and risk transfer. Washington, DC, Finance, Private Sector & Infrastructure Department, Environmental & Social Sustainability Department, Mexico Country Office, Latin & the Caribbean Region, World Bank.
Hardaker, J. B., R. B. M. Huirne, et al. (1997). Coping with Risk in Agriculture. Wallingford, CAB International.
Hausmann, P. (2001). Personal Communication.
Hecker, G. (1995). A Review of the Disaster-Related Activities of the Asian Development Bank: An Economic Perspective. In M. Munasinghe and C. Clarke (eds.). Disaster Prevention for Sustainable Development: Economic and Policy Issues. Washington DC, World Bank: 77-85.

Hershey, J. D. and P. J. H. Shoemaker (1979). "Risk -Taking and Problem Context in the Domain of Losses - An Expected Utility Analysis." Journal of Risk and Insurance **47**(March).
Heston, A. and R. Summers (1991). "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988." Quarterly Journal of Economics(May): 327-368.
Hirshleifer, J. (1989). Time, Uncertainty, and Information. Oxford, Basil Blackwell.
Hirshleifer, J. and J. Riley (1992). The analytics of uncertainy and information. Cambridge, Cambridge University Press.
Hoogeveen, J. G. M. (2000). Risk and Insurance by the Poor in Developing Nations. In A. Kreimer and M. Arnold (eds.). Managing Disaster Risk in Emerging Countries. Washington DC, World Bank**:** 103-128.
IDB (2000). Facing the Challenge of Natural Disasters in Latin America and the Caribbean. An IDB Action Plan. Washington DC, Inter-American Development Bank.
IFRC (1999). World Disasters Report. West Chiltington, International Federation of Red Cross and Crescent Societies.
IMF and IDA (2000). Honduras. Decision Point Document for the Enhanced Heavily Indebted Poor Countries (HIPC) Initiative. Washington DC.
IMF and World Bank (2001). El Salvador. IMF and World Bank Staff Assessment of the Macroeconomic Effects of the Earthquakes. Washington DC.
IMF and IDA (2002). Islamic Republic of Mauritania. Completion Point Document under the Enhanced Heavily Indebted Poor Countries (HIPC) Initiative. Washington DC.
IPCC (2001). Climate Change 2001: The Scientific Basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press.
Irwin, T., M. Klein, et al. (1997). The Management of Contingent Liabilities: A Risk Management Framework for National Governments. Washington DC, World Bank.
Jaeger, C. C., O. Renn, et al. (2001). Risk, Uncertainty and Rational Action. London, Earthscan.
Johansson, P.-O. (1991). An introduction to modern welfare economics. Cambridge, Cambridge University Press.
Kajitani, Y., N. Okada, et al. (2001). Time Series Analysis of Post-Earthquake Disaster: A Case Study of the Port of Kobe. Proceedings of First Annual IIASA-DPRI Meeting on Integrated Disaster Risk Management: Reducing Socio-Economic Vulnerability, 1-4 August 2001, Laxenburg, IIASA.
Keeney, R. L. and H. Raiffa (1993). Decisions with Multiple Objectives. Cambridge, Cambridge University Press.
Keller, G. R. (2001). The Argentinean Insurance Market. Dallas, International Risk Management Institute.
King, R. P. and L. J. Robison (1984). Risk Efficiency Models. In P. J. Barry (ed.). Risk management in agriculture. Ames, Iowa, Iowa State University Press**:** 68-81.
Klein, T. M. (1994). External Debt Management: An Introduction. Washington DC, World Bank.
Kobayashi, K. and M. Yokomatsu (2001). Economic Valuation of Catastrophe Risks: Beyond Expected Losses Paradigms. Proceedings of the Second EuroConference: Global Change and Catastrophe Risk Management: Earthquake Risks in Europe, Laxenburg, Austria, July 6-9, 2000, IIASA.

Kopp, R. J., A. J. Krupnick, et al. (1997). Cost-Benefit Analysis and Regulatory Reform: An Assessment of the Science and the Art. Discussion paper 97-19. Washington DC, Resources for the Future.

Kramer, R. A. (1995). Advantages and Limitations of Benefit-Cost Analysis for Evaluating Investments in Natural Disaster Mitigation. In M. Munasinghe and C. Clarke (eds.). Disaster Prevention for Sustainable Development: Economic and Policy Issues. Washington DC, World Bank**:** 61-76.

Kreimer, A. and M. Munasinghe (1991). Managing environmental degradation and natural disasters: an overview. In A. Kreimer and M. Munasinghe (eds.). Managing Natural Disasters and the Environment. Washington DC, World Bank**:** 3-6.

Kreimer, A., J. Eriksson, et al. (1998). The World Bank's Experience with Post-Conflict Reconstruction. Washington DC, World Bank.

Kreimer, A., M. Arnold, et al. (1999). Managing Disaster Risk in Mexico: Market Incentives for Mitigation Investment. Washington DC, World Bank.

Kreimer, A. and M. Arnold (2000). "World Bank's role in reducing impacts of disasters." Natural Hazards Review **1**(1): 37-42.

Kunreuther, H. (1992). Presentation. Session: Differential Impact of Earthquake Events. The Economic Consequences of a Catastrophic Earthquake: Proceedings of a Forum, The National Academy Press.

Kunreuther, H. (1996). "Mitigating Disaster Losses through Insurance." Journal of Risk and Uncertainty **12**(2/3): 171-187.

Kunreuther, H. (1997). Managing Catastrophic Risks through Insurance and Mitigation. Philadelphia, Wharton Risk Management and Decision Processes Center.

Kunreuther, H. (1997). New strategies for dealing with the earthquake hazard. In B. G. Jones (ed.). Economic consequences of earthquakes: Preparing for the unexpected. Buffalo, NY, New York State University at Buffalo.

Kunreuther, H. (1998a). Insurability Conditions and the Supply of Coverage. In H. Kunreuther and R. J. Roth (eds.). Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States. Washington DC, Joseph Henry Press**:** 17-50.

Kunreuther, H. (1998b). A Program for Reducing Disaster Losses Through Insurance. In H. Kunreuther and R. J. Roth (eds.). Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States. Washington DC, Joseph Henry Press.

Kunreuther, H. C. (1999). "Insurance as an Integrating Policy Tool for Disaster Management: The Role of Public-Private Partnerships." Earthquake Spectra **15**(4): 725-745.

Kunreuther, H. and R. J. Roth (1998) (eds.). Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States. Washington DC, Joseph Henry Press.

Kunreuther, H. (2002). Benefit-Cost Analysis for Earthquake Mitigation: Evaluating Measures for Apartment Houses in Turkey.

Lane, M. N. and R. G. Beckwith (2001). "Current Trends in Risk-Linked Securitizations." Lane Financial 2001, April 30.

Lass, W., F. Reusswig, et al. (1998). Katastrophenanfälligkeit und nachhaltige Entwicklung. Bonn, Deutsche IDNDR-Reihe Nr. 14, Deutsches Komitee für Katastrophenvorsorge e.V.

Layard, P. and A. Walters (1978). Microeconomic Theory. New York, McGraw Hill.

Lester, R. (1999). The World Bank and natural catastrophe funding. The Changing Risk Landscape: Implications for Insurance Risk Management. Proceedings of a Conference sponsored by Aon Group Australia Ltd., Sydney, Australia.
Lewis, C. M. and A. Mody (1997). The Management of Contingent Liabilities: A Risk Management Framework for National Governments. In T. Irwin, M. Klein, G. E. Perry and M. Thobani (eds.). Dealing with Public Risk in Private Infrastructure. Washington DC, Worldbank: 131-153.
Lewis, C. M. and K. C. Murdock (1999). Alternative Means of Redistributing Catastrophic Risk in a National Risk-Management System. In K. A. Froot (ed.). The Financing of Catastrophe Risk. Chicago, National Bureau of Economic Research: 51-85.
Litan, R. E. (2000). Catastrophe Insurance and Mitigating Disaster Losses: A Possible Happy Marriage. In A. Kreimer and M. Arnold (eds.). Managing Disaster Risk in Emerging Countries. Washington DC, World Bank: 187-193.
Little, I. M. D. and J. A. Mirrlees (1974). Project appraisal and planning for developing countries. London, Heinemann.
Little, I. and J. Mirrlees (1990). Project Appraisal and Planning twenty years on. Proceedings of the World Bank Annual Conference on Development Economics. S. Fischer. Washington DC: 351-382.
Lucas, R. E. J. (1987). Models of Business Cycles. Oxford, Basil Blackwell.
Machina, M. J. (1992). Choice Under Uncertainty: Problems Solved and Unsolved. In G. Dionne and S. E. Harrington (eds.). Foundations of Insurance Economics: Readings in Economic and Finance. Boston, Kluwer Academic Publishers: 49-82.
Markovitz, H. M. (1959). Portfolio Selection: Efficient Diversification of Investments. New Haven, Yale University Press.
McIsaac, D. and D. Babbel (1995). The World Bank Primer on Reinsurance. Policy Research Working Paper 1512. Washington DC, World Bank.
Mechler, R. (2002). Natural Disaster Risk and Cost-Benefit Analysis. Conference "The Future of Disaster Risk: Building Safer Cities," Washington DC, World Bank.
Mechler, R. and G. Pflug (2002). The IIASA Model for Evaluating Ex-ante Risk Management: Case Study Honduras. Report to IDB. Washington DC, IDB.
Meier, G. M. (1995). Leading Issues in Economic Development. New York, Oxford University Press.
Mileti, D. S., Ed. (1999). Disasters by Design: A Reassessment of Natural Hazards in the United States. Washington DC, Joseph Henry Press.
Mooney, S. (2001). Government Catastrophe Programs. Workshop "Innovations in Managing Catastrophic Risks: How Can They Help The Poor?" January 8-10, 2001, World Bank, Washington DC.
Munasinghe, M. and C. Clarke (eds.) (1995). Disaster Prevention for Sustainable Development: Economic and Policy Issues. Yokohama, World Bank.
Münchener Rückversicherung (1999). Naturkatastrophen in Deutschland. Schadenerfahrungen und Schadenpotentiale. München.
Münchener Rückversicherung (2000). topics. Jahresrückblick Naturkatastrophen 1999. München.
Munich Re (1996). Natural catastrophe losses will continue to increase. Munich.
Munich Re (1997). Flooding and Insurance. Munich, Munich Re.
Munich Re (1998a). World Map of Natural Hazards. Munich, Munich Re.
Munich Re (1998b). Topics: Natural Catastrophes. Annual Review of Natural Catastrophes 1997. Munich, Munich Re.

Munich Re (1999a). topics 2000. Natural Catastrophes: The current position. Munich, Munich Re.
Munich Re (1999b). topics: Natural Disasters. Annual review of natural catastrophes 1998. Munich, Munich Re.
Munich Re (2000). topics. Jahresrückblick Naturkatastrophen 1999. Munich, Munich Re.
Munich Re (2001). topics: Natural Disasters. Annual Review of Natural Disasters 2000. Munich, Munich Re.
Munich Re (2002). topics: Natural Disasters. Annual Review of Natural Disasters 2001. Munich, Munich Re.
Murlidharan, T. L. and H. C. Shah (2001). Catastrophes and Macro-economic Risk Factors: An Empirical Study. Proceedings of First Annual IIASA-DPRI Meeting on Integrated Disaster Risk Management: Reducing Socio-Economic Vulnerability, 1-4 August 2001, Laxenburg, IIASA.
Nakagawa, M., M. Saito, et al. (2002). On Aversion Toward Earthquake Risks: The Case Of The Tokyo Metropolitan Area. Second Annual IIASA-DPRI Meeting. "Integrated Disaster Risk Management: Megacity Vulnerability and Resilience", 29 - 31 July 2002, Laxenburg, IIASA.
Newbery, D. M. G. and J. E. Stiglitz (1981). The Theory of Commodity Price Stabilization. A Study in the Economics of Risk. Oxford, Clarendon Press.
OAS (1991). Primer on Natural Hazard Management in Integrated Regional Development Planning. Washington DC, Organization of American States.
OAS (1996). Insurance, reinsurance and catastrophe protection in the Caribbean. Washington, DC, Organization of American States, Unit for Sustainable Development and the Environment.
OECD (1994). Project and Policy Appraisal: Integrating Economics and Environment. Paris, OECD.
OECD and DAC (2000). Net ODA Flows in 2000. Paris, OECD. (http://webnet1.oecd.org/pdf/M00005000/M00005137.pdf)
OECD and DAC (2001). Net ODA Flows from 1950 to 1999. Paris, OECD. (http://webnet1.oecd.org/xls/M00002000/M00002883.xls)
Okuyama, Y., G. J. D. Hewings, et al. (1996). "Economic Impacts of an Unscheduled Event: Interregional Analysis Based on Miyazawa's Framework." Journal of Applied Regional Science(2): 79-93.
Otero, R. C. and R. Z. Marti (1995). The impacts of natural diasters on developing economies: implications for the international development and disaster community. In M. Munasinghe and C. Clarke (eds.). Disaster Prevention for Sustainable Development: Economic and Policy Issues. Washington DC, World Bank**:** 11-40.
PAHO (1999). Huracanes Georges y Mitch 1998. Washington DC, Pan-American Health Organization.
Pallage, S. and M. A. Robe (2000). Magnitude X on the Richter Scale: Welfare Cost of Business Cycles in Developing Countries. Montreal, Centre de recherche sur l'emploi et les fluctuations economiques (CREFE), Universite de Quebec a Montreal.
Pearce and Nash (1981). The Social Appraisal of Projects. London, Macmillan.
Peffekoven, R. (1992). J. Öffentliche Finanzen. In D. Bender et al. (eds.). Vahlens Kompendium der Wirtschaftstheorie und Wirtschaftspolitik. Band 1. 5. Auflage. München, Verlag Franz Vahlen**:** 479-560.
Penning-Rowsell, E. C. (1996). "Flood-Hazard Response in Argentina." The Geographical Review **86**(1): 72-90.

Plate, E. J. and B. Merz (2001). Naturkatastrophen. Ursachen-Auswirkungen-Vorsorge. Stuttgart, E. Schweizenbart'sche Verlagsbuchhandlung (Naegele und Obermiller).

Pollner, J. (2000). Managing catastrophic risks using alternative risk financing & insurance pooling mechanisms. Washington DC, World Bank.

Pollner, J., M. Camara, et al. (2001). Honduras. Catastrophe risk exposure of public assets. An analysis of financing instruments for smoothing fiscal volatility. Washington DC, World Bank.

Pouliquen, L. Y. (1970). "Risk analysis in project appraisal." World Bank Staff Occasional paper, 11. Washington DC, World Bank.

Pratt, J. W. (1992). Risk Aversion in the Small and in the Large. G. Dionne and S. E. Harrington (eds.). Foundations of Insurance Economics: Readings in Economic and Finance. Boston, Kluwer Academic Publishers**:** 83-98.

Priest, G. L. (1996). "The Government, the Market, and the Problem of Catastrophic Loss." Journal of Risk and Uncertainty **12**(2/3): 219-237.

Quarantelli, E. L. (1991). Disaster response: generic or agent-specific? In A. Kreimer and M. Munasinghe (eds.). Managing Natural Disasters and the Environment. Washington DC, World Bank**:** 97-105.

Ray, A. (1984). Cost-Benefit Analysis. Issues and Methodologies. Baltimore, World Bank.

Reutlinger, S. (1970). Techniques for Project Appraisal under Uncertainty. Washington DC, World Bank.

Robison, L., P. Barry, et al. (1984). Risk attitudes: concepts and measurement approaches. In P. J. Barry (ed.). Risk management in agriculture. Ames, Iowa, Iowa State University Press**:** 11-30.

Rose, A., J. Benavides, et al. (1997). "The regional economic impact of an earthquake: direct and indirect effects of electricity lifeline disruptions." Journal of Regional Science **37**(3): 437-458.

Rose, A. and G.-S. Guha (2001). Computable general equilibrium modeling of electric utility lifeline losses from earthquakes. In S. Change and Y. Okuyama (eds.). Modeling the Spatial Economic Impacts of Natural Hazards. Heidelberg, Springer.

Rothengatter, W. (1996). Assessment. Volkswirtschaftliche Wirkungsanalysen. Vorlesungsbegleitendes Skript Wintersemester 96/97, Universität Karlsruhe.

Rothengatter, W. (2002). The Role of CBA in Assessing European Transport Projects and Strategies. Karlsruhe, Universität Karlsruhe.

Saha, A., R. C. Shumway, et al. (1994). "Joint Estimation of Risk Preference Structure and Technology using Expo-Power Utility." American Journal of Agricultural Economics **76**(May 1994): 173-184.

Sen, A. (1999). Development as Freedom. New York, Alfred A. Knopf.

Shinozuka, M. and A. Rose (1997). Proceedings of the U.S.-Japan Joint Seminar on Civil Infrastructure Systems Research. U.S.-Japan Joint Seminar on Civil Infrastructure Systems Research, August 28-30, 1997, Honolulu, Hawaii, Multidisciplinary Center for Earthquake Engineering Research, University at Buffalo, State University of New York.

Simon, H. A. (1957). Models of Man: Social and Rational. New York, John Wiley and Sons.

Slovic, P. and S. Lichtenstein (1968). "Relative Importance of Probabilities and Pay-offs in Risk-Taking." Journal of Experimental Psychology Monograph(November).

Smith, K. (1996). Environmental Hazards. Assessing Risk and Reducing Disaster. London, Routledge.
Smith, K. V. (1986). A Conceptual Overview of the Foundations of Benefit-Cost Analysis. In J. D. Bentkover, V. T. Covello and J. Mumpower (eds.). Benefits Assessment, The State of the Art. Dordrecht, Kluwer: 13-34.
Squire, L. (1989). Project Evaluation in Theory and Practice. In H. Chenery and T. N. Srinivasan (eds.). Handbook of Development Economics. Amsterdam, North-Hollland: 1093-1137.
Squire, L. and H. G. van der Tak (1975). Economic Analysis of Projects, Worldbank.
Swiss Re (1988). Natural Hazard and event loss. Zurich, Swiss Reinsurance Company.
Swiss Re (1992). Earthquakes and Volcanic Eruptions: A Handbook on Risk Assessment. Zurich, Swiss Reinsurance Company.
Swiss Re (1993). Storms over Europe: Losses and scenarios. Zurich, Swiss Reinsurance Company.
Swiss Re (1996a). An introduction to reinsurance. Zurich, Swiss Reinsurance Company.
Swiss Re (1996b). Natural Catastrophes and major losses in 1995: decrease compared to previous years, but continually high level of losses since 1989. Zurich, Swiss Reinsurance company.
Swiss Re (1997a). Too little reinsurance of natural disasters in many markets. Zurich, Swiss Reinsurance Company.
Swiss Re (1997b). Proportional and non-proportional reinsurance. Zurich, Swiss Reinsurance Company.
Swiss Re (1997c). Natural catastrophes and major losses in 1996: high losses from man-made disasters, but not extremely costly losses from natural catastrophes. Zurich, Swiss Reinsurance Company.
Swiss Re (1999). Natural catastrophes and man-made disasters in 1998: Storms, hail and ice cause billion dollar losses. Sigma 1/1999. Zurich, Swiss Reinsurance Company.
Swiss Re (2000a). Natural catastrophes and man-made disasters in 1999: Storms and earthquakes lead to the second-highest losses in insurance history. Sigma 2/2000. Zurich, Swiss Reinsurance Company.
Swiss Re (2000b). Storm over Europe. An underestimated risk. Zurich, Swiss Reinsurance Company.
Swiss Re (2001). Natural catastrophes and man-made disasters in 2000: fewer insured losses despite huge floods. Sigma 2/2001. Zurich, Swiss Reinsurance Company.
Swiss Re (2002a). Natural catastrophes and man-made disasters in 2001: man-made losses take on a new dimension. Sigma 1/2002. Zurich, Swiss Reinsurance Company.
Swiss Re (2002b). Insurance in Latin America: growth opportunities and the challenge to increase profitability. Sigma 1/2002. Zurich, Swiss Reinsurance Company.
Szekeres, S. (2000). La consideracion de desastres naturales en la evaluacion de proyectos federales en Mexico. Analisis y recomendaciones. Washington DC, World Bank.
Tatano, H., W. Isobe, et al. (2000). Economic Evaluation of Seismic Risks. Proceedings of 2000 Joint Seminar on Urban Disaster Management. Beijing: 36-39.

Tobin, G. and B. Montz (1997). Natural Hazards. Explanation and Integration. New York, The Guildford Press.

Tol, R. S. J. and F. P. M. Leek (1999). Economic analysis of natural disasters. In T. E. Downing, A. A. Olsthoorn and R. Tol, S.J (eds.). Climate, Change and Risk. London, Routlegde**:** 308-327.

Tversky, A. and D. Kahnemann (1974). "Judgment under uncertainty: Heuristics and biases." Science **185**(1974): 1124-1131.

UNDP (2001). Disaster Profiles of the Least Developed Countries. Report for Third United Nations Conference on Least Developed Countries, Brussels, 14-20 May 2001. Geneva.

UNISDR (2002). Natural disasters and sustainable development: understanding the links between development, environment and natural disasters. Geneva, United Nations International Strategy for Disaster Reduction.

Van Dieren, W. (1995). Mit der Natur rechnen: Der neue Club-of-Rome-Bericht. Basel, Birkhaeuser.

Van Shoubroeck, C. (1997). "Legislation and Practice Concerning Natural Disasters and Insurance in a Number of European Countries." The Geneva Papers on Risk and Insurance **22**(83): 238-267.

Varley, A., Ed. (1994). Disasters, development, and the environment. New York, John Willey & Sons Ltd.

Vatsa, K. S. and F. Krimgold (2000). Financing Disaster Mitigation for the Poor. In A. Kreimer and M. Arnold (eds.). Managing Disaster Risk in Emerging Economies. Washington DC, World Bank**:** 129-153.

Verbeek, J. (1999). RMSM-X. Revised Minimum Standard Model eXtended. A Simple Tool for Feasibility and Sustainability Analysis. Washington DC, Development Data Group, World Bank.

Vermeiren, J., S. Stichter, et al. (1998). Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A case study in small island developing states. Conference of The International Emergency Management Society.

Wagner, J. J., A. Kreimer, et al. (2001). Benchmarking of Countries with the Natural Hazard Apparent Vulnerability Indicator (NHAVI). Assessment of High-Risk Disaster Hotspots: A Joint World Bank/Columbia University Workshop, Lamont-Doherty Earth Observatory, Palisades, New York, World Bank Disaster Management Facility.

West, C. T. and D. G. Lenze (1994). "Modeling the Regional Impact of Natural Disaster and Recovery: A General Framework and an Application to Hurricane Andrew." International Regional Science Review **17**(2): 121-150.

Wik, M. (1996). Individual Decision Making under Risk: Deficiencies of and Alternatives to Expected Utility Theory. Aas, Department of Economics and Social Sciences, Agricultural University of Norway.

Willms, M. (1995). Internationale Währungspolitik. 2. Auflage. München, Verlag Franz Vahlen.

Wolfensohn, J. and D. Cherpitel (2002). Why we need to do what we are doing. Washington DC, Provention Consortium, World Bank (www.proventionconsortium.org /articles/whyweneed.htm).

World Bank (1994). World Development Report: Infrastructure for Development. Washington DC, World Bank.

World Bank (1997). RMSM-X Reference Guide. Washington DC, Development Group, Development Economics, World Bank.

World Bank (1999a). Honduras Country Brief. Washington DC, World Bank.

World Bank (1999b). World Bank Today. February 16-19, 1999. Washington DC, World Bank.
World Bank (2000a). Managing the Financial Impacts of Natural Disaster Losses in Mexico. Government Options for Risk Financing & Risk Transfer. Washington DC, World Bank.
World Bank (2000b). Argentina at a glance. Washington DC, World Bank.
World Bank (2000c). Argentina Country Brief. Washington DC, World Bank.
World Bank (2001a). World Bank Development Indicators. Washington DC, World Bank.
WorldBank(2001b). The HIPC Initiative: Background and Progress Through December 2001. Washington DC, World Bank.
World Bank (2001c). Memorandum of the President of the International Bank for Reconstruction and Development and the International Finance Corporation to the Executive Directors on a Country Assistance Strategy Progess Report of the World Bank Group for the Argentine Republic. Washington DC.
World Bank (2002a). Detailed Description of the HIPC Initiative. Washington DC, World Bank.
World Bank (2002b). Organization of Eastern Caribbean States - Country Brief. Washington DC, World Bank.
World Bank (2002c). Argentina Data Profile. Washington DC, World Bank.
Yezer, A. M. and C. B. Rubin (1987). The Local Economic Effects of Natural Disasters. Washington DC, National Hazard Research, George Washington University.
Yokomatsu, M. and K. Kobayashi (2001). The Catastrophe Risk and Economic Valuation of Disaster Prevention Investment. Proceedings of the Second EuroConference: Global Change and Catastrophe Risk Management: Earthquake Risks in Europe, Laxenburg, Austria, July 6-9, 2000, IIASA.
Young, D. (1984). Risk concepts and measures in decision analysis. In P. J. Barry (ed.). Risk management in agriculture. Ames, Iowa, Iowa State University Press: 31-42.
Zerbe, R. O. and D. D. Dively (1994). Benefit-Cost Analysis in Theory and Practice. New York, Harper Collins.

A APPENDICES

AI RMSM-X MODEL DESCRIPTION

1 GENERAL

RMSM is a flow of funds consistency model, where consistency in and between economic sectors is to be achieved. That means that every source of funds to one sector is a use of funds to another and total sources for one sector have to equal total uses, i.e. budget equations have to be fulfilled.

RMSM consists of 4 sectors: Government, Monetary, Foreign and the Private Sector which is the residual sector, the consolidation of all sectors is the national accounting identity which can also be seen as the equilibrium condition for the real goods market. Residual variables in the 5 budget equations assure consistency.

As well, there are 4 "behavioral" equations for 4 financial assets, thus 4 market clearing conditions: Money, domestic monetary credit, foreign credit and government bonds.

There are different solution procedures for the variables:

- By assumptions (values, ratios, growth rates etc).
- As functions of exogenously specified variables (behavioral detail).
- As residual variables: endogenous variables.

The residual variables are used to close the individual budget accounts. RMSM-X aims at keeping the behavioral detail and assumptions small.

All of the sectors are split up into a current and a capital account. Current income less current expenditure for each sector is defined as savings/dissavings adding to or subtracting from the stock of wealth.

Savings are interpreted as a current use of funds in the current account and it is introduced in the capital account as a source of funds

2 THE FOUR SECTORS AND BUDGET CONSTRAINTS

2.1 Notation

Government Sector

Capital account

Sg	Savings government
KREV	Capital revenue government
Ig	Investment government
KTg	Capital transfers government
Def.	Government deficit
CR	Monetary credit
B	Government bonds (change indicates new borrowing)
Fg	Foreign borrowing
KOG	Capital official grants

Current account

DT	Direct tax
IT	Indirect tax
NTR	Non Tax revenue
Cg	Government consumption
TRp	Current transfers to private sector
TRf	Current transfers to foreign sector
SUB	Subsidies
iF	Interest payments to foreign sector (on foreign assets
iCR	Interest payments to monetary sector (on credit)
iB	Interest payments to private sector (on bonds)

Monetary sector

Current account

iCRt	Interest received on credit
iRES	Interest received on reserves
iDD	Interest paid to demand deposits
iFm	Interest paid to foreign sector
P&L	Profits and losses private sector
Sm	Savings monetary sector (=0)

Capital account

M	Money
Fm	Medium- and long-term foreign liabilities
NOL	Net other liabilities
RES	Foreign reserves (Central Bank incl. Gold, commercial banks)
CR	Monetary credit

Rest of the Economy, private sector

Current account

Yfc GDP at factor costs
NTY Net transfer income
NIY Non-interest income
DT Direct tax
Cp Private consumption
Sp Savings private sector

Capital account

Sp Savings private
DFI Direct foreign investment
POR Portfolio investment
CRp Credit private
Fp Foreign borrowing
KTg Capital transfers government
Ip Investment private
M Money
B Government bonds

Foreign sector

Current account

Sf Savings foreign sector = inverse of current account balance (CAB)
X Exports
Im Imports
NFY Net factor income (workers remittances + interest on reserves + other factor service receipts less other factor service payments)
NCT Net current transfers

Capital account

RES Reserves
Sf Savings foreign sector
KOG Capital official grants
DFI Direct foreign investment
POR Portfolio investment
F Foreign assets/lending

National accounting identity

Cg Government consumption
Cp Private consumption
Sg Government savings
Sp Private savings
Sm Monetary savings
Sf Foreign savings
Y GDP
Im Imports
X Exports

Money

M^s Money growth
P Price level P
V Money velocity
Y GDP

Domestic Monetary credit

Supply

CR Monetary credit
M Money
Fm Medium- and long-term foreign liabilities
NOL Net other liabilities
RES Foreign reserves (Central Bank incl. Gold, commercial banks)

Demand

CRpr Credit to private sector
CRg Credit to government sector

Foreign credit/foreign assets

Demand/Balance of Payments (BOP)

F Foreign borrowing
RES Reserves
CAB Current account balance
KOG Capital official grants
DFI Direct foreign investment
POR Portfolio investment

Sources

Fg Foreign borrowing government, (change indicates gapfill loan)
Fp Foreign borrowing private sector
Fm Foreign borrowing monetary sector

Government Bonds/Private sector credit to Gov

Bp Private sector lending to government via bonds
Gov Def Government deficit
RER Real exchange rate
GDP* GDP of rest of the world

Other variables

K Capital stock
L Labor
Pr Premium
$G,Im_{premium}$ Loading part of premium adding to current expenditure G
$Tr_{premium}$ Foreign transfer part of the premium

G,dom	Domestic component of government consumption
ΔIg,dom	Domestic component of government investment

Economic activity is separated into 4 sectors, which are consequently aggregated to the consolidated sector, the national accounting identity. The system thus results in 5 budget equations, for which sources have to equal uses. To achieve consistency there are residuals in the budget equations.

2.2 Government sector

Capital account

Sg + KREV– Ig (y)– KTg = Def. = ΔCR + ΔB + Δ Fg + KOG

Capital revenues- expenditures Deficit *Financing*

where ΔB is the residual, all remaining deficit will be financed by the private sector with Sg the saldo from the **current account**

DT + IT + NTR = Cg(y) + TRp + TRf +SUB + iF + iCR + iB + Sg

Current Revenue *Current Expenditures*

2.3 Monetary sector

Comprising the Central Bank and deposit money banks, no savings by definition.

Current account

iCRt + iRES = iDD + iFm + P&L + Sm (=0)

Current Revenue *Current Expenditures*

Capital account

M + Fm + NOL = RES + CR

Liabilities *Assets*

2.4 Rest of the Economy, private sector

The private sector is the residual domestic sector, in addition to the "more narrow private sector" it also comprises non-central government agencies, parastatal enterprises and nonmonetary financial institutions.

Current account

Yfc + NTY + NIY-DT = Cp + Sp

Current Revenue *Current Expenditures*

Capital account

Sp + DFI + POR + Δ CRp + Δ Fp + KTg - Ip = Δ M + Δ B

Capital revenues- expenditures *Financing*

2.5 Foreign sector

The foreign sector is the reverse of the Balance of Payments.

Current account
Sf (= - CAB) = X - Im + NFY + NCT

The current account balance consists of the resource balance (exports – imports) plus net factor income (workers remittances + interest on reserves + other factor service receipts - other factor service payments) plus net current transfer.

Capital account:
Δ RES + Sf = KOG+DFI+POR+ΔF

The change in reserves plus foreign savings (the inverse of the current account balance) is equal to capital official grants plus direct foreign investment plus Portfolio investment plus change in foreign assets.

2.6 National accounting identity (consolidation of the 4 sectors)

This can also be interpreted as the equilibrium condition for the real goods market
Current account:
Cg + Cp +Sg +Sp +Sm +Sf = Y + Im-X

Capital account:
Ip + Ig = Sg +Sp +Sm +Sf

Consolidated:
Y + Im = Cp + Cg + Ip + Ig + X

The supply of domestically produced goods (Y) plus imported goods (IM) has to equal total consumption plus investment plus demand for export goods (X).

3 BEHAVIORAL DETAIL

3.1 Four Financial assets

There are four financial assets: Money, domestic monetary credit, foreign credit and government bonds. Demand has to equal supply, thus there are 4 market-clearing conditions in equilibrium

3.1.1 Money

Money growth M^s is determined exogenously:
$M^s = M^s * (1 + \text{growthrate})$.

This determines the price level P via the Fisher equation where V is money velocity (fixed):
$P= M^s *V/Y$

3.1.2 Domestic Monetary credit

The **supply** of domestic monetary credit is:

CR = M + Fm + NOL - RES
= *total liabilities (Money, medium- and long-term foreign liabilities, net other liab.(capital transfers from private, savings = new wealth, reevaluation))*
- *foreign reserves (Central Bank incl. Gold, commercial banks)*

Credit (an asset) is determined by liabilities less reserves (assets). E.g. granting more credit results in giving out more money.

Demand
Total domestic monetary credit is supplied to private and government credit

CR = CRpr + CRg
where CRpr: Private sector + other financial institutions (exogenous)
CRg : Gov Budget + other non-fin'l public sector (exogenous)

Policy Closure:
In policy closure, the residual goes to the private sector.

CRpr = CR - CRg (= ratio of deficit) - CRpr,other -CRg,other

3.1.3 Foreign credit/foreign assets

Demand (BOP)
Δ F = Δ RES - CAB -KOG - DFI - POR

Imports adjust (part of CAB), so that the BOP can be closed

Sources:
Policy:
Δ F = [ΔFg + ΔFp + ΔFm (Debt Module)]

Orginally: no gapfill, only disbursements from Debt Module
Modified: additional gapfill according to financing requirements and indebtedness indicators.

3.1.4 Government Bonds/Private sector credit to Government

All private sector borrowing goes to the government. Government accesses private lending by issuing bonds.

Δ Bp = - Gov Def - Foreign Gov Borrowing- CRp

3.2 Other behavioral detail

Import and export demand are functions of the real exchange rate (RER) and domestic and foreign GDP

X = X (RER, GDP*) GDP*: GDP of rest of the world
Im = Im (RER, GDP)

Exports X are a positive function of the RER and a positive function of foreign GDP. Imports are a negative function of the RER and a positive one of domestic GDP

4 CLOSURES

There are 2 main modes to run RMSM-X:

The *requirements* mode takes growth as given and translates this via the ICOR-relationship into investment necessary to sustain this growth path. The model will calculate and use the amount of gapfill, i.e. additional foreign credit necesssary. Private and public closure are run in this mode. Here, GDP growth and inflation are exogenously given.

The *availabilities* mode takes foreign credit as given and calculates growth endogenously. There is no gapfill. Policy closure runs in this mode. As the catastrophe's impacts on major economic variables depending on the availability of reconstruction financing are of interest, the policy closure approach was used as the basis for the development of the catastrophe/insurance module.

4.1 Original policy closure

Foreign financing ΔF determined in advance: ΔF = ΔFp + ΔFg
In policy closure, this drives amount of Imports ($Im_{other\ consumer\ goods}$)

1 BOP
$Im_{other\ consumer\ goods}$ = X + NFY + NCT - CAB
where CAB = Δ RES - KOG - DFI - POR - **ΔF**

2 SNA
Ip = Y + Im - Cp (NDY) - Cg (y) - X-Ig (y)

3 Price level
P = M*Y/V : M and V exogenous

4 Monetary Credit
CR = M + Fm + NOL- RES
P&Lp = iDD + iFm - iCRt - iRES - Sm - P&Lg

5 Private Credit

ΔCRp = ΔCR - ΔCRg (= fixed ratio of deficit) - ΔCRp,other -ΔCRg,other

6 Government sector

Δ Bg = Sg – Ig – KTg + CAPrev - ΔCRg - KOG - ΔFg (from Debt Module)
where Sg = DT + IT + NTR – Cg –TRg – SUB – iFg – iCrg – TR - iB
Domestic borrowing as residual financing of deficit.

7 Private lending

Δ Bp = Δ Bg
Private lending determined by borrowing requirements of government, all additional government financing has to be done by private sector

8 Private Sector,

There are no more residuals.
ΔBp = Sp + Δ CRp + KTg + Δ Fp + DFI + POR - Ip - Δ M
where Sp = NDY (=Yfc + NTY + NIY) – Cp

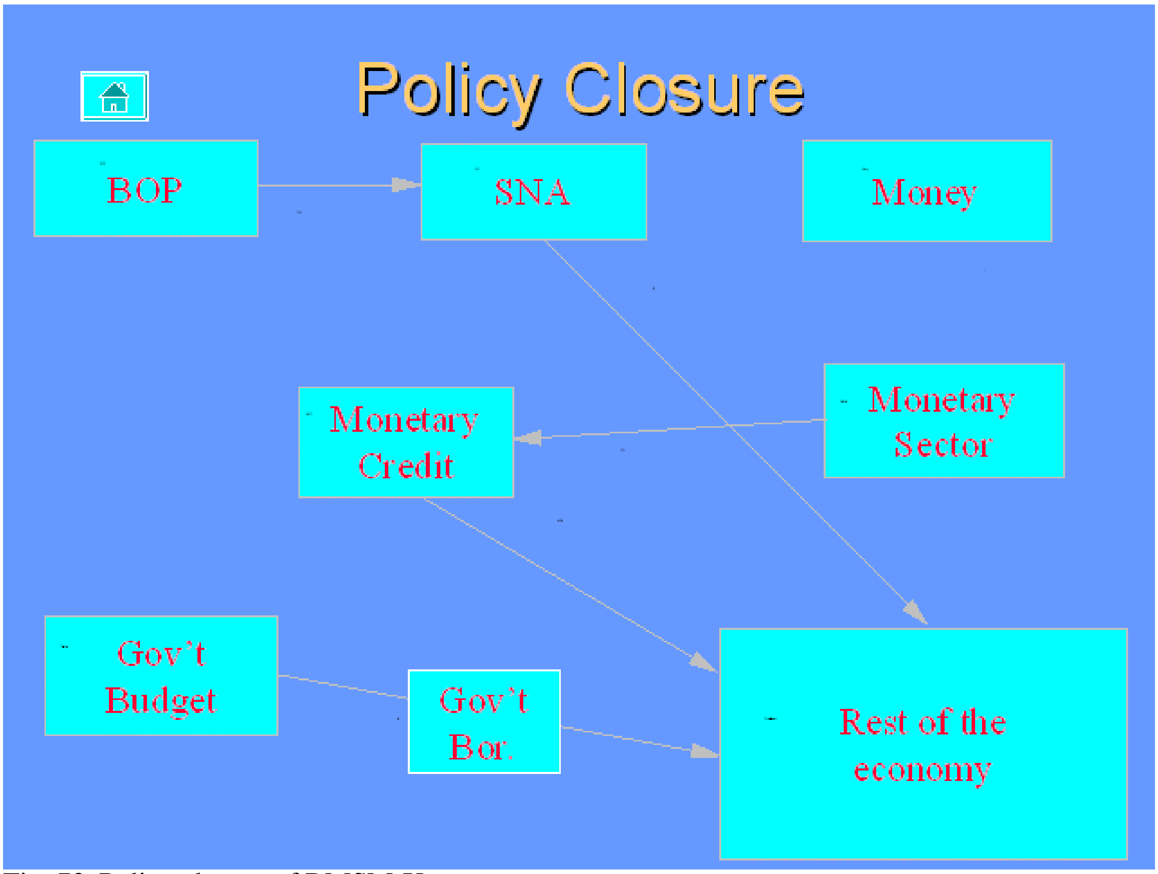


Fig. 72: Policy closure of RMSM-X
Source: Verbeek 1999: 45.

4.2 Modified policy closure

Major changes of the modified policy closure are that outcome variables are stochastic functions of the catastrophe shock to capital and labor, and that foreign financing is determined endogenously by the financing requirements post-disaster, whereas it is exogenous in the original policy closure.

1 Catastrophe shock to stocks K and L

- Capital stock loss as a fraction f of Capital K:
- Capital: $K_1=K_0\ (1-f)$
- Labor loss: Labor $L_1= L_0\ (1-f/10)$

2 GDP calculation

Disaster shocks are assumed to happen at the beginning of the year. GDP is recalculated with the shocked inputs K_1 and L_1.
GDP: GDP_{adj}
Exports adjustment: $X_{adj} \sim GDP_{adj}$

3 Determine Financing necessary and available

Necessary financing for relief and reconstruction is calculated. Some Budget diversion is assumed which will decrease requirements, also insurance and aid payments will flow in post-disaster.

Reconstruction + Relief Financing =ΔF+Insurance+Aid - diversion = RFpriv+RFgov

Financing available
Determined on demand side by fiscal sustainability (so that indebtedness stays within limits) and on supply side by assumptions on availability (0%, 50%, 100%).

4 Balance of Payments
Capital goods for reconstruction can be imported to the extent foreign financing F is available.

Im = X + NFY + NCT - KAB (= -(Δ RES - KOG - DFI - POR - $\mathbf{\Delta F}$**)**
Under assumption of constant exchange rate and foreign reserves.

Thus:
$\Delta Im_{K\ goods} = \Delta X+\Delta F - \Delta Im_{other\ consumer\ goods}$
where $\Delta Im_{other\ consumer\ goods} <0$ due to budget diversion

Thus total imports
$\Delta Im=\Delta Im_{K\ goods} +\Delta Im_{other\ consumer\ goods} = \Delta X+\Delta F$
ΔIm dependent on change in exports and availability of F

5 National accounting identity
(1) **Ip** = Y + Im - Cp (y) - Cg (y) - X-Ig (y)

The model is supply-side determined by the inputs capital and labor. The supply of goods produced in one period is fixed and determines demand that has to adjust to fulfill the equilibrium condition.

Ip is the endogenous variable. This means when insufficient goods/financing is available, the burden of adjusting is borne by a decrease in private investment.

In total, the following effects take place after an event.

The following SNA variables change

- Supply and exports decrease: $\Delta Y - \Delta X < 0$
- Government diversion, $\Delta G = 0.075 * G_{-1}$

Though disposable income would fall if national income falls, it is assumed that private consumption C does not fall, as the government stabilizes private consumption by means of transfer payments post-disaster: $\Delta C = 0$.

(2) $\Delta Y - \Delta X = \Delta Ip + \Delta G + \Delta Ig - \Delta Im$
as $\Delta Y - \Delta X$ decreases, absorption has to decrease as well to maintain equilibrium.

With Ip endogenous/residual
(2') $\Delta Ip = \Delta Y - \Delta X - \Delta G - \Delta Ig + \Delta Im$

(3) $\Delta Ip = \Delta Ip{,}dom + \Delta Ip{,}Im = \Delta Y - \Delta X - \Delta G{,}dom - \Delta G{,}Im - \Delta Ig{,}dom - \Delta Ig{,}Im + \Delta Ig{,}Im + \Delta G{,}Im + \Delta Ip{,}Im$
with

Ip,dom: domestic demand component of Ip	Ip,Im: Import component of Ip
Ig,dom: domestic demand component of Ig	Ig,Im: Import component of Ip
G,dom: domestic demand component of G	G,Im: Import component of G

(3') $\Delta Ip{,}dom = \Delta Y - \Delta X - \Delta G{,}dom - \Delta Ig{,}dom$

as $-\Delta G{,}dom = \Delta Ig{,}dom$
(3'') $\Delta Ip{,}\ dom = \Delta Y - \Delta X$

Thus, as the supply of domestic goods goes down ($\Delta Y - \Delta X < 0$), and

- In private sector, no increase of domestic savings feasible,
- Some diversion in goverment sector assumed while budget stays constant,

additional investment goods necessary for reconstruction have to be imported (and paid in foreign exchange).

Substituting in (1)

(4) $\Delta Ip = \Delta Y - \Delta X - \Delta G - \Delta Ig + \Delta X + \Delta F$

as $\Delta Ig = \Delta Fpublic + \Delta G$
then
(4') $\Delta Ip = \Delta Y - \Delta X + \Delta Fprivate$

or

(4'') $\Delta Ip = \Delta Y - \Delta X + \Delta F + \Delta G$

As it is assumed that capital lost has the same marginal productivity as new capital investment,[75] decreasing Ip and Ig to replace lost capital stock does not change the results. Thus replacement of lost capital stock, after using the available sources aid and diversion, needs to be done by importing more capital goods.

However, the BOP acts as a constraint for additional imports. RMSM-X assumes that the nominal exchange rate and reserves stay constant, thus in case of an imbalance in the CAB, either more external financing is necessary or imports have to be decreased to maintain equilibrium. Thus, importing more goods needs balancing of capital inflows in the BOP. This extra capital inflow necessary is standardly calculated in the RMSM-X models as the gapfill loan, the additional foreign loan necessary to finance additional imports allowing to continue growth objectives as planned for private and public sector (public and publicly guaranteed debt).

The gapfill loan is assumed to be undertaken by the government, and then distributed to private and public sector to the same conditions in proportion to capital stock lost in the public and private sectors.

As outlined, undertaking gapfill loans is not possible ad infinitum. Debt and debt service payments will increase. There are natural debt limits.

6 Price level

P = M*Y/V

7 Monetary sector

Credit (stock) is
CR = M + Fm + NOL- RES
P&Lp = iDD + iFm - iCRt - iRES - Sm - P&Lg

Flow of new credit
$\Delta CR = CR - CR_{-1}$

8 Credit to private and government

ΔCRg : fixed ratio of deficit, baseline deficit
Private sector obtains the rest: **ΔCRp =**ΔCR - ΔCRg - ΔCRp,other -ΔCRg,other

9 Gov sector residual deficit financing by private lending

ΔBg = Sg – Ig – KTg + CAPrev - ΔCRg - KOG - ΔFg (from Debt Module)
where Sg = DT + IT + NTR – Cg –TRg – SUB – iFg – iCrg – TR - iB

Domestic borrowing as residual financing of deficit
ΔBp = Δ Bg : private lending determined by borrowing requirement of government.

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[75] The issue of increased marginal productivity from new investment is sometimes debated, as older capital stock is replaced by newer possibly more efficient capital. However no empirical evidence for natural disasters exists to the knowledge of the author and equal marginal productivities are assumed for this purpose.

10 Private Sector

$\Delta Bp = Sp + \Delta CRp + KTg + \Delta Fp + DFI + POR - Ip - \Delta M$

where $Sp = NDY (=Yfc + NTY + NIY) – Cp$

4.3 Algorithm for insurance purchase

Budget

- Insurance is paid from fixed budget, diverted from existing investment and spending components.
- Consists of G and I, parts of G and I are imported: G,Im, Ig,Im.
  (where G, Im: Imports for government spending and Ig, Im: Imports for government investment)

Thus, the budget is:

(1) $B=G+I=G,dom+G,Im+Ig,dom+Ig, Im$

Insurance is financed from above constant government budget, no extra deficit is incurred, i.e. it is diverted from G and I. Insurance payment is partially current expenditure, partially current transfer. In the System of National Accounting (SNA) the pure premium, the expected losses, are considered a transfer payment, only the loading factor on top of this may create value added and is considered current expenditure (Willms 1995: 4).

Thus

(2) $Pr=Tr_{premium} +G,Im_{premium}$

where Pr=Premium

$G,Im_{premium}$ is the loading part of premium adding to current expenditure G

$Tr_{premium}$ is the foreign transfer part of the premium

Insurance paid from diverting import components of G and Ig.

(1') $\Delta B= \Delta G,dom+ \Delta G,Im+ \Delta Ig,dom+ \Delta Ig, Im+G,Im_{premium}+Tr_{premium}=0$

As

$\Delta Gdom= \Delta Ig,dom=0$, i.e. no change in domestic spending

thus

(3) $\Delta G,Im+ \Delta Ig,Im+G,Im_{premium}+Tr_{premium}=0$

$\Delta G,Im+ \Delta Ig,Im =-G,Im_{premium}-Tr_{premium}$

Assuming that the total premium is paid from government investment and consumption in proportion to their shares in the total budget (Ig+G), diversion from G,Im and Ig,Im is calculated as the relationship x:1 (according to their historical proportions)

(4) $\Delta G,Im=x*\Delta Ig,Im$

thus

(4') $\Delta Ig,Im = -Pr/(1+x)$

and

(4'') $\Delta G,Im = -Pr/(1+1/x)$

Implications for BOP and SNA

BOP
Premium is diverted from other imports
$Pr=-\Delta Im_{other}$

And consists of:
$Pr=\Delta Im_{ins}+\Delta Transfer$

Thus
$\Delta Im=\Delta Im_{other}+\Delta Im_{ins} = -\Delta Transfer<0$

NAI
$\Delta Ip=\Delta Im<0$ less imports/goods available, thus Ip as residual decreases.

AII ESTIMATION RESULTS FOR PRODUCTION FUNCTION PARAMETERS

1 Honduras

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.993[a]	.986	.985	3.577E-02

a. Predictors: (Constant), VAR00003, VAR00002

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.038	.168		23.971	.000
	VAR00002	.253	.054	.453	4.680	.000
	VAR00003	.517	.091	.548	5.658	.000

a. Dependent Variable: VAR00001

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.211	2	1.105	863.809	.000[a]
	Residual	3.071E-02	24	1.280E-03		
	Total	2.241	26			

a. Predictors: (Constant), VAR00003, VAR00002

b. Dependent Variable: VAR00001

2 Argentina

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.861[a]	.741	.720	6.811E-02

a. Predictors: (Constant), VAR00006, VAR00005

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	8.730	2.250		3.879	.001
	VAR00005	.287	.319	.232	.899	.378
	VAR00006	.722	.290	.643	2.488	.020

a. Dependent Variable: VAR00004

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.319	2	.160	34.421	.000[a]
	Residual	.111	24	4.639E-03		
	Total	.431	26			

a. Predictors: (Constant), VAR00006, VAR00005

b. Dependent Variable: VAR00004