Natural disasters and economic development:
A neoclassical review of theoretical perspectives and empirical evidence

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St. Gallen, January 22, 2007

The President:

Prof. Ernst Mohr, PhD
To my father

Karl Zenklusen

1947 – 2002
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Oliver Zenklusen
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<tr>
<td>ART</td>
<td>Alternative Risk Transfer</td>
</tr>
<tr>
<td>Bn, bn</td>
<td>Billion, $10^9$</td>
</tr>
<tr>
<td>CEPAL</td>
<td>Comisión Economica para América Latina y el Caribe (also: ECLAC), UN</td>
</tr>
<tr>
<td>CHF</td>
<td>Swiss Francs</td>
</tr>
<tr>
<td>CRED</td>
<td>Centre for Research on the Epidemiology of Disasters, Université catholique de Louvain, Belgium</td>
</tr>
<tr>
<td>ECLAC</td>
<td>Economic Commission for Latin America and the Caribbean (also: CEPAL), UN</td>
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<td>DFID</td>
<td>Department for International Development, UK</td>
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<tr>
<td>DHA</td>
<td>Departement of Humanitarian Affairs, UNDRO</td>
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<tr>
<td>DRI</td>
<td>Disaster Risk Index</td>
</tr>
<tr>
<td>EM-DAT</td>
<td>Emergency Disasters Data Base, CRED</td>
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<tr>
<td>ENSO</td>
<td>El Niño Southern Oscillation</td>
</tr>
<tr>
<td>EUR</td>
<td>Euro</td>
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<tr>
<td>FEMA</td>
<td>Federal Emergency Management Agency, USA</td>
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<td>FDI</td>
<td>Foreign direct investment</td>
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<td>GCE</td>
<td>General Computable Equilibrium</td>
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<tr>
<td>GDP</td>
<td>Gross domestic product</td>
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<td>GIS</td>
<td>Geographical Information Systems</td>
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<tr>
<td>GNI</td>
<td>Gross national income</td>
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<tr>
<td>GNP</td>
<td>Gross national product</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>IDB</td>
<td>Inter-American Development Bank</td>
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<tr>
<td>IFI</td>
<td>International financial institution</td>
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<td>IMF</td>
<td>International Monetary Fund</td>
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<td>IDNDR</td>
<td>International Decade for Natural Disaster Reduction</td>
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<td>IFRC</td>
<td>International Federation of Red Cross and Red Crescent Societies</td>
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<td>IIASA</td>
<td>International Institute for Applied Systems Analysis</td>
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<tr>
<td>IMF</td>
<td>International Monetary Fund</td>
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<td>I-O, IO</td>
<td>Input-Output</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<tr>
<td>ISDR</td>
<td>International Strategy for Disaster Reduction, UN</td>
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<tr>
<td>MPK</td>
<td>Marginal productivity of capital</td>
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<tr>
<td>MPL</td>
<td>Marginal productivity of labour</td>
</tr>
<tr>
<td>MSM</td>
<td>Minimum Standard Model, World Bank</td>
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<tr>
<td>NATHAN</td>
<td>Natural Hazards Assessment Network, Munich Re</td>
</tr>
<tr>
<td>NBER</td>
<td>National Bureau of Economic Research, USA</td>
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<tr>
<td>NIBS</td>
<td>National Institute of Building Sciences, USA</td>
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<tr>
<td>NYSE</td>
<td>New York Stock Exchange, USA</td>
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<tr>
<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
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<tr>
<td>RMSM</td>
<td>Revised Minimum Standard Model, World Bank</td>
</tr>
<tr>
<td>SIDS</td>
<td>Small Island Developing State</td>
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<tr>
<td>UNO</td>
<td>United Nations Organisation (also: UN)</td>
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<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
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Disaster variables introduced in the neoclassical model are listed in Table 2-1. Standard notation is used for macroeconomic variables.
Abstract

What are the macroeconomic implications of natural disasters? In the literature, two fundamentally contrasting positions on this question prevail. The first emphasises the negative effects of natural disasters on macroeconomic performance whereas the second position considers disasters to leave economic growth largely unaffected.

With a focus on growth effects in developing economies, the thesis discusses these competing positions. For this purpose, it will provide an analysis of institutional perspectives, theoretical approaches and empirical evidence. Based on the analysis, this study argues that natural disasters do not have systematic effects on economic growth. Explanations include the geographic and economic localisation of most catastrophes, the compensatory effects of reconstruction, and the primary importance of human capital for aggregate output.

This conclusion requires several qualifications. Firstly, in small developing countries, aggregate effects may be observed for large disasters. Secondly, catastrophes may have repercussions on variables other than aggregate output, such as external balances. Thirdly, macroeconomic effects may be related to floods, storms and droughts, but rarely to earthquakes and volcanic eruptions. Finally, catastrophes appear to primarily affect the poor. On the one hand, this may explain that effects in the aggregate remain indiscernible. On the other, it indicates that welfare implications of disasters can only be understood if the distributional aspects of shocks are taken into account.

As a policy suggestion, it is concluded that a focus on the most exposed and vulnerable socio-economic groups – rather than concerns for macroeconomic effects – may maximise the benefits of disaster aid and disaster risk reduction.
Zusammenfassung


Die Studie kommt zum Schluss, dass sich im Allgemeinen keine bedeutenden Wachstumseffekte von Naturkatastrophen nachweisen lassen. Erklärungen für diesen Befund sind die geographische und ökonomische Begrenztheit der meisten Katastrophen, kompensatorische Effekte des Wiederaufbaus und die Bedeutung von Humankapital als Produktionsfaktor.

"The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk: The notion that the future is more than a whim of the gods and that men and women are not passive before nature."

*Peter L. Bernstein (1996)*

## I Introducing a macroeconomic perspective on natural disasters

How are natural catastrophes related to economic development? The literature that supplies answers to this question is multifarious: A variety of academic disciplines propagate a spectrum of perspectives that fundamentally differ in both analytical approaches and findings. Kroll-Smith and Gunter (1998) diagnose a paradigmatic and methodological "untidiness" of disaster studies.

This thesis takes a macroeconomic perspective; it draws on basic economic concepts for structuring the problem and reviewing the arguments and evidence on the above question. As Horwich (2000) points out, such an approach is "hardly novel" but "seldom applied systematically to natural disasters."

In the subsequent two chapters that constitute part I of the thesis, the problem of natural catastrophes¹ is introduced from a macroeconomic perspective.

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¹ A convention is to distinguish between natural disasters such as caused by floods, storms or earthquakes and man-made disasters that may include technical accidents and social crises such as riots and wars (Guha-Sapir et. al., 2004; Albala-Bertrand, 2000; Hewitt, 1983).
point of view. Chapter 1 includes a brief review of disaster literature and states the need for research in the form of a missing stylised fact. After specifying the objectives, the research question and the overall approach, an overview of the thesis is presented. Chapter 2 outlines the main concepts of disaster research and the respective terminology. This includes, as an analytical tool, a neoclassical growth model adapted to the study of catastrophes.

Subsequently, part II of the thesis will summarise the results of the analysis of both theoretical arguments and empirical evidence on the macroeconomics of disasters. Part III synthesises the findings and provides a conclusion.

An overview of the thesis, both of the research process and the resulting paper (this thesis), is supplied in section 1.4.

1 Natural disasters and economic development

For as long as historical records of extreme events in the natural environment have been kept, statistics indicate an increasing frequency of disasters. In the second half of the 20th century the number of large natural catastrophes doubled and yearly damages in monetary terms increased by more than a factor of 6 (Munich Re, 2006)².

Causes and effects of disasters appear to be closely related to economic development. In rich countries, natural catastrophes involve physical damage and few casualties, whereas in the developing world the human cost is far greater. Globally, more than 90% of total lives lost to natural disasters are due to events in developing countries (Kreimer and Arnold, 2000; Guha-Sapir et al., 2004). In absolute

² These illustrations anticipate the stylised facts and definitions supplied in section 1.1. Sources of data are given primarily there. According to Thorne (1984) the "earliest catalogued flood disaster" occurred around the year 4000 BC in Babylon; see also Crossley (2005).
monetary terms, natural disasters entail greater damages in industrialised countries while in relation to GDP, impacts appear primarily significant in the developing world (Mechler, 2003).

A variety of explanations\(^3\) is put forward in the literature for both the increase in disaster impacts over time and their contrasting repercussions in developing and industrialised countries. Firstly, global demographic dynamics and economic growth expose more people and their assets to risk. Secondly, urbanisation leads to a concentration of population, wealth and increasingly complex economic activities – a trend which may be accompanied by the growth of cities onto marginal lands\(^4\). In combination, these processes can increase both the vulnerability of socio-economic systems and their exposure to natural hazards. Thirdly, anthropogenic changes to the natural environment from local deforestation to global climate change are assumed in most of the literature to contribute to the rising frequency of extreme weather events and to their increasingly disastrous effects. Finally, development appears to explain differences in the vulnerability of physical structures and socio-economic systems to extreme events in the natural environment\(^5\). In other words: disaster risk is a ramifications of poverty – at the level of individuals, households, regions and countries.

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\(^3\) These are discussed in a number of sources including, e.g. Munich Re (1999), Munich Re (2006), Smith (2004), Engeström (1995).

\(^4\) While in developing countries, marginal land is predominantly settled by the poor, this pattern may be reversed in industrialised economies: Industry and the rich may settle in suburban areas where risk exposure may be higher but insurance is available (Munich Re, 1999). And, in the words of Engeström (1995), "quality of living makes us concentrate along the shorelines and seek to live in warmer climates. ... The migration towards the Sun Belt in the US is a prime example. People elect to live on the fault lines in California and on low-lying beaches like the Keys in Florida. Gradually large conurbations with high value infrastructure are established in these exposed areas."

\(^5\) As will be discussed in detail, the causality from development to vulnerability includes, among others, factors such as institutional quality, technology, the development of insurance markets, and resources for self-insurance.
If the distribution of catastrophic risk is influenced by the level of development, what are, in reversed causality, the effects of natural disasters on development? On this problem, there is considerable disagreement in catastrophe literature. Contrasting statements on the macroeconomic repercussions of disasters and their effects on growth and development indicate an intense debate.

DHA (1994), for example, concludes that "disasters frequently wipe out years of development programming and set the slow course of improvement in the third world countries further behind, wasting precious resources." ECLAC (2003) finds natural catastrophes to "have a major impact on the living conditions, economic performance and environmental assets and services of affected countries or regions. Consequences may be long term and may even irreversibly affect economic and social structures and the environment."6 Such statements, however, are not undisputed as is illustrated by Albala-Bertrand’s (1993a) objections, which have become a classic in this debate: "... disasters are primarily a problem of development, they are not necessarily a problem for development." Albala-Bertrand finds small, if any, discernible effects of natural disasters on macroeconomic aggregates – a hypothesis which he supports with theoretical arguments and data.

This is the controversy around which the following thesis is centred. It will take a macroeconomic perspective on the "schools of thought" on disasters, reviewing theoretical arguments and empirical evidence. The focus will be on issues of economic growth, with the overall objective of contributing a synthetic hypothesis to one of the main debates in catastrophe literature.

6 On the basis of a comparative economic history of Europe and Asia, Jones (2003) hypothesises that the different exposure to natural disasters in combination with the different institutional responses and further factors have made possible faster economic development in Europe than in Asia already in pre-industrial times. For historical perspectives see also Steinberg (2001).
The remaining sections of the chapter provide a succinct introduction to the economic literature on disasters (section 1.1). This includes an outline of the need for research which is translated into overall objectives and specified as a research question in section 1.2. The overall approach to the project is outlined in section 1.3. Finally, section 1.4 concludes with an overview of the research project and the resulting thesis.

1.1 Research on the economics of catastrophes

An in-depth review of catastrophe literature will be presented in part II. Therefore, the following outline of the state of knowledge on the economics of disasters remains brief and has a threefold purpose: Firstly, to present summary statistics and key stylised facts on natural catastrophes. Secondly, to introduce the main points of reference of the thesis in economic literature. This will include research traditions not directly related to the study of disasters. Thirdly, the need for research is illustrated in the form of a "missing stylised fact" – the observation that the intense debate on the economics of disasters receives little attention in mainstream economic literature.

Stylised facts on natural disasters

There are distinct patterns in the global distribution of disasters over space and time. Some socio-economic systems are more exposed to natural hazards; others have become more resilient to extreme events in the environment. The following paragraphs present four stylised facts on disasters including a geography of catastrophes.

In the interest of indicating the global orders of magnitudes of disaster effects: Munich Re (1999) has recorded 235 great natural disasters in the second half of the 20th century which caused total economic
losses\textsuperscript{7} of almost US$ 1,000 bn (1998 values). For the period of 1974 – 2003, Guha-Sapir et al. (2004) estimate the cumulated number of casualties at 2 million with 182 million people becoming homeless and economic losses at US$ 1,380 bn.

\textit{Stylised fact 1: disaster frequency and damages are increasing}

Globally, the frequency of natural disasters and the related damages have been increasing over time (figures 1-1 and 1-2). As outlined above, the main factors proposed as explanations of this trend are\textsuperscript{8}:

- the global growth of wealth and population;
- urbanisation involving a concentration of population, assets and economic activity;
- expansion of cities onto marginal lands with higher exposure to disaster risk;
- anthropogenic change of the environment (stylised fact 4);
- better historical and statistical coverage of disaster situations.

\textsuperscript{7} Note that the terminology used in the literature for describing disaster impacts may be confusing as definitions of concepts such as "economic damage" vary substantially from publication to publication (see section 1.2 as well as in chapters 4 and 5).

\textsuperscript{8} Further sources that observe this trend for various periods and drawing on different data bases include: Dacy and Kunreuther (1969), Gilbert and Kreimer (1999), Charveriat (2000), Benson and Clay (2004), Smith (2004), Guha-Sapir et al. (2004) Swiss Re, (2001c). Most sources note that the observed trend reflects the improving quality of disaster statistics, in particular on economic effects (Guha-Sapir et al., 2004). Qualitatively, stylised fact 1 remains robust, however.
Figure 1-1: The frequency of large natural catastrophes is increasing. Y-axis: number of events per year; colours indicate types of trigger events. Definitions, explanations and further sources for this observation are given in the text. From Munich Re (2006).
Figure 1-2: Disaster damages in monetary terms are increasing. Insured losses are increasing at a faster rate than total losses. Y-Axis: annualised losses in 2005 US$. As opposed to physical damage, the numbers of fatalities (not shown) exhibits no trend. Definitions of loss and damage as well as the availability of data are discussed in part II. From Munich Re (2006).
Stylised fact 2: The geography of natural hazards exhibits distinct patterns for each type of events

Geography determines the exposure of economies to natural hazards. A world map of geophysical hazards (earthquakes, volcanoes, tsunamis) and weather-related hazards (windstorms and floods) is given in figure 1-3. Geophysical hazards are primarily related to the boundaries of tectonic plates and therefore predominantly relevant in countries around the Pacific Ocean as well as along the collision zone of the African and the Eurasian plate, that is, along a line from Morocco through Central Asia to the Himalayan region. Hydro-meteorological hazards include tropical storms, primarily cyclones, as well as mid-latitude storms such as tornadoes and winter cyclones. Tropical cyclones occur primarily in the Indian Ocean, the Caribbean and in the western Pacific while mid-latitude storms affect mainly regions bordering on the northern Atlantic.

From an anthropocentric view, most extreme events in the natural environment remain without consequences. A disaster may only result, if social, economic or technical systems are affected (Cannon, 1994). As illustrated by figure 1-3, many large urban centres, often referred to as mega-cities, are highly exposed to natural hazards. Examples for cities in earthquake-prone areas are Tokyo, Los Angeles, Mexico City, Istanbul and Tehran (Munich Re, 2005; OECD, 2000).

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9 This includes the Pacific coast of the Americas from Chile to Alaska and regions to the west of the Pacific, i.e. Japan, the Philippines, New Zealand as well as Indonesia. The collision zone of the African and the Eurasian plate runs through Northern Africa, Turkey, Central Asia and continues to the Himalayan region, where the Indo-Australian plate collides with the Eurasian plate.

10 Tropical storms occur primarily in the northern Indian Ocean including the Bay of Bengal (where they are called tropical cyclones), to the north of Australia, in the Caribbean (hurricanes) and in the northwest Pacific (typhoons). Mid-latitude storms include tornadoes, primarily in the United States and winter storms, which occur mainly in the northern Atlantic, that is northern Europe and northern America.
Figure 1-3: A global geography of natural hazards. Source: Smith (2004)\textsuperscript{11}.

\textsuperscript{11} World maps of natural hazards are available from Reinsurers (Swiss Re, 1993; Munich Re, 2000 and online application NATHAN on mrnathan.munichre.com). See also the recent publication by Dilley et al. (2004), the most advanced geography of natural disasters available at the time of writing.
For storms and floods, Dilley et al. (2005)\textsuperscript{12} identify "disaster hot spots" primarily in the Caribbean, in India and Bangladesh as well as in Asian regions bordering the Pacific Ocean.

Different extreme events in the natural environment trigger disasters with distinct characteristics. Earthquakes cause primarily local losses of human life and capital, while effects on economic aggregates are rarely reported. Disasters triggered by windstorms and floods however, affect larger areas and were found to entail substantial macroeconomic effects (DHA, 1994; Smith, 2004). Around half of the total fatalities are related to disasters triggered by earthquakes and windstorms, respectively, while less than 10\% are related to floods and other hazards. Economic losses of natural disasters are attributed to around a third each to earthquakes, windstorms or floods\textsuperscript{13}.

\textit{Stylised fact 3: disaster risk is a matter of development}

The patterns of economic and social effects of disasters are related to the levels of income and development. While large natural disasters\textsuperscript{14} seem to occur equally frequent in both the developing world and the industrialised world, the number of fatalities is highest in the poorest country group (figure 1-4). In absolute terms (not shown in the figure but correlated with insured loss), damages in monetary terms are

\begin{flushleft}
\textsuperscript{12} An excellent source for a geographic perspective on disaster risk: the distribution of disaster risk is analysed in high resolution (smaller units than countries) and for a variety of trigger events and effects.

\textsuperscript{13} Statistics for 1950 – 1999, excluding droughts; from Munich Re (1999).

\textsuperscript{14} Munich Re (1999: 41) defines disasters as great natural catastrophes "if the ability of the region to help itself is distinctly overtaxed, making interregional or international assistance necessary. This is usually the case when thousands of people are killed, hundred of thousands are made homeless, or when a country suffers substantial economic losses, depending on the economic circumstances generally prevailing in that country." The terms large natural disasters or great natural disasters, respectively catastrophes are used as synonyms in this thesis.
\end{flushleft}
highest in industrialised countries, as are aggregate insured losses. In addition, only in industrialised countries is a significant share of economic losses insured, which explains that more than 90% of insured losses due to natural disasters (see figure) are related to the richest group of countries. Finally damages in relation to GDP per capita are predominantly significant in poor countries15.

**Figure 1-4: Disaster effects and per-capita income.** Loss-to-GDP ratios16 and casualty figures are highest in poor countries, while insured losses are highest in industrialised countries. A large number of events qualify as "large natural catastrophes" in industrialised countries for their monetary losses in absolute terms. Figure from Mechler (2003: 22), based on data from (Munich Re, 2000).

15 Not to be confused with effects on GDP; one of the central issues discussed in part II.

16 Questions with regard to the definition and interpretation of "economic losses as %
The observed patterns of disaster risk and development are explained in literature by the higher incidence of extreme events in the natural environment of developing countries and by a greater vulnerability to these trigger events (e.g. Albala-Bertrand, 1993a; Crowards, 2000; UNDP, 2006). The higher vulnerability of developing countries has, on the one hand, structural causes, which are related to the level of development\textsuperscript{17}. On the other hand, poverty is, both at the micro and at macro levels, the main explanation for the high vulnerability of individuals and societies in developing countries (UNDP and UNDRO, 1992). Poverty discourages investment in technical and financial risk management, increases the volatility of income and consumption in case of disasters and protracts their economic effects (Hoogeveen, 2000)\textsuperscript{18}. These mechanisms are related to the limited availability of both formal and informal insurance in developing countries and to poor households. In industrialised countries, the percentage of formally insured disaster losses is typically 10 – 20\%, in some cases up to 60\%. In the developing world, this percentage is around 1 – 2\% (Freeman et al., 2002).

\textit{Stylised fact 4: climate change is expected to lead to an rise in frequencies and severities of weather-related disasters}

The increase of disasters in both frequency and size of damages is attributed in part to an increase of weather-related trigger events such as

\textsuperscript{17} Tol and Leek (1999) present an overview of the change in disaster effect patterns over time for selected countries.

\textsuperscript{18} On the interrelation between poverty and risk, Hoogeveen (2000) comments that a high income volatility of poor households may have irreversible consequences, if resources available do not allow for sufficient nutrition, if productive resources are sold in order to ensure survival, or if investment in human capital are postponed owing to the need for income in the short term. This may explain why natural disasters in poor countries have the potential to evolve into humanitarian disasters.
as windstorms and floods. Causes for this trend are assumed to be primarily anthropogenic and to range from global climate change to local deforestation (Dilley, 2000; Warner and Freeman, 2001). Climate change scenarios as published e.g. by IPCC\(^\text{19}\) entail rising sea levels and an increase in extreme weather events for the next decades (Smith, 2004; Swiss Re, 1994; Swiss Re, 2002b).

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![Figure 1-5: Hydro-meteorological disasters have been increasing faster over time than geophysical disasters.](image)

**Figure 1-5: Hydro-meteorological disasters have been increasing faster over time than geophysical disasters.** The Y-axis indicates the number of events per year recorded in EM-DAT. Figure modified\(^\text{20}\) from ISDR (2006a).

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\(^{19}\) Intergovernmental Panel on Climate Change, various years; reports available at: www.ipcc.ch. Examples for overviews in addition to the literature quoted in the text: Downing et al. (1999), Kokoski and Smith (1987), Tucker (1996), West et al. (1999).

\(^{20}\) The original figure covers the period of 1900 – 2004. Before 1950 few events are recorded; this part of the figure has been removed in the version depicted here.
To summarise the four stylised facts, the implications of natural disasters appear to be most relevant to economies and socio-economic groups that are both exposed and vulnerable to hazards. From a development perspective, natural catastrophes are an issue because the main determinant of disaster risk, besides exposure to hazards, is vulnerability – which appears closely associated with development. Globally, various factors from economic growth to climate change may increase disaster risks in the future. The stylised facts are commonly translated into the following policy recommendations: Firstly, disaster risk management should be part of any development strategy as it is a prerequisite for sustainable development (Freeman et al., 2002; IDB, 2000). Secondly, disaster prevention, humanitarian aid and reconstruction should first and foremost aim for a reduction of vulnerability (Zapata Marti, 2000; Benson and Clay, 2000).

The missing stylised fact: macroeconomic effects of natural disasters

While there is little controversy on the above patterns of disaster risk, consensus becomes fragile on the macroeconomic repercussions of catastrophic shocks. Statements in the literature are contradictory, involving polemic debates in some instances. Evidence, however, remains thin.

Biological disasters include epidemics, which are not discussed in this thesis.

21 The target audience for these recommendations includes developing countries’ governments, development finance institutions, the variety of development and humanitarian aid organisations as well as the insurance sector.

22 Example: In 1989 the hurricane Hugo damaged large parts of buildings and infrastructure on Montserrat. Reconstruction considered technical standards for hurricane resistance of buildings. In 1995, volcanic eruptions destroyed most of the infrastructure rebuilt. This risk had not been taken into account in urban planning (Benson and Clay, 2000).
Some literature considers natural disasters as setbacks or obstacles for development (e.g. Kreimer and Arnold, 2000). Arguments refer to effects on output and on the reallocation of domestic resources as well as international aid from long-term investment to humanitarian interventions and reconstruction (UNDP and UNDRO, 1992; Clarke and Munashinge, 1995; Zapata Marti, 2000). According to Freeman et al. (2000) it is a characteristic of developing countries that they lack the wealth for financing significant shocks to their capital stock. Moreover, the consequences may be aggravated if the disaster is accompanied by political or social destabilisation (UNDP and UNDRO, 1992; Caviedes, 1995), by business cycles, financial crises or fluctuations in the price of important exports or import goods (Benson and Clay, 2000). Quantitatively, significant impacts of natural disasters on macroeconomic aggregates are found for case studies of countries or individual events (e.g. Benson and Clay, 2004).

Disasters are also reported to have distributional implications regarding wealth, income, and exposure to risk (Hoogeveen, 2000; Wisner, 2003). Albala-Bertrand (1993a) even concludes that distributional effects may be more important from a welfare and development perspective than impacts on economic aggregates. His arguments are that the poor are not only exposed to higher risks and more vulnerable, but that they also benefit least from insurance, reconstruction efforts and aid.

On the hypothesis that the poor are most exposed to catastrophic risk, there is, as for the four stylised facts, little controversy. However, the "received view" of natural catastrophes draws criticism from the likes of Howards (2000) or Albala-Bertrand (1993a: 86), who concludes that "... there are no such things as economic ‘national calamities’, ‘long-

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23 Analogous diagnoses led the UNO to declaring the 1990s to the "International Decade for Natural Disaster Reduction" or IDNDR (Advisory Committee on the IDNHR, 1987; UN-ISDR, 2002).
term stagnation’, ‘formidable obstacles to economic growth’ due to natural disasters or ‘that (they) can significantly retard the growth of developing countries’.

Overall, the various positions defended by disaster scholars are in fundamental contradiction – on the macroeconomic implications of disasters the literature does not allow for generalising conclusions.

**Points of reference in the literature**

Defined by the subject under study and the macroeconomic perspective, the thesis draws primarily upon two research traditions: On the one hand, economic literature on growth and development and, on the other hand, "disaster literature" – an umbrella term introduced here for contributions from various disciplinary and institutional backgrounds. The following two sections will outline how the thesis relates to these two research traditions. It will be illustrated that the growth literature provides the theoretical perspective. The catastrophe literature will provide the sources for the analysis in part II.

**The catastrophe literature**

Samuel Henry Prince is often regarded as the founding father of disaster studies in the social sciences with the first catastrophe systematically described being an explosion in the harbour of Halifax, Canada in 1917 (Prince, 1920). In the second half of the 20th century,  

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24 In this thesis, discussions of the disaster literature focus on contributions with substantial statements on the macroeconomics of catastrophes. This excludes most parts of the "disaster studies" literature from social sciences other than economics, from finance and the actuarial sciences, from the medical sciences and psychology, as well as from the natural and engineering sciences.

25 The historical outline of the field given here is grossly simplified and serves for illustrative purposes only. For overviews of the history of disaster studies see Russel (1970), Dacy and Kunreuther (1969) as well as Quarantelli (1998) and contributors.
the disaster literature devoted much attention to scenarios of thermonuclear war (Tiryakian, 1959), in some cases studying the socio-economic effects of the plague in medieval Europe (e.g. Hirshleifer, 1966), which was discussed as an analogous event\textsuperscript{26}. Examples of landmark contributions on the economics of \textit{natural} disasters include the case study of the 1964 earthquake in Alaska by Dacy and Kunreuther (1969), a review of selected catastrophes by Cochrane (1975) and the seminal book by Albala-Bertrand (1993a). Since 2001 disaster studies increasingly address the economic effects of terrorism (e.g. Green, 2004) – analyses, which refer to natural catastrophes as illustrations while early studies of natural disaster drew upon analogies from armed conflicts.

In the last two decades, research on the effects of natural catastrophes on development has proliferated in various disciplines including sociology, geography, economics and the actuarial sciences. Many contributions, however, have other institutional backgrounds than academia. The insurance sector, on the one hand, produces a considerable amount of applied research on natural disasters. On the other hand, institutions involved in humanitarian aid and economic development contribute valuable reports and data on the economics of disasters. While the diverse institutional perspectives imply different approaches, there are a number of unifying concepts in disaster research. Most prominently, these include \textit{risk} and \textit{vulnerability} – both concepts will be discussed in section 1.3 and remain central throughout the thesis.

After the current areas of consensus in disaster research have been outlined and a missing stylised fact has been identified, the review of catastrophe literature pauses here. It will be continued in part II to constitute the analytical core of the thesis.

\textsuperscript{26} On differences in the socio-economic implications of wars as opposed to natural disasters see Albala-Bertrand (2000).
Literature on economic development and the natural environment

In the catastrophe literature (preceding paragraphs), macroeconomic repercussions are studied as one of the various aspects of natural disasters. The following paragraphs take a different perspective on the problem: literature on economic development in general is reviewed for insights on catastrophes as one of the many factors that may influence economic growth.

Studies of the relations between the natural environment and economic development have a long tradition in economics, with problems including resource endowments, geography and diseases\textsuperscript{27}. Three fields of research are briefly discussed here: Firstly, literature on factors that explain economic growth in general, secondly, literature on adverse shocks and growth, and, finally, literature on environmental factors and their influence on growth\textsuperscript{28}.

Examples of research on the determinants of economic growth include Barro (1991, 1997) or Hall and Jones (1999). The focus of this field of research is on variables of growth models – from investment rates in physical and human capital to the differences between countries’ labour productivity and fertility rates. Exogenous shocks, environmental factors, and natural disasters receive less attention in mainstream growth research.

\textsuperscript{27} This research tradition in the field of development economics has its origins in the work of Adam Smith, David Ricardo and Robert Malthus (Barro and Sala-i-Martin, 1995). The inverse relation between nature and socio-economic systems, i.e. the human impact on the environment, is addressed in theories of resource economics and environmental economics. In these disciplines implicit and explicit references to classical economics are made (Frey, 1993; Brander and Taylor, 1998). For ecological aspects of disaster risk, see Adger et al. (2005).

\textsuperscript{28} Note that a review of the literature on economic growth is not attempted here; Mookerjee and Ray (2001) or Barro and Sala-i-Martin (1995) may provide starting points. The sources quoted in the text are selected examples of a large number of contributions that were scrutinised for references to natural disasters.
An exemplary analysis of the growth effects of exogenous shocks is provided in Rodrik (1998). Similar shocks and their economic impacts in different countries are studied. From the empirical results Rodrik concludes that the economic effects of shocks depend upon the potential of social conflicts and the effectiveness of institutions for addressing these conflicts: The lower the conflict potentials and the higher the institutional quality, the more economically efficient the responses to exogenous shocks are.

The influence of geography, climate, diseases and further environmental factors on growth is discussed in papers by Easterly und Levine (2002) as well as Sachs (2003). Easterly and Levine conclude that the natural environment exerts a significant influence on growth, however only indirectly via institutional quality: Favourable environmental conditions support the development of institutions of high quality which, in turn, is the main factor that leads to higher growth rates. In Acemoglu et al. (2001) and Sachs (2003) this hypothesis is challenged. Using the example of Malaria, Sachs shows that environmental factors may have a direct effect on growth, independently of institutional quality. Jones (2003) develops an analogous argument in a long-term comparative economic history of Europe and Asia. In his analysis, disasters, natural and man-made, play a central role.

To conclude from the survey of mainstream growth research: There is a large body of literature (beyond the few examples quoted) on environmental influences on economic development. These inspire the perspective and the theoretical approach of this thesis. However, natural disasters receive little attention in the main scholarly journals and therefore provide few insights directly related to the research subject of the thesis.\textsuperscript{29}

\textsuperscript{29} For the keyword „natural disaster“, Yezer (2000) found only 38 entries in the index to the Journal of Economic Literature and Hirshleifer (1991, 2006) observed that the New
Need for research

Concluding from the preceding, the need for research on the macroeconomics of natural disasters can be delineated from two perspectives: on the one hand, from the missing stylised fact and the controversy in the general disaster literature; on the other hand, and more specifically, from the nearly complete absence of the problem in mainstream macroeconomic research.

On the development economics of natural disasters there exists, to the author’s knowledge, no synthesis of a conceptual rigour and analytical depth that could compare with standard works on other economic problems. What is available in catastrophe literature includes, on the one hand, a range of compilations of articles edited as books (e.g. Varley, 1994; Munasinghe and Clarke, 1995; Kreimer and Arnold, 2000; Pelling, 2003; Kunreuther and Rose 2004). These anthologies provide valuable overviews of topics and perspectives but generally do not seem to aim at a synthesis. Moreover, macroeconomic aspects remain marginal even in comprehensive compilations. On the other hand, there are literature surveys in the introductory sections of academic publications such as Albala-Bertrand (1993a), Yezer (2000), Mechler (2003), Murdilidharan and Shah (2003) or Okuyama (2003). By definition, such reviews normally remain brief and serve primarily for introducing the work and the specific position of the respective author.

To anticipate the findings of part II, the missing stylised fact may be explained, in part, by the primarily applied nature of disaster research. Regardless of its institutional background, catastrophe literature was

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Palgrave Dictionary of Economics (1987) did neither list the keywords "disaster" nor "recovery" in its index. The latest version of the Handbook of Economic Growth (Aghion and Durlauf, 2005) does neither refer to natural disasters or other catastrophic shocks.

30 Arbitrarily selected examples of such reviews or syntheses: Mankiw (1990), Temple (1999), Easterly and Levine (2001), Collier and Gunnings (1999). The reader is asked not to refer to these landmark contributions as a benchmark for this thesis.
found to focus primarily on practical policy recommendations, such as on humanitarian aid, insurance, reconstruction as well as ex-ante and ex-post disaster risk management (e.g. Anderson and Woodrow, 1989; IDB, 2000; Mechler, 2003). In other words, the approaches in the catastrophe literature are predominantly normative rather than positive. For the provisionary observation that few studies of disasters explicitly draw on macroeconomic theory, the author can present no explanation – nor for the low attention that natural disasters receive in mainstream growth research.

1.2 Objectives and scope of this thesis

Overall objectives, research question and scope

The overall objective of the thesis is to contribute to the understanding of natural disasters and their implications for economic development\(^{31}\). As outlined in the preceding sections, the macroeconomic effects of catastrophes are subject to controversial debate but remain thinly covered in the literature. Moreover, there is consensus that with development and environmental change natural disasters could become a more relevant problem in the future than historical experience suggests. Analytical insights into the macroeconomics of catastrophes will prove invaluable for addressing these problems in policy design at any institutional level, both in the private and in the public sector.

The following research question specifies the overall objective:

*How do natural disasters influence economic growth in developing countries?*

On the one hand, this question relates to two fundamental problems of economics: The mechanics and determinants of development and the

interrelations between the natural environment and socio-economic systems. Drawing on these research traditions, the thesis aims at synthesising the disaster literature that allows for new insights with regard to the missing stylised fact. On the other hand, the research question makes the focus of this project explicit: The thesis will be a partial analysis that centres on GDP growth as a crude indicator of macroeconomic performance and development.

There are various arguments for this focus: Most importantly, aggregate output may be considered the key macroeconomic variable. GDP as an indicator for output is universally known – as are the difficulties of its interpretation in welfare terms. As will be shown in part II, the diversity of measures for "economic impacts" of disasters is daunting. Resorting to GDP as a smallest common denominator for the analysis of a fragmented literature will therefore both facilitate comparisons and the synthesis of findings to an answer to the research question.

Where statements and data on distributional aspects and poverty are found in the literature, these will also be included in the analysis. In combination with aggregate output, this may allow for better localising disaster effects.

In summary, aggregate and distributional aspects will provide a rudimentary description of the development implications of natural catastrophes. Note, however, that on distributional issues, there is less disagreement and literature is considerably thinner than on macroeconomic issues.

**Limits of scope**

Various relevant and interesting economic aspects of disasters will remain out of scope of the research project. Firstly, the descriptive (or positive) macroeconomic approach, indicates that normative implications with regard to disaster risk reduction will receive little attention.
In particular, neither policy analyses nor policy recommendations will be attempted. Issues such as humanitarian aid, disaster relief and prevention, or the sociology and political economics of catastrophic risk will only receive marginal coverage. Further, technical aspects of disaster insurance and finance as well as the monetary valuation of life and health will not be included. Secondly, the focus on GDP, growth and distribution implies that other macroeconomic aggregates will be discussed only as explanatory variables. Moreover, welfare issues remain out of scope of the analysis.

In brief, the thesis aims at a partial analysis of one macroeconomic aspect of catastrophes rather than at a comprehensive survey of disaster literature. To anticipate an analogy from the introduction to part II: It will provide a transect through a field of research rather than a topographical map.²²

**Expected contributions to the literature**

The potential contributions of this thesis to the economic literature, as already implied in the preceding sections, are twofold and may be summarised as follows:

*Insights into the macroeconomic effects of disasters:* an answer to the research question or a hypothesis on the missing stylised fact, respectively. Regardless of the outcome, the thesis will, as a minimum, identify the main positions and allow for conclusions with regard to their robustness. The macroeconomic approach, the depth of analysis and the inclusive review of literature will combine to a novel perspective on disasters – or, more appropriately, on disaster research.

²² Note that neither the focus nor the approach of the thesis are meant to imply that the humanitarian implications of catastrophes are considered less relevant than the economic effects; see also the conclusions in part III.
A set of analytical frameworks that facilitate orientation in the catastrophe literature – a prerequisite for the first contribution. The analytical frameworks will be tailored to the review of the fragmented catastrophe literature. As will be outlined in the following section 1.3, the second contribution includes, on the one hand, a set of categories and structuring dichotomies for orientation in the catastrophe literature. On the other hand, a neoclassical growth model will be adapted to the study of disasters. By explicitly defining macroeconomic disaster variables, this model will serve as a point of reference for comparisons, interpretations and the synthesis of conceptual approaches in the literature. The application of these frameworks beyond this research project remains to be discussed.

1.3 Approach and methodology

The overall approach to the project follows directly from the macroeconomic perspective, from the objective specified by the research question and from the meta-analytical approach to a defined field of research. The outline of five key methodological elements in the following paragraphs therefore remains brief, with refinements of analytical frameworks being supplied later in the text. Note also that the overall approach is directly reflected in both the research process and in the organisation of this paper (section 1.4).

A descriptive topography of the catastrophe literature

The introductory section of part II will verbally and graphically introduce a framework of categories and dichotomies that serves for orientation in the disaster literature. This descriptive topography includes three main institutional perspectives, which will be differentiated by level of analysis (micro versus macro) and by normative as opposed to positive positions. For each of the three perspectives,
contributions in the literature are aggregated to "schools of thought" or according to unifying theoretical concepts. Further, individual works are discussed in detail where they represent landmarks in the literature or are considered representative for an aggregate of contributions. In addition to the orientation purpose, the framework may contribute to a better understanding of the various positions with regard to the research question.

**A generic definition of disaster**

Chapter 2 will refer to the abundance of definitions that are offered in the literature for disaster, catastrophe, calamity, cataclysm and related concepts. Given the inclusive analytical approach to a diverse field of research, the definitions proposed in this thesis will represent a smallest common denominator and aim at general applicability – rather than at adding new definitions. This will include a concept of disaster risk as a function of hazard, exposed elements and vulnerability (see section 2.1).

**A neoclassical growth model for purposes of definition**

Section 2.2 will introduce a neoclassical growth model adapted to the discussion of natural catastrophes. By unambiguously defining macroeconomic disaster variables, this will provide the analytical framework for discussing the macroeconomic lines of arguments in the literature. The neoclassical framework will include a formal and graphical apparatus that describes disasters as shocks to the production factors and to productivity – as well as the resulting effects on output, consumption and further macroeconomic variables. The need for such a model results from the wide spectrum of fundamentally different definitions that are used in disaster research for seemingly self-evident concepts such as economic damage.
The choice of a growth model for purposes of definition is, on the one hand, a consequence of the development economics perspective of the thesis. On the other hand, the neoclassical model will be used as it is widely known (including its evident weaknesses) by any disaster scholar with a basic grounding in economics.

Note that the neoclassical framework will serve only as a qualitative point of reference. By providing a contrast, it may illustrate the characteristics of the various conceptual approaches in the catastrophe literature. However, the framework is explicitly not meant as an economic theory of natural disasters, nor will it be used as a basis for macroeconomic simulations or econometric analyses of its predictions.

**An analytical transect through the catastrophe literature**

After presenting a topography of disaster literature in part II, the analysis will focus on the objectives specified in the research question: the effects of natural catastrophes on economic growth and poverty. Literature will be reviewed only for statements on these two aspects, which will yield an analytical transect through the topography of research – rather than a general review of catastrophe literature. Where this appears promising, own empirical excursions will complement the analysis. This approach is detailed in the introductory sections to part II\(^{33}\).

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\(^{33}\) The inspiration for this analogy and this approach is due to Doug Aitken (1998) who presented in his video installation "Eraser" an audio-visual transect of Montserrat – an island in the Caribbean that had been devastated by hurricanes and a volcanic eruption in the preceding years.
A synthesis of the findings including a critical re-examination

The analysis of theoretical arguments and empirical evidence (part II) will be synthesised in part III to an overall conclusion with regard to the missing stylised fact – or to an answer to the research question. In addition to a, possibly revised, topography of positions in the literature, this will include a critical discussion of the findings. Inherent to this research programme is that it will raise more questions than it provides answers.

1.4 Overview of the research project and the thesis

The thesis is organised into three parts comprising eight chapters – a structure which directly reflects the research process:

Part I introduces the problem of natural disasters, specifies the scope and the objectives of the thesis, and outlines the analytical approach (chapter 1). The existing literature in the field is surveyed and the main points of reference for the thesis are highlighted. Chapter 2 introduces a neoclassical model adapted to the study of catastrophic shocks – it will provide the defining framework of macroeconomic disaster variables for the subsequent chapters.

Part II is the analytical core of the thesis. After introducing a topography of disaster research, a transect through the literature is presented. Chapter 3 discusses development policy perspectives on the research question whereas chapter 4 focuses on insurance perspective. Chapter 5 reviews macroeconomic perspectives. Each of the perspectives, "schools of thought", or individual landmark contributions, are characterised according to a set of structuring dichotomies and further criteria. The focus, however, is on theoretical arguments and empirical evidence on the macroeconomics of disasters. Contributions are summarised, translated into the neoclassical framework where necessary, exposed to a hypothetical discussion
with other scholars and scrutinised for tenable findings with regard to the research question.

Finally, *Part III* in chapters 6 to 8 synthesises the results of the analysis from part II. The main positions in disaster literature are re-evaluated. By way of a conclusion, the findings of the thesis are synthesised to answer the research question – including a number of qualifications. After touching upon the policy implications of these findings, the thesis will conclude with a critical retrospective on the project as well as with suggestions for further research.
2 What is a disaster?
A neoclassical perspective

Considering the variety of theoretical perspectives on disasters\textsuperscript{34}, the even greater variety of definitions for "disaster", "catastrophe", "cataclysm", "calamity"\textsuperscript{35} and related concepts will not come as a surprising finding. In a seminal book titled "What is a disaster?" (edited by Quarantelli, 1998) around a dozen disaster scholars from the social sciences discuss various perspectives and definitions. Quarantelli’s premise in the introduction is that "a developing field [of research] will flounder unless there emerges some rough consensus about its central concept(s)." The ensuing debate reflected in the contributions to the book illustrates the spectrum of perspectives on the problem in the social sciences: Some authors see disasters as a social construction and focus on the related discourses; others aim at defining a catastrophe as a "physical happening".

Here, a pragmatic approach to the disaster definition problem is proposed\textsuperscript{36}, primarily for three aspects of the research project: the macro-

\textsuperscript{34} See the outline in chapter 1 and the more detailed discussion in part II.

\textsuperscript{35} These concepts are considered synonyms here. In this thesis, the terms disaster and catastrophe are used.

\textsuperscript{36} This approach will also spare the reader an additional definition of "natural disaster". Sources that may serve for illustrating the debates on problems of definition, in addition to Quarantelli (1998), include Albala-Bertrand (2000), Baudrillard (2006) who describes disasters as "rogue events", Solnit (2005) for a heterodox view of the social repercussions of disasters, the anthology edited by Kunreuther and Rose (2004), McIntire (2001, 2004), or Shaluf et al. (2003) where disasters are differentiated from crises. For comments on mathematical catastrophe theory see Albala-Bertrand (1993a: 6). Further, the brief but informative comments in Russel (1970) point to the religious and mythological perspectives on disaster: Catastrophes as "acts of god" or acts of the forces of nature; see also the explanation to one of the illustrations in Munich Re (1999): "This drawing depicts a scene from ancient Japan, where victims confront the catfish (namazu), considered responsible in this country for destructive earthquakes, with anger and resentment."
economic perspective, the focus on growth effects, and the inclusive approach to the literature analysis. In combination, these characteristics presuppose a disaster definition that is, on the one hand, broadly applicable over a wide field of research and, on the other hand, directly relates to customary concepts from macroeconomic theory. In other words, the conceptual frameworks used for the analytical part II should, first and foremost, reduce complexity and provide a smallest common denominator as a point of reference.

The chapter is therefore organised as follows: Section 2.1 outlines the concepts of disaster, risk, and vulnerability. Drawing upon various sources in the disaster literature, this will introduce the terminology for discussing the impacts of catastrophes. In section 2.2, disasters will be studied as exogenous shocks to a neoclassical economy. An exercise in applied growth theory will supply a coherent set of macroeconomic disaster variables and functional relationships. Again, note that this framework is developed for purposes of definition only and is not propagated as a neoclassical theory of natural disasters.

2.1 Disaster risk: paradigms, concepts, definitions

A natural disaster may be defined as the consequence of an extreme event in the natural environment, such as an earthquake or a flood, which is limited in time and space and involves sudden and severe disruptions of socio-economic processes (Engeström, 1995; ECLAC, 2003). In the words of Blaikie (1994) "disasters occur when hazards meet vulnerability".

In the three subsequent sections, the concepts of catastrophe risk, natural hazards, and vulnerability are discussed. Figure 2-1 summarises the definition of disaster risk as a function of exposure to natural hazards, elements at risk, and vulnerability. The concept may be used both in a deterministic or a stochastic variant and at any level of analysis from individuals over infrastructure to economies.
Note that the definitions proposed here are neither novel nor specific to this thesis. On the contrary: they draw on a wide spectrum of disaster literature and aim primarily at integration and simplification. Key references are given throughout the section.

**Natural Hazard**

Natural hazards can be defined as phenomena in the natural environment, which may endanger persons or objects. Hazards may trigger disasters, given that an element at risk is both exposed and vulnerable. A hazard, however, is not a characteristic of the persons or objects at risk and is exogenous to socio-economic systems. The description of a hazard may include its occurrence probability and intensity, often presented as probability distributions or as probabilities of exceeding certain physical magnitudes (Munich Re, 2000; Swiss Re, 2003a).

The focus of this thesis is on sudden-onset natural hazards, in particular earthquakes, windstorms, floods and volcanic eruptions. This excludes, on the one hand, anthropogenic hazards such as conflicts and industrial accidents. In addition, slow-onset natural

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**Figure 2-1: Disaster risk, natural hazards, and vulnerability.** Terminology and basic equation. Based on: Weidmann (2002) as well as Benson and Clay (2004), Munich Re (2000) and Swiss Re (2003a).
hazards, primarily droughts\(^37\) and epidemics, are excluded. For detailed classifications of hazards and disasters see Smith (2004), Munich Re (2000) or Albala-Bertrand (1993a).

**Vulnerability**

Vulnerability, the susceptibility of elements at risk to natural hazards (Munich Re, 2000) or the extent of damage for a given hazard intensity (Swiss Re, 2004), is the key concept in contemporary research on natural disasters and related policy recommendations (UNDP and UNDRO, 1992; Anderson, 1995). According to Green (2004) "vulnerability can be defined as the relationship between a purposive system and its environment, where that environment varies over time." Charvériat (2000: 75), finally notes that "vulnerability is usually defined as the degree of losses, from 0 to 100% of the assets exposed that a given natural hazard would generate in a specific zone."\(^38\)

The concept of vulnerability may be applied to any element at risk from individuals, households and buildings to companies, economies, and governments. Benson and Clay (2004) propose to refine the concept to two dimensions and to include sensitivity (determining the immediate effect of hazards) and resilience (the potential and speed of recovery)\(^39\).

The focus of early disaster studies was on natural hazards as the exogenous cause of disasters – and still is in the natural and

\(^37\) Empirical work on disasters often includes droughts; this will be taken into consideration where necessary.

\(^38\) See Green (2004) for an anthology of further vulnerability definitions.

\(^39\) In ECLAC (2003) the concept of "response capacity" is introduced and defined as a "system's ability to adjust to or resist the disturbance, moderate potential damage and take advantage of opportunities."
engineering sciences (Quarantelli, 1998 and contributors; McEntire 2001). In some of this literature, disasters are equated with the related natural hazard. Other scholars, mainly from the social sciences, explain natural disasters as primarily endogenous processes (Cannon, 1994; Clarke and Munasinghe, 1995) with vulnerability determined by institutional quality, economic structures, distribution, poverty and further factors (Zapata Marti, 2000). Still others consider the concept of natural disasters as technocratic (Hewitt, 1983) and, emphasising the endogeneity of vulnerability, see natural catastrophes as man-made rather than natural40.

**Disaster Risk**

The concept of risk adds a probability dimension to the study of disasters. The actuarial definition of risk is an expectancy value, the product of the occurrence probability of an event and the loss involved. As illustrated by figure 2-1, potential damage or potential loss may be given as a function of elements at risk and their vulnerability (Munich Re, 2000)41. Elements at risk, in turn, can be described by the geography of assets, human populations or economic activity.

Three examples may serve for summarising and illustrating the disaster risk framework introduced above: Tokyo is, according to the Munich Re (2003) hazard risk index42, the city with the highest disaster risk. This is explained by the extraordinary concentration of values and the high exposure to natural hazards, but less by vulnerability. For other cities in industrialised countries, disaster risk is lower but ex-

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40 See also Charvériat (2000) and Pelling (2003).

41 In finance, the concept of risk refers to the variance of variables, such as return, which allows for "upside risk" and "downside risk" (Holton, 2004; Mechler, 2003). For reviews on risk in economics and histories of thought on risk: Knight (1921), Arrow (1970, 1996), Bernstein (1996).

42 The disaster risk index will be discussed in more detail in chapter 4.
hibits analogous patterns. In cities of developing and emerging countries, however, such as Istanbul, Mexico or Tehran, it is primarily vulnerability that contributes to a high disaster risk index. For Switzerland, disaster risk related to earthquake is high owing to high densities of values and population, medium hazard exposure and medium to high vulnerability. In central Greenland, disaster risk may be considered irrelevant as hazard exposure is low as is the density of elements at risk (Weidmann, 2002).

### 2.2 Natural disasters in a neoclassical economy

The following sections study the macroeconomic implications of a catastrophic shock to a neoclassical economy. A set of disaster variables will be introduced to various versions of the Solow-Swan growth model. These include: $\Delta K_d$ and $\Delta L_d$ for describing the shock to the production factors; $\Delta Y_d$ and $\Delta C_d$ for the effects on aggregate output and consumption; $\Delta D_d$ for changes in net foreign debt and, finally, $\Delta A_d$ as a proxy for effects on productivity (see table 2-1). A rudimentary formal and graphical apparatus and a description of the behaviour of neoclassical economies following a catastrophe will make the definitions of these macroeconomic disaster variables explicit.

For the basic neoclassical growth model, the section draws primarily on Solow (1956a, 1962, 2000) and Swan (1956), as well as on Barro and Sala-i-Martin (1995), Jones (2002), Gärtner (2006) and Mankiw et al. (1992). Literature for refinements of the model beyond the textbook versions is given in the text. The disaster variables are proposed by the author\(^43\).

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\(^{43}\) For reviews and critiques of, as well as for alternatives to the neoclassical approach see e.g. Lucas (1988), Mankiw et al. (1992), Sala-i-Martin (1995), Temple (1998, 1999), McCallum (1996). Whether the model is considered obsolete or not – it remains one of the foundations of development economics as it has inspired a productive theoretical
In the analytical part II, the model will serve for formalising verbally stated concepts and for translating variables as well as quantitative evidence into customary macroeconomic terminology. Implicitly this approach will represent a litmus test for the relevance of literature with regard to the missing stylised fact: if statements can be translated into the macroeconomic disaster variables, they will be reviewed; if not, they will be considered out of scope. Whereas such translations will raise few problems at the level of statements, some of the respective theoretical approaches to disasters will prove difficult to reproduce in a Solow-Swan model. Examples include demand-side approaches or models with endogenous saving rates. For such contributions, the neoclassical framework may provide a point of reference for comparative discussions. In other words: for the purpose of this thesis, the strong assumptions (such as on the full utilisation of production factors) and the deficiencies of neoclassical growth theory may prove equally useful as its conceptual simplicity.

It should be underlined again that the neoclassical model is not proposed here as a novel theory of catastrophes but as a tool for reviewing a highly diverse literature. Formalised applications of the Solow-Swan models are rare in this literature. However, as will also be shown, neoclassical intuition – without explicit reference to the model – might explain a considerable part of the macroeconomic arguments in disaster literature.44

In the following sections the model will be developed as follows: Starting from the basic textbook model, disasters will be discussed as shocks to the capital stock. The model is then augmented to include human capital and technological progress. After presenting a small and empirical research tradition. This is for both its strengths and its deficiencies, which have motivated the innovation of numerous refinements and alternatives.

44 The review of empirical evidence in part II may be read as a test of the predictions of the neoclassical model on disasters. For the reasons given in the text these will, however, not be explicitly discussed.
open economy version, a model with multiple equilibria or poverty traps is introduced. The section concludes with an overview of further refinements and a summary of the macroeconomic disaster variables. With the exception of these variables, standard notation is used.

**Natural disasters in a textbook Solow-Swan model**

One of the main characteristics of Solow-Swan models is that they explain growth as the result of capital accumulation\(^{45}\). In a basic variant with neither population growth nor technological progress, the economy asymptotically grows towards a stable steady state \((K^*, Y^*)\) where growth of both output and capital stock comes to a standstill. In the steady state, capital depreciation is in balance with investment. Augmented models introduce population growth, human capital as a third production factor, and technological progress as a source of constant growth. This replaces the steady state with a balanced growth path, where output and capital grow at the rate of technological progress\(^{46}\).

Figure 2-2 illustrates the basic model and the output effects \(\Delta Y_d\) of a disaster that is depicted as a shock \(\Delta K_d\) to the capital stock. Equation 2-1 and following supply the formalism.

Qualitatively, the effects of a disaster in a neoclassical economy (basic model) can be described as follows: Following a shock to the production factors, \(\Delta K_d\) and \(\Delta L_d\) output immediately falls by \(\Delta Y_d\). The

\(^{45}\) Solow (1956a) notes: “For many purposes it is remarkably useful to assume that there exists only one physical commodity, which can either be consumed or used as capital in the production of more of itself.”

\(^{46}\) In the interest of brevity, the outlines in this chapter remain cursory and focus on discussing the effects of disasters. For details, customary assumptions, formalisms and notation see Jones (2002) as well as Barro and Sala-i-Martin (1995). A range of central predictions of the model, such as "convergence" or "conditional convergence", are not recapitulated here as they appear not essential for the purpose.
size of the output shock is determined by the size of the shock to the production factors, by the characteristics of the production function and by the position of the economy on the production function. Owing to the decreasing returns, the output effect increases disproportionally with the size of the shock. Reversely, the larger the stock of production factors (the richer an economy), the smaller, ceteris

Figure 2-2: A natural disasters as a shock to the capital stock in a neoclassical economy. The figure illustrates a textbook neoclassical growth model and its three main components: a production function $Y$, an investment requirement function $I$, and a savings function $S$. The steady state (or balanced growth path) is indicated with $K^*$ and $Y^*$. A shock to the capital stock $\Delta K_d$ translates into a shock to output $\Delta Y_d$. After the shock, the economy asymptotically grows back to the steady state (see figure 2-3).
paribus, the effect of a shock on output. After the shock, growth rates of output and capital rise suddenly and gradually decrease as the economy approaches its steady state – the position of which is not affected by the disaster\textsuperscript{47}. Figure 2-3 illustrates these dynamics.

Mathematically, the effects of a disaster may be expressed by the following differentials of the production function:

(Equation 2-1) \[ \frac{dY}{dK} = \alpha \cdot (L/K)^{1-\alpha} \cdot dK + (1-\alpha) \cdot (K/L)^{\alpha} \cdot dL \]

(Equation 2-2) \[ \frac{dY}{dL} = MPK \cdot dK + MPL \cdot dL \]

(Equation 2-3) \[ \frac{dY}{dK} = \alpha \cdot (A \cdot \eta \cdot L)^{1-\alpha} \cdot K^{\alpha-1} \cdot dK \]

where \( Y \) denotes aggregate output, \( K \) the capital stock, \( L \) the labour force, and \( \alpha \) the capital share in a Cobb-Douglas production function. MPK and MPL are the marginal productivities of capital and labour, respectively. In Equation 2-3 \( A \) denotes the level of technology and \( \eta \) serves as a proxy for human capital \( H \) with \( H = \eta L \)\textsuperscript{48}.

Equations 2-1 and 2-2 show that for small shocks, the output effects depend upon the size of the shocks and the marginal productivities of the production factors. Note that for larger shocks this linear approximation is not applicable as output effects increase disproportionately with the size of the shock.

\textsuperscript{47} Throughout this chapter, the assumption is that the economy is in or below its steady state or balanced growth path at time \( t_d \).

\textsuperscript{48} The notation here follows Jones (2002).
Figure 2-3: The dynamic effects of a natural disaster in a neoclassical economy (basic model). Following the shock $\Delta K_d$, output is temporarily reduced by $\Delta Y_d$ while output growth $(dY/dt)$ exhibits a "hike". As output approaches its steady state $Y^*$, growth decreases asymptotically to zero. The effects in the augmented model with technological progress are analogous (see explanations in the text): After the shock, output would fall temporarily below its balanced growth path. The growth rate would surpass its long-term trajectory before asymptotically decreasing to the rate of technological progress.

Equation 2-3 illustrates the effects of a shock to the capital stock in the model with human capital and technological progress$^{49}$. Labour is

$^{49}$ The level of technology $A$ may be thought of as exponentially growing at a rate $g$ – an assumption, which replaces the steady state of the basic model with a balanced growth path.
assumed to remain unaffected\textsuperscript{50}. In the augmented model, output effects of a disaster are, ceteris paribus, larger in an economy with higher levels of technology and human capital.

**Natural disasters in a small, open neoclassical economy**

This section extends the Solow-Swan framework to a small economy with open capital markets. Natural disasters are depicted as idiosyncratic shocks to the capital stock of the small open economy\textsuperscript{51}.

**Outline of the model**

The small open economy \( A \) is linked to the world economy \( W \) via perfect capital markets\textsuperscript{52}. In per capita terms, the steady states \( y^* \) and \( k^* \) are, on the one hand, identical for \( W \) and \( A \) and on the other hand, identical for the autarky case and for open capital markets. Deviations

\textsuperscript{50} In per capita terms, the equations would show that the effects of a disaster on per capita output depend upon the ratio of the shocks to \( K \) and \( L \), respectively. A disaster that leaves the capital stock largely unaffected but entails numerous casualties, such as an epidemic, may result in an increase of per capita output. The following sections will focus, as a simplification of the qualitative and formal discussions, on the case where labour remains unaffected – an assumption that will have to be reconsidered in part II and part III of the thesis.


\textsuperscript{52} Further assumptions include: Besides their different size, both countries are identical in all characteristics such as production functions, saving rates and depreciation rates. There is no population growth and no technological progress. The (immobile) labour force, the capital stock and thus the output of country \( A \) is assumed to be a negligibly small fraction of the global aggregates of the respective variables, that is \( L_W \gg L_A \) and \( K_W \gg K_A \). Capital markets and competition among firms are assumed to be perfect; capital and labour are paid their marginal products. Letters in lower case denote per capita variables as opposed to aggregate variables.
from the steady state trigger capital flows between W and A that satisfy the following interest rate parity:

\[ r_A + d_A = R_A = MPK_A = MPK_W \]

where \( r \) is the interest rate, \( d \) the depreciation rate and \( R \) the rental price for a unit of capital. \( R \) is, under the assumptions given in the footnotes, equal to \( MPK \), the marginal productivity of capital.

**Figure 2-4: Disaster effects in a small, open neoclassical economy.**
Reaction of perfect international capital markets to an idiosyncratic shock to the small and open economy A in steady state. With \( K_W >> K_A \), GNP, becomes a linear function of foreign debt \( D_A \) (Equation 2-5). After a shock of size \( \Delta K_d \) the capital stock of A is restored to its former level by capital inflows from W. The foreign debt of A increases by \( D_A = \Delta K_d \), reducing net wealth by \( \Delta W_d \). The gains from trade for A are indicated by an arrow marked \( gT \) – for W they are positive but infinitesimally small.
Equal MPK in A and W imply equal capital stocks per capita at all times. Differences between countries in these variables would be equalised by capital flows from countries with higher k (lower MPK) to countries with lower k (higher MPK). Therefore, the possibility to borrow in W yields a linear GNP function for the small open economy A, as illustrated in figure 2-5.

**Effects of a natural disaster**

An idiosyncratic shock to the capital stock of country A in world steady state would trigger the following processes: Firstly, the capital stock in country A is reduced by $\Delta K_d$ with a respective increase in MPK_A. Interest parity, and therefore the capital stock of A, is restored by an inflow of capital from W to A equal to the size of the shock, $\Delta K_d$. This leaves country A with a foreign debt of $D_A = \Delta K_d$. Owing to the assumed large size of W, the effects of this capital outflow and the debt service paid by A are negligible for the world economy. Given that all capital is paid its marginal product, GNP_A and GDP_A become:

\[
\text{GNP}_A = Y^*_A - R^* \cdot D_A \quad \text{GDP}_A = Y_A = C_A + S_A + R^* \cdot D_A
\]

(Equation 2-5)

Income (GNP) is a linear function of the size of foreign debt with steady state output $Y^*$ defining the intercept and the constant world interest rate defining the slope ($\text{GNP} = Y - RD$, where $R = r + d$); see figure 2-5. As a consequence of the linear functions for output, savings (not depicted in the figure) in A exceed investment requirements. For interest parity to hold, A will repay its debt at the rate of approximately $(S_A - I_A)/D_A = d - s(r + d)$. With international debt asymptotically approaching zero, both the economy A and the world economy W will move towards their original steady states.
The effects of a disaster in an open economy differ from a closed economy in four aspects: Firstly, in an open economy output remains unaffected by shocks to the capital stock. Secondly, disaster effects on income (GNP) are lower in an open economy by the "gains from trade" (see figure 2-5) than under autarky. Thirdly, owing to the higher saving rates in the open economy (linear saving function), the capital stock of the affected country is rebuilt faster than in a closed economy. Finally, the possibility to borrow in the international capital markets temporarily changes the functional income distribution. In steady state, capital is paid a fraction $\alpha$ of income and labour a fraction of $(1 - \alpha)$. With increasing foreign debt $D_A$, this distribution is shifted towards a larger share of global income paid to capital.

**Natural disasters and poverty traps: multiple equilibria models**

Azariadis and Stachurski (2005) define a poverty trap as "any self-reinforcing mechanism, which causes poverty to persist." This section illustrates the potentially permanent effects of disasters in modified neoclassical models: adverse shocks may shift an economy from a high-income steady state to a low-income steady state, a poverty trap. In other words: A catastrophe may entail the opposite of a "big push" in development (Murphy et al., 1989).53

By relaxing customary assumptions, the neoclassical growth model can be adapted to exhibit multiple equilibria and path dependent

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behaviour. Popular variants in the literature include:

- Production functions with increasing returns at either low or high capital stocks, reflecting economies of scale, large fixed costs of technologies, or externalities of knowledge (Romer, 1990);
- Saving rates which increase with income;
- Population growth rates which decrease with wealth or income (endogenous fertility).

Figure 2-5 illustrates the example of a non-linear saving function: saving rates are low at subsistence levels of income and increase only above a certain level of wealth. This modification produces two stable steady states. For any value of $K$ above the threshold capital stock, the economy will approach the high-income steady state, for values of $K$ below the threshold, it will collapse to $K = Y = 0$.

The evident difference to the previous variants is that in a model with multiple steady states a disaster may have permanent long-term effects. In probabilistic terms, disaster risk increases the risk for an economy to be in its low-income steady state. Moreover, as will be argued in chapter 4, disaster risk may also be a cause of poverty traps (Hoogeveen, 2000). On the other hand, the existence of poverty traps may become less likely – or more likely to be overcome – with the development of markets for capital, insurance and risk.

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54 Path dependency implies that otherwise identical economic systems may approach different steady states – depending upon the starting point.

55 For further examples, such as non-homogeneous capital stock and output, complementarities or coordination failures, market failures (e.g. of markets for risk; see chapter 4) refer to the comprehensive overview of multiple steady state growth models in Azariadis and Stachurski (2005).

56 See in particular Azariadis and Stachurski (2005) and, for a probabilistic formulation of the neoclassical model Schenk-Hoppé (2001).

57 See, for example, Acemoglu and Zilibotti (1997) or Da Rin and Hellmann (2002); more detailed discussions will follow in chapter 4.
Figure 2-5: The potentially permanent effects of a disaster in a neoclassical economy with multiple steady states (poverty traps). In the example: Non-linear saving behaviour. A shock of $\Delta K_{d, \text{critical}} > K_{\text{high}} - K_{\text{threshold}}$ may shift the economy from the high-income steady state to the poverty trap at $K_{\text{low}} = Y_{\text{low}} = 0$.

**Outlook and concluding remarks**

In the following paragraphs that precede the summary, a number of caveats and options for further refinements are listed. These include, on the one hand, alternative approaches to discussing natural disasters in a neoclassical economy. On the other hand, they involve a selection of various refinements of the neoclassical model that are proposed in the literature.
Alternative approaches

Simplistically, disasters have been depicted here as shocks to the capital stock. The effects on further variables, primarily on output, were determined by the respective functions. Direct effects of the disaster on these variables, however, were ruled out. A first option of modelling disasters in the neoclassical framework would be to consider them as a factor that increases depreciation rates – rather than to depict them as shocks. This may well be appropriate for small and frequent events. It would result in an upward rotation of the investment requirement curve. As opposed to the shock approach, increased disaster risk would result in a permanent shift of the steady state. A second option relates to the production function or productivity. In many instances, it is argued that, on the one hand, catastrophic shocks lead to either larger (e.g. Murlidharan, 2003) or smaller (e.g. ECLAC, 2003) effects on output than could be explained by capital stock losses alone. An example for such arguments include damage to essential infrastructure, which may not amount to a large loss of capital but cause widespread economic disruptions. In the neoclassical model, this would correspond to a shift of the production function, which implies a shock to $A$, the level of technology or productivity. In other instances it is hypothesised that reconstructing the capital stock entails a discrete positive productivity shock due to the use of capital goods of the latest technology (e.g. Samuels and Puro, 1991; Abramowitz, 1986)\textsuperscript{58}. These lines of arguments can be accommodated qualitatively in a neoclassical framework and will be reconsidered in the analytical part II of the thesis.

\textsuperscript{58} Some contributions discuss discrete rather than gradual structural changes in economies as a consequence of disasters, such as Horwich (2000; see chapter 5) or Benson and Clay (2004) who invoke analogies of disaster effects with Schumpetarian creative destruction.
Refinements

A large theoretical literature proposes refinements of the neoclassical growth model beyond those discussed here. This includes stochastic versions of the model (Schenk-Hoppé, 2001), models with several types of physical capital59, models with a public sector that raises taxes and invests into infrastructure or disaster preparedness (Tol and Leek, 1999; Gärtner, 2006), and models that include monetary aspects (e.g. Johnson, 1966). Furthermore, multi-country, multi-sector, dual-economy or north-south models have been proposed for studying the distributional aspects of growth and development. Examples include Checchi and García-Penalosa (2002), Marino (1975), Pasinetti (1962), and Uzawa (1961). Given the purely analytical purpose of the neoclassical framework in this project, this variety of sophisticated approaches is not included here.

Overview of disaster variables

To summarise, the neoclassical framework was primarily introduced for two purposes: firstly, for defining and illustrating the macroeconomic disaster variables and secondly, for outlining the mechanisms triggered by disasters in neoclassical economies. Both the variables and the intuition based upon the model will be referred to in the following chapters where this facilitates the discussion.

An overview of the variables is provided in table 2-1 for reference. Some of the main assumptions, predictions and refinements of the model will be touched upon in later chapters. Moreover, in many instances, central assumptions of the neoclassical model, such as on

59 One of the central arguments in Albala-Bertrand (1993a) and Murlidharan and Shah (2003); see chapter 5. On the inhomogeneity of capital see the further Samuels and Puro (1991), Ellson et al. (1984), or Rose et al., (1997). Problems of measuring capital are discussed in, among many other instances: De Soto (2000), Robinson (1966), Samuelson (1962, 1966), Smith (1962) and Solow (1956b).
the full utilisation of production factors, will be further relaxed. Finally, the usefulness of the neoclassical framework as an analytical point of reference will be evaluated in part III.

Table 2-1: Overview of macroeconomic disaster variables, as illustrated using a neoclassical growth model. See chapter 4 for a comparison with insurance definitions and chapter 5 for a comparison with the ECLAC loss estimation methodology and with a variety of further definition.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description and comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta K_d$</td>
<td>Shock to the aggregate capital stock, in some (but not all) cases equivalent to &quot;economic loss&quot; or &quot;economic damage&quot;.</td>
</tr>
<tr>
<td>$\Delta K_d/Y$</td>
<td>&quot;Loss-to-GDP ratio&quot;, a widely used relative measure of the &quot;economic impact&quot; of a disaster on an economy. Sometimes confused with $\Delta Y_d$. $\Delta K_d/K$ is rarely reported.</td>
</tr>
<tr>
<td>$\Delta L_d$</td>
<td>Shock to the labour stock; may include the fraction of the workforce temporarily not available. Only in few cases discussed from a macroeconomic perspective; primarily reported in terms of humanitarian or &quot;social&quot; impacts.</td>
</tr>
<tr>
<td>$\Delta A_d$</td>
<td>Shock to technology or aggregate productivity; an imprecise qualitative summary proxy for disaster effects that involve a shift of the production function rather than the effects of $\Delta K_d$ or $\Delta L_d$.</td>
</tr>
<tr>
<td>$\Delta Y_d$</td>
<td>Shock to output ($Y$); normally discussed as an effect of $\Delta K_d$, in some cases of $\Delta A_d$. Note that $\Delta Y_d$ includes only the immediate effects of a disaster in $t_d$; an integral over all years until $Y = Y^*$ would provide a more inclusive measure of output lost.</td>
</tr>
<tr>
<td>$\Delta C_d$</td>
<td>Shock to consumption; in the neoclassical model a linear function of output: $C = (1-s)Y$.</td>
</tr>
<tr>
<td>( \Delta D_d )</td>
<td>Increase in net foreign debt following a disaster; reflects repercussions on the external balances such as changes in exports and imports, foreign direct investment, aid and credit, insurance payments etc.</td>
</tr>
<tr>
<td>( \Delta K_d/M_d )</td>
<td>Vulnerability of the capital stock; ( M ) denotes the physical magnitude of an extreme event in the natural environment.</td>
</tr>
<tr>
<td>( \Delta L_d/M_d )</td>
<td>Vulnerability of the labour force, or more generally of the population. Various measures are proposed for ( \Delta L_d ) including number of casualties, number of homeless, total affected people etc. ( M_d ) denotes the physical magnitude of the trigger event.</td>
</tr>
<tr>
<td>( \Delta Y_d/M_d )</td>
<td>Macroeconomic vulnerability of a region or a country. ( M_d ) denotes the physical magnitude of the trigger event.</td>
</tr>
<tr>
<td>( E[\Delta K_d] )</td>
<td>Expectancy values for shocks to capital, labour and output; measures of disaster risk, normally given in expected damages per year; estimates may be based on historical data or on simulations of disaster scenarios.</td>
</tr>
<tr>
<td>( E[\Delta L_d] )</td>
<td></td>
</tr>
<tr>
<td>( E[\Delta Y_d] )</td>
<td></td>
</tr>
</tbody>
</table>
II The macroeconomics of natural disasters: Institutional perspectives, theoretical approaches, empirical evidence

Part II constitutes the analytical core of the thesis. In three chapters economic literature on catastrophes will be reviewed for statements, theoretical arguments and empirical evidence related to the research question: *What are the implications of natural disasters for economic growth?*

After a brief specification of the field of research the following paragraphs will introduce the analytical approach, the scope of the work and outline the contents of part II.

**Objectives of part II**

The following chapters aim at developing the analytical basis for answers to the research question. As a prerequisite to this primary objective and as an analytical framework for the literature review, a secondary objective includes a topography of disaster research. First and foremost, this will serve for structuring the analysis in this thesis. An additional purpose of the topography is to supply an aid for interpretation of and orientation in the diversity of the catastrophe literature. This may facilitate a clearer view of institutional perspectives and theoretical approaches beyond the narrow focus of the research question.

**Scope of the review and analytical approach**

The scope of analysis is delineated, firstly, by the macroeconomic perspective and, secondly, more precisely specified by the research
question. Thirdly, the neoclassical framework from section 2.2 provides a point of reference or a conceptual fallback position for definitions and comparisons.

Figure II-1 illustrates the scope of analysis and proposes a topography of research on natural disasters: The literature to be reviewed is organised according to the institutional backgrounds into three fundamentally contrasting perspectives on the research question. These are characterised by differing levels of analysis (microeconomic versus macroeconomic) and their either normative or positive perspectives.

![Figure II-1: A topography of economic disaster literature. Characteristic perspectives on the macroeconomics of natural disasters and their relation to the research question (indicated with a black square). The primarily normative development policy perspectives are reviewed in chapter 3, insurance perspectives in chapter 4. The focus of the analysis is on the positive macroeconomic perspectives discussed in chapter 5.](image-url)
Literature related to the development policy perspective has its institutional background primarily in humanitarian aid and development organisations as well as in international finance institutions. Insurance perspectives include academic contributions on microeconomic theory of risk and publications by reinsurance firms. However, the analysis will focus on the macroeconomic perspectives with predominantly academic backgrounds. To each of these three perspectives one chapter will be devoted with more detailed characteristics provided in the introductory sections of the chapters.

As a principle, the review will be inclusive in order to cover a wide range of contributions that contain hypotheses, theoretical considerations or empirical evidence on the macroeconomics of disasters. However, the scope of the analysis will be highly specific, focusing on issues of economic growth and poverty. The result should therefore be considered a transect through the topography of disaster research rather than a comprehensive and general work of reference.

In other words: The partial analysis of a small subset of economic problems related to disasters will leave a wide range of both relevant and interesting issues out of scope. This includes most aspects of welfare economics, political economics, disaster risk management, humanitarian aid and disaster relief as well as policy implications with regard to disaster risk reduction. Furthermore, technical aspects of insurance, the monetary valuation of life and health as well as the

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60 In simple terms, the three perspectives may be associated with the public sector, with business and with academia, respectively.

61 Note that this topography does not include contributions from other social sciences than economics, from the natural and engineering sciences, or from medicine and psychology. Further, to recapitulate, the focus is on sudden-onset natural disasters with, on the one hand, climate change, droughts etc. only casually referred to and man-made disasters such as wars and technological disasters completely excluded.

62 These are illustrative analogies from geography: while a topography is a three-dimensional representation of a landscape (e.g. in the form of a map), a transect is a "cut" through a landscape and represented as a line on maps.
politics and ethics of risk will not be discussed – even if the thesis substantially draws upon sources, which focus on these problems but contain only marginal statements on macroeconomic problems.

The analytical procedure will be as follows: For each of the three main perspectives, contributions are reviewed for relevant statements on the research question, related to the overall perspective and, where applicable, aggregated to "schools of thought". A brief outline of conclusions, theoretical arguments and empirical evidence is followed by a critical discussion. This may include a translation into the neo-classical framework and a comparison with other positions, both contrasting and congruent. The null hypothesis that disasters do not discernibly affect economic growth may serve as a litmus test. In some instances, explicit debates in the literature will provide valuable insights. Case studies and own empirical explorations complement the analytical transect. Each section on a school of thought or on a landmark publication and each of the three chapters will conclude with a provisional answer to the research question – with an overall synthesis of conclusions provided in part III.

Methodologically, the analytical approach is inspired by examples such as Hirshleifer's (1966) survey of economic literature on the plague in late medieval Europe or by Easterly (2002), who analyses the practical application of growth theories to development policy, thereby providing a concise history of economic thought from the 1950s to the present63.

**Structure and contents of part II**

The organisation of part II is straightforward with one chapter devoted to each of the three main perspectives (figure II-1). The sequence of
the chapters reflects the gradual approach to the research question, which also explains that the length and analytical depth of the chapters progressively increases from chapter 3 (circa 20 pages) to chapter 5 (circa 80 pages).

Chapter 3 on development policy perspectives reviews contributions that discuss primarily humanitarian aspects of natural disasters and policy recommendations for disaster risk management. Owing to the primarily normative approach characteristic for this category of literature, the review will remain selective and focus on contributions with representative positive statements on macroeconomic aspects. Chapter 3 will be the most concise of part II.

Chapter 4 on insurance perspectives covers a broad range of approaches from microeconomic theories of risk to business reports by reinsurance companies. The first part on primarily academic contributions will provide theoretical insights into the special economic problem of catastrophic risk while the second, more practical part is interesting for its quantitative analyses.

Chapter 5 on macroeconomic perspectives represents the analytical core of the thesis and will be the largest chapter. The first of three sections will review empirical work on natural disasters, including the author's own empirical excursion. In the second and third sections, examples of macroeconomic theory applied to the study of catastrophes will be discussed. Examples range from Keynesian approaches to macroeconomic simulations drawing on Harrod-Domar models and Ramsey models.

In part III the findings of part II will be synthesised to an overall answer to the research question with further arguments and points of view discussed.
3 Development Policy Perspectives

Under the umbrella term of development policy perspectives, chapter 3 introduces humanitarian aid and development literature related to catastrophic risk. This includes a broad spectrum of approaches, which is reflected in the diversity of institutional contexts of the respective contributions\textsuperscript{64}: International financial institutions such as The World Bank may promote strategies for ex-ante disaster risk management at the macro level. The International Federation of Red Cross and Red Crescent Societies (IFRC) and other Humanitarian organisations may direct disaster aid and preparedness programmes to a micro and community level. Furthermore, a tradition of applied research, mainly from outside of economics, studies the effects of natural catastrophes and proposes strategies for risk management.

As illustrated by figure II-1, the overall perspective of the development policy literature, as defined here, is normative and applied rather than positive and academic. At the risk of overgeneralisation, the objective of most of the involved institutions is to develop practical solutions to the humanitarian\textsuperscript{65} problems related to natural disasters. "Vulnerability" or "vulnerability reduction" (see section 2.1) can be considered the central paradigms in the respective discourses, both analytical and normative.

\textsuperscript{64} The institutional background of the development policy literature may be illustrated by the partners of the ProVention Consortium (www.proventionconsortium.org, July 2006) with the difference that in this thesis a separate chapter is devoted to insurance perspectives (chapter 4).
The strategies recommended in the development policy literature may be outlined by the following three points\(^6^6\): Firstly, "mainstreaming" of disaster risk management into long-term development strategies is suggested – with the double argument that disaster effects are closely related to development, and that disasters are setbacks for development. Secondly, development programmes are recommended to aim at decoupling vulnerability from poverty\(^6^7\), although the ex-post observation of respective correlations should not be interpreted as a deterministic causal relation. Thirdly, natural disasters ought not be considered as "natural" (see also Hewitt, 1983). On the contrary: the awareness should be raised that vulnerability is to a large degree influenced by factors including socio-economic structures, institutional quality and the resilience of productive capital. Such a perspective on "natural" disasters is considered by many experts to encourage arrangements for disaster risk reduction – rather than a passive attitude towards events that are wrongly seen as "natural"\(^6^8\).

Measured by the multitude of contributions and the number of scholars and practitioners, the development policy literature is the largest of the three literature traditions covered by this thesis (see figure II-1). However, the extensive review\(^6^9\) led to the conclusion that

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\(^6^5\) This implies a focus on the affected people and on the people at risk, respectively, which explains the micro to meso perspectives that predominate in this category of the catastrophe literature.

\(^6^6\) See, for example, IFRC (2002), Pelling et al. (2002), or DFID (2004).

\(^6^7\) In the words of IFRC (2002: 7): "you don’t need to be rich to be well informed and well prepared."

\(^6^8\) See also Anderson and Woodrow (1989) where a dichotomous analytical framework is proposed that includes both vulnerabilities and capacities.

\(^6^9\) Further sources that were reviewed for this chapter but are not separately discussed include: Coburn et al. (1994), Dayton-Johnson (2004), the introduction to Guha-Sapir et al. (2004), the special edition of the Science Magazine introduced by Hanson (2005), the proceedings of the German Committee for Disaster Reduction (2002), Kratt (2005), Munasinghe and Clarke (1995) and contributors, Pelling (2003) and contributors, Pelling (2004), Varley (1994) and contributors. In addition, reports and further resources
the overlap of the research question with this literature is marginal. Therefore, chapter 3 will remain the briefest of the three analytical chapters and will be organised as follows:

Section 3.1 will discuss an exemplary contribution to the policy literature. The World Bank report titled "Understanding the Economic and Financial Impacts of Natural Disasters" (edited by Benson and Clay, 2004) was chosen for this purpose. This is for three reasons: Firstly, the report was considered a representative illustration for the development policy perspectives on the macroeconomic aspects of disasters. Secondly, aiming at a "state-of-the-art review" of disaster research, the authors of the report provide an outstanding synthesis of the literature reviewed for this chapter (see above). Thirdly, the survey contains various references to the macroeconomic literature that will be discussed in detail in chapter 5. Overall, section 3.1 will provide a critical introduction to the macroeconomic excursions in the development policy literature. This will include contrasting views, primarily from macroeconomic perspectives.

Section 3.2 will summarise the review of the development policy perspectives and draw conclusions from the chapter with regard to the research question.

Note that the following discussion does not imply a critique of policy recommendations. Their potential "dividends in terms of lives and livelihoods saved" (IFRC, 2002: 9) are considered beyond doubt here and policy reviews remain out of scope of this thesis.

3.1 Macroeconomic arguments in the development policy literature on natural disasters

The aforementioned survey by Benson and Clay (2004) will provide the guiding example for a brief introduction to the development policy literature. Owing to the macroeconomic perspective of this review, the focus will be on chapters 1 and 2 of their report. Note that, in spite of its title, the Benson and Clay survey takes, first and foremost, a policy perspective and contains suggestions on a range of further problems beyond macroeconomic issues.

The review will begin with Benson's and Clay's main hypotheses on the macroeconomic implications of disasters. This will include an outline of selected country case studies and a discussion of their interpretation of previous research. The second part of section 3.1 will centre on the relation between economic development and disaster vulnerability. A selection of contrasting views to Benson and Clay will be presented – for clarification, comparison and as a virtual debate among disaster scholars.

The effects of natural disasters on economic development

The premise of the Benson and Clay survey is that "natural disasters can and do have severe negative short-run economic impacts" and that there may be "adverse longer-term consequences for economic growth, development and poverty reduction", which implies "potentially high economic and social returns to disaster reduction" (Benson and

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70 Where case studies are discussed, Benson and Clay provide summaries in the appendix of their report. On most of their country case studies, detailed reports are available; see references given there.

71 The perspective of the report remains normative with a focus on policy recommendations. Further chapters address the implications of catastrophe risk for government budgets (primarily reallocation), for disaster finance (weather derivatives and catastrophe bonds, insurance etc.), external aid, and early warning systems.
Clay, 2004: 1-3). The subsequent sections will outline the case studies and the arguments from previous disaster research that Benson and Clay present in support of their working hypothesis.

The above view of the development effects of natural catastrophes is widespread throughout the policy literature. The World Disasters Report (IFRC, 2002: 7), for example, observes that "disasters, however, can wipe out years of development in a matter of hours" and that they "... are a major threat to the global economy and to society." For the example of Honduras, hurricane Mitch is assumed in the same publication to have "... put the country’s economic development back 20 years." As an additional example, UNDP and DHA (1994) include economic aspects into their definition of a disaster "... as an event that seriously disrupts a country’s economic, causing it to modify substantially its investment programmes, (which will have a long term impact), and its economic policies, (which are likely to have an effect only in the short and medium term)."

Benson and Clay (2004) provide additional, more differentiated statements on their position, such as, on the one hand: "the implied null hypothesis is that there is no direct link between disaster shocks and (...) economic performance" (ibid.: 6) or, on the other hand that "the study is based on the premise that natural hazards potentially have significant adverse macroeconomic consequences" and "other studies have also recognised the economy-wide significance of natural hazards and the problems they pose for long-term development" (ibid.: 21). Statements of the second type predominate.

The World Disaster Report, published yearly by the IFRC, is one of the leading publications on the humanitarian aspects of disasters and humanitarian aid related to disasters. It contains a wealth of primary information, maps, analysis and practical policy suggestions. Macroeconomic aspects are out of scope of this report. The above quotes, however, are characteristic for the use of macroeconomic illustrations in the development policy literature.
Country case studies – anecdotic evidence

Benson and Clay illustrate their conclusions on the macroeconomic effects of disasters with case studies – an approach they describe as eclectic, inductive and non-formalised. Narrative evidence is combined with semi-quantitative chart analysis, such as using GDP time series. Their analysis of the Dominica and Bangladesh case studies are briefly summarised here.

In Dominica, a small developing island state in the Caribbean, agricultural output is found to be volatile. This is attributed to frequent hurricanes. Years of negative GDP growth are associated with hurricanes, while in the subsequent years positive or no effects on growth are observed. Benson and Clay explain these patterns by the large agricultural share of output and the high vulnerability of banana plantations to tropical storms. Bananas are Dominica’s main export cash crop. Over the period studied, the macroeconomic vulnerability, as measured by GDP volatility, has been decreasing with the agricultural share of output (from 37% in 1978 to 19% in 1997) and an accompanying increase in manufacturing, tourism and services.

Bangladesh is characterised by both high population density and a high exposure to various natural hazards. In analogy to Dominica, Benson and Clay conclude that disasters affect primarily agricultural output. In 1974, this lead to respective negative growth rates of around -5%. Over time, volatility of GDP growth decreases with an increase in the manufacturing and service sector’s share of output.

Overall from the eight country case studies, Benson and Clay inductively draw the first conclusion that disasters do have substantial

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74 A longer list of analogous statements may be found in Albala-Bertrand (1993a). His contrasting position will be central to the discussions in sections 5.3 and 5.4.

75 It may be noted that GDP growth (including all sectors) is significantly negative only in two years following the war of independence of 1971 with a rate of -15% in 1972.
effects on macroeconomic performance as measured by GDP and growth. These repercussions are more pronounced for small than large economies ($\Delta K_t/K$ in the neoclassical framework, section 2.2).

The second conclusion of Benson and Clay (2004) is that different natural hazards lead to disasters with different economic characteristics: Hydro-meteorological events occur more frequently, affect larger areas and may have a significant impact on agriculture. Geophysical events are less frequent and cause localised damage. This presents risks primarily for infrastructure, but only to a lesser degree for agriculture. Macroeconomic effects of earthquakes and volcanic eruptions may only be observed if urban settlements are affected.

As will be demonstrated in the subsequent chapter of part II, country case studies and individual disaster case studies are highly popular in the catastrophe literature. From a development policy perspective, they usually serve for illustrating the significant economic effects of disasters. Economic data presented include loss-to-GDP ratios, estimates of indirect effects, and, less commonly, GDP time series.

The analysis of different socio-economic repercussions of different trigger events in Benson and Clay (2004) can be considered exceptional. Generally, this problem is rather studied in the academic literature than from a development policy perspective. The respective discussion is therefore deferred to later chapters.

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76 A further source of detailed, however more sociologically oriented case studies of individual disasters can be found in the contributions to Quarantelli (1998). For ECLAC disaster reports, see references given in section 5.1.

Theoretical perspectives: Benson's and Clay's review of previous research

In the available catastrophe literature, Benson and Clay diagnose a focus on immediate impacts of disasters and on their humanitarian aspects. Indirect and secondary effects of disasters, however, as well as the long-term cumulative effects are little analysed in their view\textsuperscript{78}. Complementary to their "eclectic" approach, they survey a selection of theory-guided approaches to the economic study of disasters. This supplies the theoretical section to their review and is discussed here as a reference for the subsequent review of macroeconomic approaches in chapter 5.

The key result in Albala-Bertrand (1993a) – disasters do not or positively affect GDP – is according to Benson and Clay in less stark contrast to their findings if the results are specified for the various trigger events\textsuperscript{79}. As a theoretical explanation for Albala-Bertrand’s arguments, an analogy to Schumpeterian creative destruction is invoked, without, however, discussing his Keynesian model. Overall, Benson and Clay find it problematic to conclude from Albala-Bertrand’s study that "... natural disasters are beneficial for long-term development ..."\textsuperscript{80}. The findings of Charveriat (2000) are referred to in support of the hypothesis that disasters are reflected in GDP trajectories by sudden decreases and subsequent temporary increases. This is in line with the neoclassical framework, to which Benson and Clay refer for emphasising the importance of capital for economic

\textsuperscript{78} See chapter 1 and literature quoted there for analogous conclusions on the state of disaster research. Concepts of impacts, loss and damage will be discussed in section 4.3.

\textsuperscript{79} The work of Albala-Bertrand will be discussed in section 5.2.

\textsuperscript{80} Benson and Clay (2004: 22); this illustrate ones of the central confusions that accompany the respective debate in the disaster literature. Difficulties of interpreting GDP figures in welfare terms and aggregate growth in terms of development will be discussed in part III.
development. On the same line of argumentation, the Mechler-Freeman approach (see section 5.3) is used for illustrating "that the ability to finance losses following a catastrophe is crucial to recovery and affects how quickly a country can resume its growth path"\textsuperscript{81}.

In summary, Benson and Clay (2004) conclude from their case studies and from their literature review that natural disasters have negative impacts both on short-term economic performance and long-term development. While most contributors to the development policy perspectives will share this conclusion, the in-depth discussion in Benson and Clay of both empirical and theoretical research can be considered exceptional in the disaster literature.

\textbf{Development and disaster vulnerability: a Kuznets curve?}

"Vulnerability" may be considered the main unifying analytical concept in the development policy literature. Both analytical approaches to disaster risk and recommendations for disaster risk management centre around this concept\textsuperscript{82}. This section reviews hypotheses on how vulnerability to catastrophes depends upon development. The "Kuznets curve"\textsuperscript{83} proposed in Clay and Benson (2005) will serve as a basis for comparisons with further approaches.

\textsuperscript{81} Further, a cross-sectional approach by Benson is referred to. Including over 115 countries (1960 – 1993) the study demonstrated, apparently, a negative correlation of disaster frequencies with growth rates. The study was not yet available at the time of writing (March 2006).


\textsuperscript{83} In its original form, the hypothesis of Simon Kuznets states that income inequality increases at early stages of development before it decreases again.
A three-stage theory of development and disaster vulnerability

Benson and Clay (2004) hypothesise that vulnerability depends upon levels of development, which again is reflected in production-side structures, policy environments, the quality of physical infrastructure and institutions, the development of financial markets, and further factors. Their semi-formalised line of argumentation is characteristic for macroeconomic considerations in the policy literature. It is illustrated by figure 3-1 and may be summarised as follows:

The least developed economies are highly vulnerable to natural hazards but effects remain localised. Vulnerability then increases with development to a maximum for middle-income countries. This is, on the one hand, explained by the increase in assets that are highly vulnerable to natural hazards ($\Delta K_d/M_d$; see chapter 2). On the other hand, production-side structures become more complex with development (intersectoral and interregional linkages). Via "multiplier" effects and "knock-on" effects, local disaster impacts may spread through the economy, resulting in macroeconomic consequences (increased $\Delta Y_d/M_d$). Finally, in a highly developed economy, disaster vulnerability ($\Delta Y_d/M_d$) decreases again while direct impacts may increase in absolute terms ($\Delta K_d$). Reasons include larger financial resources, high levels of diversification, negligible poverty rates, high insurance densities, and strong institutions.

The view that disaster vulnerability may increase with development is shared in a number of further contributions. Tool and Leek (1999)\textsuperscript{84} argue from a growth perspective and discuss counteracting influences of growth-related influences on vulnerability. Their argument is illustrated empirically, using country data for average disaster effects in terms of damage and casualties.

\textsuperscript{84} See the discussion of their paper in section 5.3.
Figure 3-1: Economic development and disaster vulnerability. Referred to as a "Kuznets curve" in the original source, the figure illustrates the three-stage theory of development and disaster vulnerability by Benson and Clay (2004). With development, direct damages (loss-to-GDP ratio, $\Delta K_d/Y$) decrease while indirect impacts increase. The "time to recover" is assumed to increase with development before it decreases. In summary, the curve illustrates the hypothesis that disaster effects (as a % of GDP) increase with development for poor countries and decreases with development for rich countries. From Clay and Benson (2005).

Graphically, countries may move on different development trajectories from a low-income high-vulnerability position to a high-income low-vulnerability state. Case studies and general considerations on disaster risk increasing with development are also presented by reinsurers. Swiss Re (2006), for example, concludes for China: "... growth in values outweighs any technological improvements or

85 The source gives no formalism that explicitly relates the variables shown in the figure. For a discussion of various concepts of loss, impact etc. see sections 4.3 and 5.1.
preventive measures aimed at reducing the financial impacts of catastrophes”. Further analogous arguments from an insurance perspective will be discussed in chapter 4.

Besides case studies, no quantitative evidence (e.g. cross-country regressions) of the three-stage theory is reviewed in Benson and Clay (2004). Empirical indications on the hypothesis may be found in the following two studies. Auffret (2003a) demonstrates a negative correlation between consumption volatility and per-capita income, which could be interpreted as a vulnerability index. Graphically, the relation found by Auffret, however, appears linear rather than inversely U-shaped. In Murlidharan and Shah (2003), per-capita income is plotted versus disaster damage ($\Delta K_d/Y$) and the population affected ($\Delta L_d/L$) by disasters. It is found that both measures of disaster impact decrease with per-capita GDP. However, the graphs exhibit no evident U-shape.

In the following chapters, the Kuznets theory on development and disaster vulnerability will therefore occasionally be referred to as a hypothesis. However, on the basis of the available evidence it is neither rejected nor supported here. A contrasting macroeconomic approach will be outlined in the next section.

**Localised versus widespread disasters**

The left part of the vulnerability curve in figure 3-1 illustrates the assumption that both damages to assets ($\Delta K_d/K$) and macroeconomic effects ($\Delta Y_d/Y$) of disasters may increase with development. The macroeconomic aspects of this hypothesis relate to the increase of linkages between sectors and regions due to development. The

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86 Both of these studies will be discussed in more detail in chapter 5.

87 Annual losses are given as a percentage of GDP and the population affected as a percentage of total population.
assumption that these linkages allow otherwise local disasters to cause "larger systemic impacts ... on regional or national economies" and that "disruptions can spread through economic networks" (Pelling et al., 2002) is widespread in disaster literature. Clay and Benson (2005) refer to "multiplier effects of adverse performance in a particular sector or regional economy" and Van der Veen (2004) points out the potential "ripple effects" of catastrophic shocks.

As will be discussed in section 5.1, such hypotheses are popular in disaster research that is related to regional economics. However, mainstream macroeconomists (e.g. Horwich, 2000)\(^88\) may rather emphasise the compensatory supply-side and demand-side market mechanisms triggered by catastrophic shocks. These might involve substitutions of production factors and consumption goods in addition to (temporary or permanent) redistributions of output between regions, sectors, economic actors, as well as over time.

The following paragraphs will outline a conceptual framework by Albala-Bertrand (2006)\(^89\) that provides a different angle of view on the above Kuznets hypothesis: a concept of geographic and economic localisation of disasters. On the one hand, Albala-Bertrand explicitly uses the same case studies as Benson and Clay (2004) for illustrating his arguments. On the other hand, the localisation concept can accommodate a large range of macroeconomic arguments – it will serve for reference in subsequent discussions. Table 3-1 provides an overview of the framework.

A localised disaster, according to this framework, would be an event that affects both a limited geographical area and only certain eco-

\(^88\) See section 5.2 for an outline of his line of argumentation and an analysis of the Kobe earthquake.

\(^89\) The work of Albala-Bertrand will be reviewed in chapter 5, as his perspective is a macroeconomic one. The localisation concept is introduced here as it explicitly refers to the Benson and Clay (2004) report.
nomic activities (top left cell in table 3-1). Albala-Bertrand argues that this is the most common case. The geographic localisation of most disasters results from the size of countries as compared to the limited area affected by, for example, an earthquake. Moreover, even if a disaster is geographically widespread it is more likely to become economically localised through "endogenous response mechanisms" – rather than to cause ripple effects throughout the economy\textsuperscript{90}.

**Table 3-1: The localisation concept of disasters.** Most natural disasters are both geographically and economically localised. In diversified economies, even geographically widespread disasters become economically localised. Disasters with economically widespread effects are exceptions. Adapted from Albala-Bertrand (2006).

<table>
<thead>
<tr>
<th>Geographically localised</th>
<th>Economically localised</th>
<th>Economically widespread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most disasters</td>
<td>Some disasters</td>
<td>Some disasters</td>
</tr>
<tr>
<td>(if capital city or key industry is affected)</td>
<td>(if capital city or key industry is affected)</td>
<td></td>
</tr>
<tr>
<td>Some disasters in diversified economies (droughts, floods and storms)</td>
<td>Disasters in undiversified agricultural economies or in small islands</td>
<td></td>
</tr>
</tbody>
</table>

In the case of a widespread drought, primarily agriculture would be affected, implying economic localisation in a diversified economy. Economically widespread disasters are a possibility in undiversified agricultural economies, in island economies\textsuperscript{91} or if a "pivotal" industry is affected. However, only disasters with the characteristics of the

\textsuperscript{90} For macroeconomic arguments that correspond to the concept of "disaster localisation" see the preceding pages, chapter 5 and Albala-Bertrand (2006).

\textsuperscript{91} See also Briguglio (1995) or Pelling and Uitto (2001).
bottom right cell in table 3-1 may have significant macroeconomic repercussions. This conclusion contrasts with the view that at first localised disasters may, through multiplier effects, evolve into macro-economic disasters – a popular hypothesis in the catastrophe literature and supported by Benson and Clay (2004).

In a localisation framework, development may be understood as a "process that transforms all types of disasters into economically localised ones" (Albala-Bertrand, 2006). For the two countries discussed in Benson and Clay (2004; see above), both Bangladesh and Dominica have moved from the right column to the left column in table 3-1, while disasters remain geographically localised in Bangladesh and widespread in Dominica. Albala-Bertrand does not explicitly refer to the Kuznets hypothesis (figure 3-1) but his localisation concept is interpreted here as an argument for a monotonous (rather than U-shaped) relation between development and disaster vulnerability at the macro level.

3.2 Conclusions from the development policy perspectives

The conclusions from the policy literature review as illustrated with the exemplary discussion of Benson and Clay (2004) will be summarised from two viewpoints. First, the marginal relevance of the reviewed literature for the research question is explained. The second section

92 In these cases, a "disaster" may translate into an (economic) "catastrophe", the superlative of a disaster as defined in Albala-Bertrand (2006). However, only on the following conditions: "first, direct (stock) effects have to be massive or pivotal; second, indirect (flow) effects have to be uncontrollable, and third, institutional effects have to be so perverse that recovery (economic rehabilitation and reconstruction) becomes unachievable."

93 See Albala-Bertrand (2006); Malawi, a further case study from Benson and Clay (2004), is found to have moved from bottom right to top left.
summarises how the macroeconomic insights presented in the policy literature may contribute to an answer to the research question.

**A macroeconomic view of the development policy literature**

As anticipated in the introduction, the research question was found to overlap only marginally with the development policy perspectives on natural disasters. This is primarily due to two characteristics of the respective literature: Firstly, the normative perspective implies a focus on recommendations for disaster risk management rather than on macroeconomic analysis. Secondly, the lines of argumentation behind policy suggestions were found to draw primarily upon "eclectic" models and illustrative case studies. References to macroeconomic theory or empirical analyses and data are the exception.

The following paragraphs give an outline of the macroeconomic hypotheses including their theoretical and empirical underpinnings.

**Hypotheses on the macroeconomic effects of natural disasters**

From a development policy perspective, natural disasters are seen as adverse macroeconomic shocks and setbacks for economic development. There is widespread consensus that catastrophes have negative macroeconomic impacts beyond the destruction of capital stock ($\Delta K_d$) and the affected people ($\Delta L_d$). Effects on aggregate output ($\Delta Y_d$) are to some extent explained as a direct implication of the shock to the capital stock – an intuition in congruence with the basic neoclassical model (section 2.2). On the other hand, it is hypothesised that local shocks have repercussions for macroeconomic aggregates via "knock-on effects", "multiplier effects" or "ripple effects". These lines of arguments may draw on concepts and models from regional economics (see section 5.1).
As has been indicated, these hypotheses on disaster effects are rarely explicitly related to mainstream macroeconomic theory or discussed using customary macroeconomic terminology. For applied policy literature this may be due to the purpose and target audience of the respective publications whereas academic contributions to the policy literature explanations typically has disciplinary backgrounds other than macroeconomics.

Empirically, the hypothesis of disasters as adverse macroeconomic shocks is primarily supported with anecdotic evidence. This includes country case studies and analyses of individual catastrophes. Both narratives and figures such as loss-to-GDP ratios or cost-benefit analyses of policies are wide-spread formats of case studies. Econometric time series analysis or cross-country regressions are rarely referred to. While case studies may provide profound insights into individual events or country-specific contexts, inductive generalisations give rise to a number of methodological problems\(^94\). As Benson and Clay (2004: 27) point out, their "catastrophe narratives" were deliberately selected for highlighting the potentially drastic economic consequences of natural disasters.

On the relation between development levels and disaster vulnerability, the argumentation in Benson and Clay is analogous: A hypothesis is stated, explained using a heuristic conceptual framework and illustrated with case studies. The problems of inductive generalisations remain also analogous as was illustrated with contrasting indications from the catastrophe literature\(^95\).

\(^94\) See chapter 5 and, for example, Rossi et al. (1987).

\(^95\) The interpretation of these empirical studies as a contrast to the Kuznets hypothesis is due to the author. Neither Auffret (2003a) nor Murlidharan and Shah (2003) make explicit comments; see detailed reviews in chapter 5.
Hypotheses on disasters and poverty

The most widespread view in the development policy literature on distributional aspects of disaster risk may be summarised in the words of IFRC (2002): "Disasters are first and foremost a major threat to development, and specifically to the development of the poorest and most marginalised people in the world. Disasters seek out the poor and ensure they stay poor." The proposed explanations for the relation between poverty and disaster risk have been outlined in chapter 1 and complemented with a poverty trap model in section 2.2. Theoretical considerations will be continued in chapter 4. In the reviewed literature, no controversy on the distributional aspects of disasters was identified. This may be one of the reasons why there are few references to empirical research on this problem\(^96\).

**In summary**, it is concluded that macroeconomic aspects of natural disasters receive little in-depth coverage in the development policy literature\(^97\), even if hypotheses on catastrophes as setbacks for growth abound. Such often pronounced statements are mainly underpinned by working assumptions, qualitative arguments and illustrated with anecdotic evidence. Lines of argumentations that refer to macroeconomic theory or empirical evidence are not common. As will be argued in the remainder of the thesis, the macroeconomic statements

\(^96\) Benson and Clay (2004) consider distributional aspects out of scope of their review.

\(^97\) As will be argued in part III, macroeconomic arguments may be by definition little relevant for policies that focus on the survival, livelihood, welfare, or development perspectives of the poor and most vulnerable socio-economic groups.

It may also be argued that these conclusions on the development policy literature are tautological as it reflects, first and foremost, the literature categorisation (figure II-1): Publications with substantial macroeconomic contributions – theoretical or empirical – would be considered under "macroeconomic perspectives" (chapter 5) rather than in this chapter. Note, however, that the three literature categories are an element of the (pragmatic) analytical framework used here. This provides a structure to the analysis and to the resulting thesis; it should not be considered as a result of the thesis. Moreover, the analytical approach is not expected to significantly influence the answers to the research question.
in the policy literature should therefore be understood as hypotheses or views rather than as evidence. They remain important, however, for the support they provide to one of the two main positions in catastrophe literature: The view of natural disasters as setbacks for economic growth.

**Conclusions with regard to the research question**

Concluding from the macroeconomic review of the development policy perspectives on natural catastrophes, the following findings are considered robust\(^98\): In specific circumstances, natural catastrophes may have macroeconomic repercussions. This may be the case for geographically widespread events in little developed or small island economies or if an essential economic entity is affected (key industry, infrastructure or urban centre). Droughts, floods and storms will be geographically widespread, whereas earthquakes and volcanic eruptions will be localised. Economically, disasters may become widespread primarily in small island developing states (SIDS; see Briguglio, 1995) or, in case of droughts, in agricultural economies\(^99\). In large and developed economies, however, almost any disaster will become economically localised.

From this it follows that economy-wide effects of natural disasters are the exception rather than the rule. The literature reviewed in this chapter therefore allows for insights primarily into these exceptional events. Thereby, it contributes to the understanding of the specific

\(^98\) These conclusions should be regarded as provisional and will be scrutinised in the subsequent chapters.

\(^99\) As Benson and Clay (2004: 23) observe, they found "difficulties in estimating the short-term effects of disasters in a geographically extensive economy" such as the Philippines or Indonesia, both countries with a significant exposure to natural hazards. Further, while Benson and Clay reinterpret the empirical findings of Albala-Bertrand (1993a), no empirical evidence or theoretical arguments are presented that would challenge his central hypothesis on the macroeconomics of disasters.
circumstances, in which disasters may affect growth and development at the aggregate level. The prevailing hypothesis that natural disasters imply macroeconomic setbacks is not considered tenable on the basis of the theoretical arguments and empirical evidence provided in the development policy literature.

From the perspective of the research question, chapter 3 should be read primarily as an introduction to one of the two contrasting macroeconomic hypotheses held in the catastrophe literature. The assumptions behind this position are shared by literature that is more closely related to the research question – as will be illustrated in the subsequent chapters.

In conclusion, note that a critical view of macroeconomic statements in the policy literature does not imply a critique of policy recommendations for disaster risk management. As the subsequent chapters will demonstrate, the welfare and development problems of catastrophes and the benefits of the respective policies are difficult to understand from a macroeconomic point of view. A summary of these arguments is provided in part III.
4 Insurance Perspectives

Historically, natural disasters\textsuperscript{100} are one of the main factors that have shaped the insurance industry, in particular reinsurance (Munich Re, 2004; Swiss Re, 2005)\textsuperscript{101}. In the financial markets in general, disaster risk has evolved into a mainstream topic during the last decades (Scholes, 1996; Swiss Re, 1996; Swiss Re, 2001a). As natural disasters may, by definition, defy the law of large numbers, one of the cornerstones of insurance practice (Loubergé, 1995), there is a large body of literature on these low-probability and high-consequence events\textsuperscript{102}. Most contributions take a microeconomic perspective; they address disaster risks at the level of households and firms. The unifying concepts of the literature reviewed here under the umbrella term of "insurance perspectives" are considered to be risk as a function of potential losses and probabilities (e.g. Swiss Re, 2003a).

\textsuperscript{100} In the insurance and finance literature natural disasters are often referred to as natural catastrophes, giving rise to vocabulary involving the prefix "cat" (e.g. cat bonds). In this thesis, disaster and catastrophe are used as synonyms.

\textsuperscript{101} Two brief definitions: Firstly, insurance is transfer of risk in exchange for a premium and reinsurance is insurance for (primary) insurers. Secondly, risk management, according to Kobayashi and Yokomatsu (2000) may be defined as to include risk control (minimising risk) and risk financing (optimal allocation of a given risk). Russel (1970) proposes an analogous distinction of adjustment and insurance while Auffret (2003a) differentiates between risk reduction and risk coping. A multitude of further and more detailed definitions abound in the literature. For historical notes on insurance with a focus on catastrophic risk see: Winchester (2005), Odell and Weidenmier (2002), Jaffee and Russel (1997) or Hofstede (1995) who studies cultural aspects of insurance.

\textsuperscript{102} Further terms or concepts referring to low-probability high-frequency (Zeckhauser, 1996) events: Stress loss (in the banking sector; e.g. UBS, 2003: 53ff), extreme event losses, maximum probable losses, and catastrophe accumulation (Swiss Re, 2003a). For a detailed comparison of high-frequency events (fire hazard) with low-frequency events (natural catastrophes) from an insurance perspective see Swiss Re (2003a). For a discussion of the limits of insurability see the comments in Swiss Re (2003b) on nuclear risk and property insurance.
Insurance literature with references to the macroeconomic effects of disasters may have its institutional backgrounds in both reinsurance practice and in academia. Irrespective of its origins, these contributions equally cover positive and normative aspects of disaster insurance. Positive approaches in the practical literature aim at understanding disaster risk and develop methods for quantitative predictions of losses and their probability distributions\(^{103}\). In academic literature positive approaches also include the theoretical and empirical study of insurance markets and of behaviour under risk and uncertainty (e.g. Arrow, 1971; Arrow, 1996; Kahnemann and Tversky, 1979). Consequently, the normative implications of research on risk by the private sector primarily include solutions for formal disaster insurance. Normative conclusions from academic research often address market failures, such as welfare and distributional issues of underinsurance against natural disasters.

In spite of its microeconomic perspective, the insurance literature contains numerous references to the macroeconomic aspects of disasters. Reinsurers traditionally estimate and publish both insured and "economic losses\(^{104}\) of natural disasters. These aggregates are then often interpreted in macroeconomic terms or used for macroeconomic projections. Owing to its sound reputation for technical expertise, its access to data and the respective publication policies the reinsurance sector is one of the key sources for researchers on natural disasters from any disciplinary background\(^{105}\). What differenti-
ates the insurance perspective, on the one hand, from the development policy perspective (preceding chapter) is its focus on financial rather than humanitarian aspects of disasters. What sets it apart from the macroeconomic perspective (chapter 5), on the other hand, is that macroeconomic analysis begins where insurance research becomes thin: at the level of macroeconomic aggregates and mechanisms.

The review of the insurance literature with regard to macroeconomic statements is organised as follows: Section 4.1 outlines a theory of markets for risk and insurance with an emphasis on the special problem of catastrophe risk and poverty. In section 4.2 reinsurance sources are analysed for qualitative and theoretical statements on the macroeconomics of natural disasters. Section 4.3 discusses the concept of "economic loss" which is central to the insurance perspective and to the catastrophe literature in general but entails considerable confusion. Section 4.4 concludes with provisionary answers to the research question.

4.1 A microeconomic perspective on disaster risk: Markets for insurance, problems of catastrophe insurance, macroeconomic implications

For Zeckhauser (1995) natural disasters "provide a principal justification for insurance. (...) One pays premiums to secure financial protection against low-probability high-consequence events – what we normally label catastrophes." Emphasising the economic importance of insurance in general, Giarini (1995) speculates that, if Adam Smith was drafting "The Wealth of Nations" today, he would illustrate his arguments with the insurance industry as the engine of modern economies rather than the textile sector. In contrast, Loubergé (1995)

sees catastrophes as social risks that are, by definition, uninsurable as they cannot be "diversified within the confines of the reference area". Finally, on risk and development, Hoogeveen (2000) notes that "a distinctive feature of developing countries is the importance of risk in daily life". In combination with low-income levels and the lack of options for consumption smoothing, he argues, risk may imply poverty, unequal income distributions and decreased growth rates.\footnote{For an empirical to these hypotheses see Auffret (2003a, 2003b) and the respective review in section 5.1.}

Considering this range of perspectives in the microeconomic literature and the theoretical insurance literature, the review will begin with a brief outline of a theory of markets for risk. The focus will then shift to problems specific to catastrophe insurance and the respective macroeconomic implications.

**Markets for risks: Notes on insurance theory**

In order to provide a basis for the analysis of the theoretical risk and insurance literature, the objectives of this section are twofold: Firstly, to briefly outline the microeconomic concepts of risk and insurance and secondly, to give an overview of the general problems identified by insurance theory, such as market failures and catastrophe insurance. This will allow for specific theoretical conclusions with regard to the macroeconomic implications of disasters. From a different angle, the purpose of the conceptual introduction is to permit a conceptually consistent analysis of the academic and practical literature on disaster insurance and its relevance for growth and development.\footnote{Given the macro perspective of the research question, the conceptual outline developed here remains selective. It draws primarily on "the standard theory of risk-bearing" as summarised in Arrow (1971) and applied to catastrophe insurance in Arrow (1996); see these papers for references to Arrow (1953, 1964) and Debreu (1959) – the primary sources of this theory. A vast theoretical and empirical literature exists on the microeconomics of risk, on the perception of risk (e.g. Slovic, 1987), on decision under}
Risk, and contracts for sharing risk may be thought of as goods traded on markets (Arrow, 1971; 1996). Gains from trade in these markets are a consequence of diminishing marginal utility of wealth, an assumption that is identical to (or explains) risk aversion\textsuperscript{108}. The main formal institutions for risk trade are the stock markets and insurance. With contractual arrangements involving risk transfer (or risk sharing) and risk pooling\textsuperscript{109}, "an insurance system distributes the random costs of individual losses across a pool of people. Absent inefficiencies, in the Pareto optimal scheme, each person will substitute his/her individual loss for a proportionate share of the aggregate losses of the whole community" (Doherty, 1997). Welfare gains result from individuals and firms investing in (risky) activities that they would otherwise not undertake, and from the efficient allocation of resources on safety and insurance, thereby increasing output and growth (Gollier, 1997).

However, observed markets for risk are far from perfect in Arrow's sense and less risk-shifting takes place than is predicted by theory\textsuperscript{110}.

\textsuperscript{108} Note that if expected values of risk or "outcomes" define utility, that is, if individuals are risk neutral, these potential gains from trade do not exist. Arrow and Lind (1970) note that it is "widely accepted that individuals are not indifferent to uncertainty and will not, in general, value assets with uncertain returns at their expected values." For trade in risk over time, diminishing utility of wealth implies Friedman's permanent income hypothesis and serves as a basic assumption in theories of intertemporal consumption smoothing and, in international economics, in theories of intertemporal trade (Mundell, 1957; Gosh and Ostry, 1995; Obstfeld and Rogoff, 1995).

\textsuperscript{109} In Skogh and Wu (2003) these two concepts are illustrated by a tale from ancient merchant shipping – one of the historical origins of insurance arrangements.

\textsuperscript{110} According to Arrow (1996) the real world differs in many respects from the model: 1. Insurance covers individual risks, not "states of the world"; 2. In the model, everyone is insuring everyone else; there is no specific institution such as an insurance company. In
Insurance remains limited in scope and amounts: not all types of risks are covered and demand for coverage of individual risks may not be met. The main reasons for these market failures are attributed in the literature to moral hazard, adverse selection, non-diversifiable risks, complex contract designs, and high transaction costs.

Risk and related market failure are primary arguments for government intervention in risk shifting, such as by providing insurance as a public good through pension schemes, medical insurance and by engaging in ex-ante risk management (Arrow, 1971; Arrow and Lind, 1970; Jones, 2003). Governments may, in addition to efficiency objectives, address distributional and poverty issues related to risk (Doherty, 1997). Finally, relativising the importance of both formal markets and government Pestieau (1994) emphasises that families and clans provide the oldest, more inclusive and broader forms of insurance, particularly in developing countries.

The outline theory of risk and insurance concludes with a note on the distinction between risk and uncertainty. Knight (1921) proposed to differentiate between risk as a calculable figure based on objective probabilities, that is, statistically or scientifically determinable probability distributions. Uncertainty, on the other hand, involves subjective probabilities. In the words of Keynes: "By ‘uncertain’ knowledge, let me explain, I do not mean merely to distinguish what is known for certain from what is only probable. The game of roulette is not subject, in this sense, to uncertainty ... The sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence ... About these matters there is no scientific basis on which to form any calculable probability whatever. We simply do not know." (Keynes, 1937 quoted in Fonseca, 2006). From this perspective, the state-
preference approach of Arrow and Debreu is a theory of uncertainty, while expected utility theory (von Neumann and Morgenstern, 1947) is a theory of risk. As Holton (2004) observes, "the validity or usefulness of such a distinction continues to be a subject of debate among economists", and he concludes that "... it is impossible to operationally define risk. At best we can operationally define the perception of risk. There is no true risk." In the following discussion, the above distinction between risk and uncertainty will primarily prove relevant in insurance practice: risk is generally considered insurable, uncertainty is not. In most other instances, risk may implicitly include uncertainty in this thesis with little loss of precision.

Catastrophe risk and insurance: The special case of low probability high consequence events

"In the ideal competitive world there is no special problem of catastrophe" as perfect markets ensure an efficient distribution of risks Arrow (1996: 109). In case of a disaster, the economy as a whole will be worse off but market mechanisms minimise the losses to society. However, the low frequency and high consequences of natural disasters entail a range of market failures and problems in addition to the ones discussed in the previous section.

Firstly, as disasters are infrequent events, statistical and scientific knowledge will be thin and the limited experience of individuals with disasters has implications for the perception of these risks. On the supply side of the insurance market catastrophe risk becomes uncertainty in the sense of Knight (see previous section) and actuarial approaches based on the law of large numbers become inapplicable (Zeckhauser, 1995). From the viewpoint of insurers (Swiss Re, 2004), catastrophic risk may violate the principle of "assessability", one of the three key principles of insurability, the other two being randomness of insured events and economic efficiency, that is, profitability in a
business context. The violation of these principles may result in market failures. For the demand side, Zeckhauser (1996) concludes with reference to prospect theory that "neither humans nor society deal effectively with ... probabilistic information" and that "underperception leads to inappropriate actions" – a second potential source of market failure (see also Cole, 2004).

Secondly, the magnitudes of catastrophes imply that risks can not be diversified. Losses may be correlated, that is, large numbers of people and businesses may be affected simultaneously (Doherty, 1997). In Swiss Re (2003c) catastrophic losses and their relation to "systemic risk" are discussed as opposed to "idiosyncratic risks" (Mahul and Wright, 2003). Pestieau (1994) refers to such non-diversifiable risks as "social risks". Zeckhauser (1995, 1996) introduces the terms of "magnitude catastrophes", "aggregate catastrophes" and "generic risk" while for Loubergé (1995) catastrophes by definition cannot be insured: "by insured, I mean diversified within the confines of the reference area, even if information problems such as adverse selection and moral hazard do not arise." From a practical insurer’s viewpoint, the difference between small and frequent losses, such as fires and catastrophic losses is explained in Swiss Re (2003a). As a further distinction, Mahul and Wright (2003) introduce the concept of "cataclysms" – extreme events with large losses relative to the size of the respective insurance pool. Larger than catastrophes, cataclysms may, according to the authors, have systemic repercussions beyond individual firms and for the insurance sector as a whole.

Normative conclusions in the disaster insurance literature are on the one hand addressed to the insurance sector and, on the other hand, related to government interventions – analogous to the non-catastrophic cases of market failures. As Engeström (1995) points out, natural disasters are examples of risks which require spreading "over
time, over geographic regions and between a multitude of players". This may involve the insurance sector, financial markets and governments. In catastrophe literature, governments are sometimes seen as the natural "reinsurers of the last resort" that are to supply implicit or explicit coverage unavailable on the markets. Moral hazard problems related to government insurance, however, may lead to suboptimal outcomes via negative incentives for prevention and private insurance (Gollier, 1996; Kunreuther, various years). Examples from these lines of argumentation are discussed in the next section. Gollier (ibid.) doubts that governments have a comparative advantage in supplying catastrophe insurance and Kane (1996), refuting the close similarities between private insurance and government insurance, criticises the treatment of disaster prevention, insurance and relief as public goods. These normative perspectives are illustrated by examples in the following section.

In a small neoclassical economy, insurance may be thought of as either precautionary foreign savings for accumulating foreign capital or as a fraction of investments being used for premium payments to the rest of the world. The optimal level of insurance depends on expected annual disaster losses to the capital stock, $E[\Delta K_d]$. In case of an idiosyncratic disaster $\Delta K_d$, the foreign savings or the contingent credit purchased in exchange for the premiums can be used for reconstructing the capital stock. A disaster with global effects could not be insured - it would be categorised as a "social risk" (Pestieau), a "magnitude catastrophe" (Zeckhauser) or a "widespread disaster" (Albala-Bertrand, 2006). Note that, in a neoclassical world, the benefits of insurance arrangements are most evident for the case that there are no cross-border capital flows other than those related to

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111 In various publications, the big reinsurance companies come to similar conclusions (Swiss Re, Munich Re, various years).

112 See the small open economy case outlined in section 2.2.
insurance. Perfect capital markets would imply maximum global spreading of risk through post-disaster credit to affected countries making insurance arrangements redundant (see section 2.2).

To summarise this brief review of theoretical literature on catastrophe insurance: In analogy to the localisation hypothesis of Albala-Bertrand (2006; see chapter 3), Arrow (1996) concludes that failures in the markets for risk may "fragment the pool of resources available in any state of the world and make it possible that a ‘catastrophe’ which is small on the scale of the economy may nevertheless loom large from the point of view of an insurer or its insured". Efficient shifting and pooling of disaster risk therefore would require both efficient institutional arrangements and the financial resources for covering actual events.

**Examples of applied microeconomic risk and insurance theory**

In the following examples the theoretical approaches outlined in the previous sections are applied to practical problems. These include: The failure of markets for catastrophe insurance, arguments for government intervention, and, finally, the focus of this section, an analysis of insurance arrangements in developing countries.

**Supply side market failure**

With regard to market failures, Jaffee and Russel (1997) find for the example of the USA that the private insurance sector supplies less than optimal coverage against natural disasters. This is considered one of the reasons for governments playing an important role in both formal and implicit insurance against catastrophes. However, in their diagnosis of market failure Jaffee and Russel challenge the private sector's position that natural disaster risk is uninsurable. Historically, the difficult assessability and the size of risks has not been an
obstacle for the insurance sector and "Elementary arithmetic shows that an insurance industry ... could spread a large infrequent risk (say a 20-year, $50 billion event) over time with annual premiums no less affordable than auto insurance." Moreover, modern catastrophe insurance could resort to financial markets for additional sources of capital and for spreading risks geographically, over market participants and intertemporally\textsuperscript{113}. For correcting market failures, Jaffee and Russel suggest, on the one hand, government intervention including regulatory incentives, compulsory insurance, and supply of coverage by the public sector. On the other hand, innovation in the private insurance sector is assumed to lead to more efficient markets for catastrophe risk, examples being catastrophe bonds\textsuperscript{114} and derivative instruments (Freeman et al., 2003).

\textit{Demand side market failure}

Again for the case of the USA and using the example of hurricanes, Kunreuther (1996) identifies market failure on the demand side of catastrophe insurance: Property owners’ underperception of disaster risk and high discount rates with regard to future events leads to inefficiently low demands for insurance and investments in protective measures. In combination with market failure on the supply side, this results in "the natural disaster syndrome", which entails limited pre-disaster awareness and high post-disaster costs to both insurers and

\textsuperscript{113} In Jaffee and Russel (1997) an important disincentive for entering the market for catastrophe insurance is labelled "early hit problem": The risk for the insurer resulting from a mismatch between annual premiums (in particular if pricing is based on expected average annual losses) and the much larger potential catastrophe losses. Related problems results from the considerable financial resources required for catastrophe insurance and the potential misuse of these resources for other purposes than payments in case of disaster – with implications for stock market performance and the risk of takeover.

\textsuperscript{114} Cat bonds in the insurance jargon; in the USA "Act of God bonds" have been issued (ibid.).
the government. In Kunreuther’s view, implicit government insurance implies moral hazard, which further exacerbates the syndrome. His normative conclusions focus on well-enforced building codes and private sector insurance – with banks, insurers and the government setting incentives for compliance with building codes and further preventive measures.

**Demand side market failure: counter-arguments**

Various of Kunreuther’s contributions (e.g. 1996) on demand side insurance market failure are in contradiction to the predictions of expected utility theory. Brookshire et al. (1985) challenge these findings by applying "the expected utility hypothesis to the description of behaviour for consumers who face a low-probability, high-loss natural hazard event". Their empirical study of property prices in California finds lower values for houses that are exposed to earthquake risk. Observed price differentials corresponding to annualised expected earthquake damages lead Brookshire et al. to the conclusion that expected utility theory explains decisions under uncertainty appropriately – even for catastrophe risks.

**Markets for risk and insurance in developing countries**

The largest share of the literature on catastrophe insurance is devoted to industrialised countries, in particular to the USA where hazard exposures, value densities and insurance penetration entail a risk of considerable losses for insurers. Problems of disaster insurance in developing countries and for the poor are in striking contrast to the situation in the industrialised world. This will be illustrated using Hoogeveen (2000) where an analytical framework analogous to the
two previous sections is developed\textsuperscript{115}. Hoogeveen’s survey provides a theoretical analysis of arrangements for consumption smoothing and an inclusive review of empirical research from various developing countries. He starts from the premise that households in poor countries are exposed to a wider variety and greater magnitudes of shocks to their income. Poor households may also lack the wealth for smoothing consumption if income is volatile. Furthermore, temporary shocks may have permanent consequences if, in order to ensure survival, productive assets have to be liquidated, if investments such as in human capital have to be suspended, or if a lack of food affects health. As formal financial services are quasi non-available to poor households and generally little developed in poor countries, Hoogeveen discusses informal arrangements for consumption smoothing. Options at the level of individual households include buffer stock strategies, the diversification of economic activities and a choice of income sources with low volatility\textsuperscript{116}. Trade of risks with other households may involve sharecropping, precautionary savings, consumption credits, and implicit mutual insurance. Even if "many of these transactions appear distant from the credit or insurance as Westerners know it" empirical evidence indicates the effectiveness of such arrangements in terms of risk-sharing and consumption smoothing. However, as Hoogeveen points out, informal and local risk sharing is a second-best solution if formal insurance markets fail. A first drawback is that reducing volatility of consumption comes at the cost of lower average income. Secondly, owing to a lack of diversification, local arrangements are ineffective against covariant shocks such as natural

\textsuperscript{115} Hoogeveen’s model world may be described as a group of households that form a village. As in Arrow (1996; see above), perfect markets would lead to full risk pooling and a Pareto efficient allocation of risk. It may be assumed in the context of Hoogeveen’s analysis that the largest share of income is spent on food and that consumption may be measured in calories.

\textsuperscript{116} An analysis of such self-insurance and self-protection arrangements as compared to formal market insurance is provided in Ehrlich and Becker (1972).
disasters. The social effects of the earthquake of 1976 in Guatemala, for example, are described as a "class quake" in Charvériat (2000: 58). A translation of the poverty trap argument into the neoclassical framework is outlined in the previous section.

For the Caribbean region, Auffret (2003b) provides an analysis of the insurance markets and market failures drawing on the theoretical approach by Arrow. In addition to considerable economic volatility in the region, natural hazards present a risk of economic shocks, in particular to the poor. Auffret finds that the "insurance market for catastrophic risk in the Caribbean region remains a ‘thin’ market characterized by ‘high’ prices and ‘low’ transfer of risk". Nominally, insurance density appears to be similar to industrialised countries at total non-life premiums of around 3% of GDP. Insurance markets, however, fail in various respects. The poor are not supplied with insurance while living in exposed areas and in vulnerable housing. Without property insurance, mortgage finance is unavailable. Auffret identifies the following main reasons for the degree of market failure in the Caribbean: Lack of or non-enforcement of land-use regulation, building codes and insurance regulation, a lack of trust in insurance companies, and the availability of ex-post financial assistance by governments or international donors.

To conclude, markets for risk appear to fail to a greater extent in the developing world and for the poor than in industrialised countries – with implications for distribution and development. As wealthier households have a greater capacity for self-insurance and better access to formal financial institutions, their consumption will be more

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117 Hoogeveen provides a detailed analysis of advantages and disadvantages of local arrangements as compared to formal or national arrangements. Issues discussed include informational problems (moral hazard, adverse selection) and enforcement problems.

118 An unequal distribution of wealth and higher premiums due to uncertainties and moral hazard may explain this percentage.
effectively isolated from income volatility and income will be higher on average. Permanent effects of shocks will be rare, even in case of covariate events such as natural disasters. For poor households and developing countries, on the other hand, risk in relation to their wealth and a lack of formal financial services may imply a poverty trap (see section 2.2)\textsuperscript{119}.

Policy implications from this analysis concern interventions in case of disasters, development strategies with regard to markets and, in particular, financial sector development. In the view of Hoogeveen, short term intervention should focus on covariate risks on the one hand and on potentially irreversible effects of shocks for the poor on the other hand\textsuperscript{120}. Development of markets in general to cover larger areas and to include more economic sectors would alleviate, via diversification, the effects of shocks on prices and quantities. Insurance of covariant risks however, requires a diversified formal financial sector with appropriate regulatory institutions. For developing countries in particular, this may imply innovation from microfinance to reinsurance and international capital markets. Examples include contingent credit, drought or rainfall insurance and catastrophe bonds\textsuperscript{121}. In the international markets, the unmet demand for risk-sharing in developing countries and the need for innovation may be considered as an opportunity for diversification.

\textsuperscript{119} For a historical and biblical illustration of these problems, see Russel (1970) who, among other points, refers to the absence of consumption smoothing in hunting and gathering societies.

\textsuperscript{120} For an ethical perspective on humanitarian interventions and development policies for disaster risk reduction see Dunfee and Strudler (2000). A discussion of risks involving irreversible events is provided in Heal and Kunreuther (2005).

\textsuperscript{121} See Skees (2000) for a discussion of risk-sharing arrangements in the agricultural sector and related, specific financial products. "Creative financing" solutions for disaster relief at the governmental level are outlined in UNDP and DHA (1994).
Conclusions with regard to the research question

The theoretical risk and insurance literature studies disasters primarily from a microeconomic perspective and with a focus on the positive welfare effects of risk-sharing. In the reviewed contributions, few statements are made explicitly on the macroeconomic effects of natural disasters. While the welfare aspects of risk-sharing are not reconsidered here, a number of cautious conclusions with regard to the effects of catastrophes on GDP and growth are drawn in this section (Loubergé, 1995). One problem is that variations in aggregate output do not necessarily have to be associated with respective variations in welfare – and vice versa. For example, the negative effects of a shock to wealth are not included in GDP, but the investments for reconstruction are (Tol and Leek, 1999; see part III).

Insurance and the short-term impact of disasters. Interpreted from a neoclassical point of view, insurance may in various ways influence the macroeconomic impacts of a disaster. Firstly, insurance contributes to the faster reconstruction of the capital stock after a catastrophe, thereby reducing the variations in aggregate output and consumption – and reducing the probability that an economy moves towards a poverty trap. A second hypothesis is that insurance markets may promote risk perception and set incentives for an optimal allocation of resources for either prevention or various forms of insurance. As Ehrlich and Becker (1972) find, this may reduce the vulnerability of an economy to natural hazards, or more specifically the economic impact of extreme events ($\Delta K_d/M_d$, $\Delta Y_d/M_d$, etc.). Caveats and specifications to this hypothesis are discussed by Kunreuther (1996 and other years).

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122 Under which circumstances this microeconomic analogy may hold will be discussed in detail in chapter 5. Note: The argument that insurance increases welfare remains valid for any effect on GDP due to disasters.
Distribution of risk and income. Exposure to risk in general and to disaster risk in particular appears to be negatively correlated with income. The underlying causality may be reciprocal and imply a poverty trap situation. On the one hand, poverty leads to higher risk exposure and, on the other hand, less options for insurance arrangements combined with a high frequency and higher magnitudes of shocks contribute to permanently low incomes (section 2.2). This hypothesis will hold primarily in developing countries, where the supply of both market and government insurance is thin (Hoogeveen, 2000). In conclusion, insurance partially reduces poverty and contributes to a more equal distribution of both incomes and economic growth.

Relevance of catastrophe insurance for growth and development. The development literature finds a generally positive association between financial sector development and economic growth. For the insurance sector, Arrow’s (1971) argument of trade in risk encouraging economic activities that could otherwise not be undertaken provides a partial explanation. An example related to catastrophe risk is property insurance, which facilitates mortgage lending (De Soto, 2000; Auffret, 2003a), a major source of finance for investments in housing and infrastructure in industrialised countries. A further influence of insurance on development may be via the mitigation of (micro)economic effects of disasters. To summarise, efficient markets for risk may reduce economic volatility due to disasters, contributing to lower poverty rates and a more equal income distribution – both factors with a positive influence on growth and development (Hoogeveen, 2000).

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123 See e.g. Da Rin (2002), Landes (1998), Rousseau (2002), Moscow (2002), or Tadesse (2002). The literature on financial sector development and socio-economic development in general, however, is not systematically reviewed in this thesis.
4.2 Reinsurance Publications: Macroeconomic Statements

A number of publications by reinsurance companies\textsuperscript{124} address problems related to natural disasters and, in some cases, their macroeconomic consequences.

The synopsis in the following section discusses qualitative and theoretical statements directly related to the research question\textsuperscript{125}. Note that catastrophe statistics provided by reinsurers are summarised in chapter 1 and that the concept of "economic loss" will be discussed in detail in the subsequent section. Overlaps between the theoretical statements (this section) and the statements based on the economic loss perspective are intentional. They may illustrate where the consensus in the reinsurance literature is most robust.

**Quantitative statements: Disaster statistics**

To recapitulate the main conclusions from disaster statistics as provided by reinsurers\textsuperscript{126}, natural disasters have been increasing over time in both frequency and total damages per year. Insured losses have been rising faster than total losses. Absolute economic losses and the percentage of insured losses are higher in industrialised countries. In developing countries, however, losses are higher if put into relation to GDP but low in absolute terms. Explanations for these

\textsuperscript{124} In particular Swiss Re and Munich Re, the biggest reinsurers at the time of writing (May 2006). Where the thesis refers to insurance and reinsurance publications they are mainly from these two institutions.

\textsuperscript{125} This section contains a number of references to Munich Re (1999), the special millennium issue of "topics". In addition to long-term statistics of natural catastrophes from the 11\textsuperscript{th} to the 20\textsuperscript{th} century and discussions of observed trends, the report contains a wealth of historical drawings, paintings and photographs – one of the most beautifully illustrated publications in its field.

\textsuperscript{126} An overview of statistics and stylised facts is presented in chapter 1.
trends include "population growth, rising standards of living, concentration of population and values in metropolitan areas, settlement and industrialisation of very exposed regions, vulnerability of modern societies and technologies, changes in environmental conditions" Munich Re (1999: 68).

In part, these explanations are in congruence with the "three stage theory of development and vulnerability" of Benson & Clay (2004; see chapter 3). Analogous reflections on disaster risk in China by Munich Re (1999: 82) and Swiss Re (2006) include critical views on flood protection as one aspect of development. Although recently constructed dams now protect large areas from regular flooding, millions of people now live in these areas and the risk of flooding is shifted to regions downstream. Taking into account the number of exposed people, the exposed values and the vulnerabilities of both, the net catastrophe risk may have rather increased than decreased due to these flood protection measures.

Among the explanations for the historical and expected increase in disaster frequencies, climate change, associated with rising greenhouse gas concentrations in the atmosphere, is considered one of the most relevant "changes in environmental conditions". Insurers expect implications for primarily two variables: The rise of mean global temperature is assumed to lead to an increase in the frequency of tropical storms and a rise of the mean sea levels (Doherty, 1997). Rising sea levels imply a shift in coast lines and the geographic distribution of associated hazards of flooding. Tucker (1997) has argued that climate change already has economic effects as the uncertainties about the degrees and the timing of changes may lead to increased insurance premiums.
Qualitative statements and theoretical explanations

Statements on the macroeconomics of natural catastrophes in reinsurance publications may, in many instances, be considered as descriptive reflections on the socio-economic implications of disasters beyond insured or economic direct losses. In other instances these statements may primarily serve for illustrating the wider benefits of insurance in terms of welfare gains and positive effects on development. The review begins with statements that are closely related to the development policy perspectives (chapter 3), then briefly looks into aspects of international economics of disasters and the special case of megacities. A growth theory perspective on catastrophes concludes the section.

At one end of the spectrum of positions in reinsurance publications are statements that are analogous to the perspective of humanitarian aid organisations (chapter 3): "The massive damage to infrastructure [caused by Hurricane Mitch], especially in Honduras, Nicaragua, and El Salvador, will put back economic development in the countries affected by years", supposes Munich Re (1999: 17) and in an analysis on natural disaster risk in China, Swiss Re (2006) describes scenarios with "disruptive" and "far-reaching economic implications". From potential losses that could exceed 6% of GDP the study concludes that "without increased insurance penetration, the financial loss burden [of natural catastrophes] could threaten China’s sustained economic and social development."

While one of the key principles of reinsurance is global geographic diversification of risks, it is sometimes hypothesised that local disasters may have repercussions on the world economy: "increasing networking at all levels, from the local to the global scene, also means that the scale of natural catastrophes is greater than ever as a result

\[\text{West and Dowlatadadi (1999) take an analogous perspective to the question of flooding risk of poldered areas in the Netherlands.}\]
of indirect losses" (Munich Re, 1999: 97)\textsuperscript{128}. Arguments behind this hypothesis are the highly specialised and quasi-monopolistic suppliers of essential components combined with just-in-time supply chains. The Kobe (Japan) earthquake of 1995 provides anecdotic evidence as it made "frighteningly clear that natural catastrophes can seriously disrupt economic and private life for several months on end in highly developed industrial societies, too" (Munich Re, 1999: 14; Swiss Re, 1995). One of the factories damaged by the earthquake supplied a significant world market share of screens for notebook computers and the earthquake created problems for producers that depended on these parts.

The Kobe earthquake also inspires catastrophe scenarios in megacities (Munich Re, 2005)\textsuperscript{129}. In a developing country capital city, which may be the centre of an open economy that depends to a large degree on international trade and finance, a disaster may entail a shock to output, disruptions of international trade, and capital flight (Cochrane, 1999). However, even substantial macroeconomic effects in a low or middle income country would globally involve low absolute magnitudes and therefore remain largely localised. A disaster affecting a megacity in the industrialised world could, in contrast, result "in the collapse of the economic system of entire countries and may even be capable of affecting financial markets throughout the world" Munich Re (1999: 72). Cochrane (1999) warns from apocalyptic exaggerations and notes that there is no historical evidence of such scenarios.

\textsuperscript{128} For a macroeconomist's contrasting view of the Kobe earthquake see Horwich (2000) and the respective discussion in section 5.2.

\textsuperscript{129} In the next section on economic loss the Munich Re natural hazard risk index for megacities will be briefly outlined. Due to their socio-economic complexity megacities are often assumed to be more vulnerable to hazards than rural areas. High concentrations of population, assets and production entail the risk of considerable losses and the central role of cities in economies may translate the impact of a catastrophe into macroeconomic shocks (Cochrane, 1999; Munich Re, 2005).
See the next section for literature on catastrophes and international financial markets.

Explicit reference to macroeconomic theory is rare in reinsurance publications and it marks the opposite end of the spectrum of these more applied perspectives. In Munich Re (2001: 16ff)\textsuperscript{130} the economic aspects of natural disasters are discussed in terms of effects on stock and flow variables – $\Delta K_d$, $\Delta Y_d$ etc. in the neoclassical framework – with the intention of clarifying the concept of "economic loss" (reviewed in detail in the next section). For describing the long-term effects of disasters, this publication presents three qualitative and graphical scenarios that refer to growth theory (see figure 4-1).

According to figure 4-1, a natural catastrophe first translates into a shock to output ($\Delta Y_d$) which is labelled "direct effect"\textsuperscript{131}. This shifts the economy below its pre-disaster growth path. Development effects in the long term depend upon various factors. In Munich Re (2001), three post-disaster growth scenarios are proposed: In the first scenario, the reconstruction of the capital stock leads to increased growth and a "modernisation surge", increasing productivity via installation of the latest technology (positive shock to $A$) and moving output to a trajectory above the pre-disaster growth path. In the second scenario, capital stock reconstruction and moderate modernisation induce a lower long-term growth trajectory. Finally, in a third scenario, the presumed political, social and economic erosion following the disaster leads to a further long-term decrease in output beyond the immediate shock $\Delta Y_d$. To anticipate the discussion of macroeconomic

\textsuperscript{130} To the author’s knowledge, this is the only publication by a reinsurer where the concept of economic loss is discussed in customary economic terms and where growth theory is explicitly used for hypothesising on the macroeconomic effects of catastrophes. Swiss Re (2000) contains macroeconomic considerations and modelling results but no explicit reference to economic theory.

\textsuperscript{131} In most of the insurance literature direct effects are defined as shocks to the capital stock ($\Delta K_d$); see section 4.3.
Figure 4-1. Long-term economic effects of natural disasters in a growth framework. Baseline development trajectory (straight line) and three growth scenarios following a natural catastrophe: Strong modernisation surge, weak modernisation surge, socio-economic erosion. GDP is on the Y-axis, time on the X-axis. Note that the direct effect of the catastrophe ("direkter Effekt der Naturkatastrophe", on the x-axis) is given here in terms of $\Delta Y_d$. From Munich Re (2001: 18)\textsuperscript{132}.

\textsuperscript{132} The figure is only available in German. Translation of the key legends: "Sozialprodukt": GDP; "direkter Effekt der Naturkatastrophe": direct effect of the disaster; "Zeitpunkt der Naturkatastrophe": time of the natural disaster, $t_d$; "langfristiger Entwicklungs­pfad ohne Naturkatastrophe": long-term development trajectory without natural catastrophe. The three post-disaster growth scenarios are explained in the legend.
perspectives in chapter 5; scenario one may correspond, depending upon the respective assumptions, to both the simplistic neoclassical model and to the Keynesian multiplier model. Scenarios two and three correspond, qualitatively, to the Harrod-Domar (or Mechler-Freeman) approach. Finally, the Ramsey model from Murlidharan and Shah (2003) may accommodate all three scenarios.

In Munich Re (2003) the above framework is applied to the analysis of the floods that affected Germany and further countries of central Europe in August 2002. The study starts from the premise that "experience of other countries that have been hit by natural catastrophes suggests that the long-term development of economic growth after a natural catastrophe is often much less favourable than it would have been if the catastrophe had not occurred" (ibid.: 30). Conclusions for the case of the 2002 floods in Germany are illustrative for the conditions under which the above scenarios may be applicable. Firstly, effects on output are predicted for the affected regions only and to last a short time. As the regions are part of a larger state structure a "rapid flow of public and private aid and, given the requisite private insurance density, claims payments" is assumed. This implies an increase in GDP following the floods and a significant modernisation surge. For the long term, macroeconomic consequences in the affected regions are considered negligible. On the relevance of insurance on economic development, the study concludes that "this catastrophe event shows again the positive effect that a strong and functioning private insurance industry has on the economy as a whole."

On distributional aspects of disaster risk as a last point of this section: The Munich Re (2003) study finds effects on regional GDP to be small, however, there may be regional and sectoral redistribution of output from affected regions and sectors to surrounding and non-

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133 Numerical loss estimates as well as figures for national and regional output are discussed in the case studies presented in section 4.3.
affected entities where in some cases even increased demand may be observed. This corresponds to the results in Swiss Re (2000) where an earthquake scenario in Switzerland is predicted to have moderate effects on GDP but a strong effect on imports. Furthermore, economic effects of disaster and risk exposure respectively, may vary with income. As observed in Munich Re (1999: 70), in developing countries primarily the poor settle in areas that are exposed to natural hazards. In industrialised countries, this pattern may be reversed, with commercial zones on marginal lands and residential areas for the wealthier in proximity to coastlines more exposed to hazards. Kunreuther (e.g. 1996, 1997) explains the reversal of risk distribution is in part by deeper markets for private insurance and the incentives presented by both explicit and implicit government insurance. Socially, however, this outcome may not be optimal as aggregate risk exposure increases. The resulting losses or costs in case of disasters are a cause of concern for insurers and governments.

Excursion: Catastrophes and the international financial markets

In disaster literature, financial markets are studied as "seismographs" for catastrophes (Munich Re, 2004), as fields of innovation for disaster risk finance (e.g. Froot, 1999), and as a link in the macroeconomic processes related to disasters (Cochrane, 1999). Problems debated include the greater potential for risk diversification, systemic risk in the financial sector (Swiss Re, 2003) and the potential globalisation of local economic shocks (Pelling, 2003).

The following excursion into the literature\textsuperscript{134} on financial markets and

\textsuperscript{134} Not reviewed here is the large body of literature on solutions for catastrophe risk finance that are complementary to traditional insurance (Niehaus, 2002). Under the catchword alternative risk transfer (ART), a variety of products such as CAT bonds is discussed in Swiss Re (1996; 2002a). For derivatives see also Scholes (1996), Borden and Sarkar (1996), Wright and Newbery (1989).
catastrophe insurance focuses on theoretical and empirical statements on the macroeconomic impacts of natural disasters.

An early historical case of a natural disaster with repercussions in the international financial markets is the San Francisco earthquake of 1906. On 6 July 1906 the London Financial Times reported: "San Francisco's $200,000,000 'ash heap' [insurance payments] involves complication which will be felt on all financial markets for many months to come [and] the payment of losses sustained ... represents a financial undertaking of far-reaching magnitude ...". According to Odell and Weidenmier (2002) the catastrophe reduced US GNP by 1.3 – 1.8 % and led to immediate stock market declines in New York (-13% in NYSE market values) and London, where the share prices of insurance companies lost up to a third of their value. The emphasis of the Odell and Weidenmier paper however, is on the claims payments by British insurers that led to capital outflows in the form of gold from Britain to the USA. These amounted to 40% of British gold exports for 1906 and to 80% of US gold imports. Defending the Dollar/Sterling exchange rates and its levels of reserves, the Bank of England and further European central banks raised interest rates and discriminated against US finance bills. Odell and Weidenmier (2002) conclude that these policies pushed the US economy into recession, were one of the causes of the "panic of 1907" and, ultimately, led to the formation of the Federal Reserve 1913.

Contemporary examples of catastrophes and their repercussions in the financial markets are studied in Munich Re (2004: 67ff). For the terrorist attacks of 11 September 2001 on the World Trade Centre in New York, the effects on the stock markets are described as "short term and moderate". However, in the fixed-income markets interest rates remained lower six months following the events. For the Kobe

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135 Quoted from Odell and Weidenmier (2002: 2).

136 For macroeconomic and methodological issues of this event see Cochrane (2004).
earthquake, one of the costliest natural disasters ever reported, no evidence of long-term effects on global stock markets was found and the downward trend in the Japanese stock markets is attributed to other factors than the earthquake (ibid.: 70).

As a third example, Brunner (2000) studies the influence of El Niño on the global economy. His findings include statistically significant relationships between the climate phenomenon in the southern Pacific Ocean and global economic indicators. ENSO appears to explain up to 20% in global commodity price inflation, consumer price inflation and variation in output. Temporary non-oil commodity price increases (primarily food prices) are attributed to disruptions of production by El Niño related natural disasters such as excessive rainfalls, floods, storms, and droughts. Affected sectors include agriculture, fisheries, and mining. Economic activity in the G7 countries is stimulated by El Niño cycles, which Brunner explains by increased demand for reconstruction of affected infrastructure and the related demand for exports.

Finally, Cochrane (1999) criticises a widely-quoted scenario developed by the research department of the Japanese Tokai bank (1990): A catastrophic earthquake in the Tokyo region could, via the increased foreign demand for reconstruction, trigger massive sales of US securities by Japan. As bond prices declined, US interest rates would rise, leading to a recession in the USA and a boom in Japan. Cochrane considers (for a range of arguments not recapitulated here) a sale of securities on a scale that leads to significant drops in market prices as unrealistic. He concludes that capital markets may be too vast to be disturbed by natural disasters. Munich Re (2004: 70) supports this hypothesis, stating that "past events suggest that the consequences

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137 Often referred to as "The El Niño Phenomenon" or "El Niño Southern Oscillation (ENSO) cycle". A brief overview of the phenomenon and its various (in part disastrous) effects in many regions is provided in Swiss Re (1998a).
for capital markets tend to be less serious than is generally assumed\textsuperscript{138}. Effects of disasters on capital markets can not be ruled out but they "would generally tend to be confined to the region in question". For the insurance sector in particular, Swiss Re (2003c) and Cochrane (1997, 1999) find that there are few theoretical arguments and no empirical or historical evidence of systemic risk entailed by the supposedly high vulnerability of the sector to natural disasters\textsuperscript{138}.

**Conclusions with regard to the research question**

In the reinsurance literature, general and qualitative statements on the macroeconomic effects of disasters may be associated with a wide range of perspectives. In some instances, reinsurance publications assume positions similar to humanitarian aid or development institutions (chapter 3). This is the case in particular for statements on developing countries. In other (rare) instances, arguments explicitly relate to macroeconomic theory (chapter 5)\textsuperscript{139}. The largest part of reinsurers’ conclusions on the economics of catastrophes, however, may be positioned between these two extremes and are primarily related to the concept of economic loss. This will be discussed in detail in the subsequent section 4.3. In some cases, this central concept serves as a starting point for deliberations on macroeconomic effects. From the

\textsuperscript{138} In an number of papers on catastrophe insurance capacity in the USA, the question "Can insurance pay for the Big One?" is raised, usually referring to a catastrophic earthquake in San Francisco or a Hurricane in the south of the USA. In an empirical survey, Cummins et al. (2002) find that a large (insured) loss in the order of US$ 100 bn would be disruptive to the industry, causing a number of insurer insolvencies and leaving some claims unpaid. However, total capacities are assumed to be sufficient with 92\% of expected claims covered for a US$ 100 bn loss. For a review of research that supports the conclusions of Cummins et al. see Niehaus (2002).

\textsuperscript{139} Where the reinsurance literature refers to other perspectives on natural disasters and vice versa, the levels of controversy are low compared to the pronounced criticism and the intense debates customary in the macroeconomic catastrophe literature. This may be because reinsurers’ publications are primarily aimed at a business audience rather than an academic audience.
respective statements in reinsurance publications, the following conclusions may be drawn:

For industrialised countries the insurance literature suggests that historically natural disasters do not have significant effects on aggregate output and growth. Given the wealth of empirical evidence, the sophistication of catastrophe modelling and the theoretical arguments, this result appears robust. Proposed explanations include the small magnitude of natural disaster in relation to wealth and output, adaptive mechanisms in well-integrated markets for goods and services, high private and public insurance density, and competent intervention by governments with access to large funds. As will be discussed in chapter 5, this conclusion is in line with Albala-Bertand’s (1993a, 2006) Keynesian position. Exceptions to this finding are discussed in the context of catastrophe scenarios for which there are no historic records, such an earthquake in a modern megacity in an industrialised country. For such events with return periods of several hundred years, significant macroeconomic implications are predicted including repercussions on international markets for goods and capital. Whether such global effects could involve global changes in risk-sharing, disruptions of supply chains and whole markets or a collapse of the insurance sector (systemic risk), remains open. Cochrane (1999), Cummins (2002) and Swiss Re (2003c) find little evidence for systemic risk in the insurance sector related to natural disasters.

Macroeconomic effects of disasters in developing countries are discussed in the reinsurance literature first and foremost, in comparison to industrialised countries. Economic losses due to catastrophes are greater in relation to wealth and GDP, insurance density is lower, markets are less integrated and more likely to be disrupted, insurance density is negligible and government interventions may draw on less
expertise and lower funds\textsuperscript{140}. The conclusion in the reinsurance literature from these arguments is that natural disasters in developing countries imply larger macroeconomic shocks in the short term and have more protracted adverse effects on growth and development in the long run. As economic shocks in a developing country are small on a global scale, the effects on the international markets will generally be negligible even for open economies. Overall, these arguments may be seen in line with the "three-stage theory of development and vulnerability" (Benson and Clay, 2004) as well as with the standard neoclassical framework. However, in insurance literature there are fewer modelling results and less empirical evidence available for disasters in poor countries. The respective statements are therefore considered less robust than for industrialised countries. The discussion of these hypotheses will continue in the chapter on macroeconomic perspectives.

4.3 Insurance practice: The concept of economic loss

Where literature by the insurance sector takes a macroeconomic perspective on natural catastrophes, "economic loss"\textsuperscript{141} is one of the key concepts. It is the quantitative loss estimates that are among the most widely quoted financial figures on disasters. This includes both data on historical events as well as projections in the form of estimates of expected losses. An overview of summary statistics and stylised facts is presented in chapter 1.

\textsuperscript{140} Note that these assumptions are in line with the predictions of the neoclassical model.

\textsuperscript{141} It is assumed for the purposes of the discussion in this chapter that "economic loss" can be treated as a synonym to terms such as "total loss", "overall loss", and "total damage". If not otherwise stated, economic loss is assumed to correspond to $\Delta K_i$ in the neoclassical framework; see table 2-1 and the further discussion of the concept in section 5.1.
For the above reasons and because of the widespread confusion\textsuperscript{142} related to the interpretation of economic losses in the disaster literature and in the media (Albala-Bertrand, 1993a; Cochrane, 1997; Munich Re, 2001; Zeckhauser, 1996), two sections of this thesis are devoted to the concept (this section and section 5.1). Subsequently, definitions and methodologies, as customary in the insurance sector, are briefly outlined, discussed using case studies and compared to other approaches. As throughout the thesis, the neoclassical model from section 2.2 provides the framework for purposes of definition\textsuperscript{143}. Section 5.1 will continue the review of approaches to disaster impact assessment in general, such as proposed by ECLAC (2002), van der Veen et al. (2003) and Cochrane (1997, 2004).

That the term "economic loss" may appear self-explanatory is one of the main reasons for the confusions that accompany it. Explicit definitions of what the respective estimates include and what methodologies were used for producing them are rarely provided. This may result in misleading interpretations of economic loss in the literature from both academic and non-academic backgrounds. An illustration: A state-of-the-art estimate of economic losses due to an earthquake includes damages to private property and public infrastructure – $\Delta K_d$ in the neoclassical framework. In relation to the GDP of the affected country, the figure may then be published as "economic loss in % of GDP". From this, conclusions on the effects of the disaster on output, $\Delta Y_d$, may be drawn – interpreting the (primary) shock to the stock variable capital as the (secondary) shock to the flow variables of

\textsuperscript{142} According to Cochrane (1999): "... the word damage is used somewhat loosely in the hazards literature. This is unfortunate since public policy debates cannot be meaningful unless the involved parties are in some agreement as to what is meant" and "...many of the misconceptions about loss can be traced to a lack of understanding about how economies function."

\textsuperscript{143} The confusion around the concept of "economic loss", and the implied need for clear definitions in standard macroeconomic terminology, was one of the reasons for developing the neoclassical framework.
Definitions, Methodologies

Economic loss figures by reinsurers are first and foremost estimates of the shock to stock variables ($\Delta K_d$). This includes buildings, production facilities, contents, inventories, public infrastructure, agricultural crops etc. (Munich Re, 2001). More precisely, the replacement costs plus the damage remediation costs. In some cases, indirect losses are also added to the economic loss figures, usually as an aggregation of income or revenue effects at the micro level – or business interruption in the insurance terminology (Munich Re, 2001; Swiss Re, 2006). An overview of loss concepts and a comparison to the neoclassical framework is provided in Table 5-1.

A customary approach to calculating economic losses in insurance practice is to divide the figures for total insured losses (claims) by the estimated insurance density (Munich Re, 2001). This method may provide estimates if no official figures are available or if they are

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144 See the UNDRO quoted in Albala-Bertrand (1993a: 4); Freeman et al. (2003) hypothesise that "... some countries ... could face losses exceeding 10 percent of GDP ..." and Swiss Re (2005): "This economic impact is often further compounded by lost production capital, business, and investment and may result in long-term impairment of the GDP."

145 In Swiss Re (2006) the definition for "total property loss" includes buildings, contents and business interruption but excludes infrastructure, agricultural crops and other components of total economic losses.

146 Munich Re (2001) notes that even these comparatively reliable figures may take several years to become available while estimates of economic losses are discussed in the media, by governments and by a variety of institutions a short time after disaster events.
considered unreliable. For developing countries, where insurance penetration is low, economic losses may have to be extrapolated from historical data as well as country and disaster characteristics (Munich Re, 2006). Note that none of the insurance perspectives on economic loss includes or directly refers to disaster effects on macroeconomic aggregates such as GDP or external balances (Munich Re, 2001). These secondary effects are discussed primarily qualitatively in the insurance literature – with remarkable quantitative exceptions, as the following case study summaries will show.

**Economic loss and the macroeconomics of disasters: Examples of historical analyses and macroeconomic projections from the insurance literature**

Four examples may illustrate the variety of applications of the concept of economic loss in reinsurance practice, both in ex-post and ex-ante analyses. In some cases, these simulations go beyond estimates of insured and total economic losses to include macroeconomic variables. A broader overview of macroeconomic statements by reinsurers is provided in the following section.

**Floods in Germany of August 2002: Analysis of a historical event.** The economic losses of the summer floods in 2002 are estimated at EUR 9.2 bn for Germany (Munich Re, 2003). Preliminary estimates by academic and government institutions ranged between EUR 5 and 23 bn. Effects on the German GDP were assumed to be negligible, between -0.023% and -0.1%, while for the affected regions a significant decrease in GDP was estimated: -3% for Saxony and Saxony-Anhalt. Actual GDP growth in 2002 was later reported at +0.2% for

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147 One set of estimates for effects on GDP was based on per capita GDP and the assumption that affected people were not productive for the duration (1 month) of the floods. This is one of the few instances in catastrophe literature where the effects on
Germany, +0.1% for Saxony and +0.5% for Saxony-Anhalt – "it appears that other, in part opposing factors play a role" (ibid.: 29). For the post-disaster years the study predicts an increase in regional GDP due to increased investments for reconstruction, even if part of the additional demand will be met by suppliers from other regions than the affected ones. In the long term, the effects of the floods on economic development are assumed to be negligible due to the level of available government resources, the high insurance density, the positive medium-term effects of reconstruction investment and an increase in productivity due to modernisation (ibid.: 30f).

Global disaster "Hot Spots": Catastrophe scenarios for identifying the largest insured loss potentials. Insuring and reinsuring natural disaster risk involves the control of "accumulation risks" entailed by dependencies between individual risks that are all related to the same trigger event. In order to identify the disaster scenarios with the maximum expected insured losses, Swiss Re (2004) simulated events with return periods of 200 to 1,000 years. The resulting "largest insured natural catastrophe loss potentials" are located in industrialised countries: USA (earthquakes and hurricanes), Japan (earthquakes), and Europe (storms) – a result that is explained by coincidences of high asset concentrations, complex economic structures and high exposure to natural hazards. Analogous simulations for total economic losses were not found in reinsurance publications but a related approach was proposed by Dilley et al. (2005). The project resulted in a world atlas of natural disaster risk, including a geography of mortality risk and expected economic losses for all types of natural hazards148. According to this study, "hot spots" of mortality risk and economic loss (E[ΔLd/L], E[ΔKd/Y]; ex-post are situated primarily in the

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148 The approach is based on historical data for disasters, primarily from the 20 – 30 last years of the 20th century.
developing world and include regions in Latin America, central Asia, Africa, India, Bangladesh, China and Eastern Asia. The project will be referred to again in chapter 5 and part III.

**Potential earthquake losses in Switzerland: Scenario based on a historical event.** Large earthquakes are rare in Switzerland but they present, by their potential economic implications, the most relevant natural hazard in this country. In Swiss Re (2000) the hypothetical effects of a historical event are simulated: The Basel earthquake of 1356, an event with a presumed return period of around 1000 years. Maximum economic losses in Switzerland (2000) are estimated at around CHF 80 bn which includes 60 bn damage to property, 10 bn damage to infrastructure and 15 bn "business interruption" (revenue losses). In comparison, losses due to the Kobe earthquake of 1995 were reported at US$ 100 bn and the 1999 earthquake in Turkey entailed damages of US$ 30 bn – the same orders of magnitude. Based on the simulations of direct losses, the effects on Swiss GDP are estimated at +2.7% in the first year following the disaster, with investment via the construction sector up by 14% and imports up by 8%. The study concludes that a 1,000-year earthquake in Switzerland would be disastrous for the affected households and businesses but it would unlikely entail a macroeconomic disaster.

**An index for potential economic losses: The Munich Re natural hazard risk index for megacities**. According to Munich Re (2004) "the loss potential from natural catastrophes is increasingly dominated by megacities" and Cochrane finds that "the destruction of a megacity in a financially strapped economy could well trigger a collapse in

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149 The index is described and discussed in detail in Munich Re (2004: 40ff) and Munich Re (2002: 32ff).

150 According to a definition by the United Nations, a megacity is a city or conurbation with more than 10 million inhabitants – a qualification that in 2004 applied to 22 cities, four of them in industrialised countries and 18 in developing countries. The Munich Re megacity risk index includes 50 urban centres (Munich Re, 2004).
Figure 4-2: The Munich Re Natural hazard risk index for megacities. In developing countries, overall risk (see text) depends primarily on vulnerability. In industrialised countries, exposed values play an important role. The largest risks (expected losses) are identified for highly exposed cities in the industrialised world such as Tokyo and San Francisco. From Munich Re (2003: 35).
exchange rates, capital flight and a subsequent economic implosion. With the exception of Tokyo, by the year 2020 the most populous cities on earth will be in disaster prone areas which are vulnerable to economic collapse." In the interest of a quantitative risk assessment based on absolute magnitudes of potential economic losses\textsuperscript{151}, Munich Re developed a risk index for megacities. As illustrated by figure 4-2, the index consists of three components. Firstly, hazard exposure is estimated as a function of average annual losses and probable maximum losses (1,000-year loss) for all types of hazards, in particular earthquakes and storms. Secondly, the vulnerability component of the index is based on the specific vulnerabilities of building classes, on building quality, on preparedness and safeguard standards, and on population density. Thirdly, exposed assets are approximated by the average value of residential property and GDP data for commercial and industrial property. Finally, values for each of the three components are standardised to a scale with a maximum value of 10. Multiplying the individual three indices for hazard, vulnerability and exposed values yields the overall risk index (figure 4-2).

For megacities in industrialised countries, overall disaster risk according to this index depends, in most cases, primarily on vulnerability and exposed values. Hazard exposure contributes significantly to overall disaster risk only in cities in Japan and both the west coast and the Caribbean coast of the USA. For these cities the highest disaster risk was estimated. This finding is in accordance with the results of the Swiss Re (2004) study discussed in the second example above, in particular if insurance density is taken into account. In developing country megacities, overall disaster risk appears to be dominated first and foremost by vulnerability. Note that the index is a proxy for potential absolute losses, the most relevant measure from an insurance perspective. An index based on a loss-to-GDP ratios might

\textsuperscript{151} Approximately corresponding variable in the neoclassical framework: $E[\Delta K_d]$. 

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produce a different ranking with developing country megacities appearing more exposed to disaster risk than those in the industrialised world.

**Summary and conclusions regarding the research question**

Conclusions from the discussion of the concept of economic loss and its application to the analysis of historical events and to simulations can be drawn with regard to three issues: Firstly, on the insurance sector as a provider of research, secondly, on problems of interpretation and, finally, on the relevance of "economic losses" for growth and development.

As a source of economic data, both on historical events (ex post) and generated by simulations (ex ante), the reinsurance sector remains unmatched\(^{152}\). In the case of natural disasters, projections are particularly valuable as catastrophes are by definition infrequent events and for some hazards there will be few historical records. In addition to the quantity and quality, reinsurance data may have the advantage of being less distorted by political or economic interests than official estimates such as by affected countries’ governments (Munich Re, 2001; Albala-Bertrand, 1993a). For the study of long-term and macroeconomic effects in developing countries, reinsurance data, however, become thin as most studies focus on their core business: On insurance issues rather than development issues, on insured losses rather than macroeconomic effects, and on industrial countries rather than poor countries.

\(^{152}\) The leading disaster data bases include (see also Dilley et al., 2005; Smith, 2004; Tschoegl et al., 2006): The Munich Re NatCatService database, Swiss Re’s sigma database, and EM-DAT of CRED (see Guha-Sapir et al., 2004). Depending upon the database, economic data is available for around a third of the recorded disasters. Methods for estimating economic figures vary widely.
The concept of economic loss entails the risk of confusion if interpreted in macroeconomic terms and beyond the direct effects on stock variables. Considering short-term mechanisms and the potential medium-term effects of investment for reconstruction, Munich Re (2001) concludes that economic loss estimates should only be interpreted macroeconomically with great care. Consequently, and taking into account the variety of loss estimation methodologies, it seems advisable to consider "economic loss" figures, if not otherwise stated, as estimates of the impacts on the capital stock ($\Delta K_d$). In brief: The concept of economic loss may mark the point where macroeconomic thinking departs from insurance perspectives on disasters.

Regardless of interpretation problems, the economic loss approach contributes a number of empirically founded hypotheses to the study of macroeconomic effects of disasters. Qualitative statements in the reinsurance literature have been reviewed in the previous section and the discussion will be continued in section 5.1 with a more general overview of methodologies for disaster impact assessment.

Concluding from the loss estimates and the "backtesting" of projections by reinsurers, natural disasters in industrial countries appear not to affect significantly aggregate output and growth. Explanations include the geographic and economic localisation of disasters, institutional quality, resources for reconstruction, and, insurance density. Exceptions to these findings are projections involving extreme events that cause massive damage in an urban centre such as earthquakes in California or the Tokyo area. For such events, global economic repercussions via financial markets and supply chains are predicted.

However, insurance literature, and in particular the economic loss perspective, supplies less quantitative evidence on developing countries. It is, however, often hypothesised that the macroeconomic impacts of disasters are more relevant in developing economies than in industrialised countries. The respective lines of arguments refer primarily to differences between the developing and industrialised
world. These include higher loss-to-GDP ratios in developing countries, less diversified economies, higher numbers of casualties, lower institutional quality, a lack of public and private resources for reconstruction, and, lower insurance densities (see previous section).

4.4 Summary of conclusions from the insurance literature

Macroeconomic aspects of natural disasters were found to be a marginal topic in the insurance literature. Academic contributions from a microeconomic perspective focus primarily on welfare problems of markets for (disaster) risk while reinsurance publications address, first and foremost, technical and business issues of catastrophe insurance. Nevertheless, this literature supplies valuable hypotheses related to the research question.

Theoretical analysis of markets for risk suggests that insurance provides welfare benefits through consumption smoothing with regard to income shocks. Respective arrangements may range from local microinsurance to global reinsurance, from informal over private to government insurance schemes, and they may include explicit and implicit insurance. Ceteris paribus, the mitigation of a shock at the micro level will translate into reduced macroeconomic volatilities (e.g. lower $\Delta C_d$) and faster reconstruction of production capacities after a catastrophe. In the long run, disaster insurance may be associated with more equal income distribution and lower poverty rates, thereby positively influencing output and growth.

Theory and empirical evidence suggests, on the one hand that poor segments of society have less scope for insurance and, more

\[153 \text{ In addition to market insurance, consumption smoothing with regard to income shocks may also be achieved – more generally and in the terminology of Ehrlich and Becker (1972) – by self-insurance (e.g. buffer stocks or savings and credit) and self-protection. The focus of this chapter remains on market insurance.}\]
generally, for consumption smoothing arrangements. In developing countries on the other hand, both private insurance markets and public sector insurance are less developed and endowed with less resources. As a result, natural hazards entail more significant economic risks for the poor due to potentially greater and more protracted effects. In a neoclassical framework, these arguments correspond to a poverty trap with disasters increasing the risk of households or economies of being shifted to the low-income equilibrium. A range of policy recommendations therefore is proposed in the literature, including insurance product innovation, financial market development in general and for the poor in particular, as well as government interventions.

Sound empirical evidence and disaster simulations support the above predictions for industrialised economies: Macroeconomic effects of catastrophes are, as a general rule, not significant. Explanations include, besides wealth as a buffer against shocks, the level of development of markets and institutions, as well as insurance densities\(^ \text{154} \). Exceptions to the rule are, according to simulations, large disasters in industrialised country megacities\(^ \text{155} \). Macroeconomic effects with repercussions in international markets would result while systemic risk in the insurance markets remains negligible.

On the economics of disasters in the developing world, less empirical evidence is available in the insurance literature. Arguments are developed in analogy to industrial country evidence and in comparison to developing country characteristics. In other instances conclusions

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\(^{154}\) Cochrane (1999), however, finds no evidence for a link between insurance and macroeconomic performance.

\(^{155}\) From a neoclassical perspective, megacities may be of particular relevance as they have a geographic accumulation of production factors (physical, human, social, institutional capital), thereby determining also the level of technology for the country as a whole. Further, macroeconomically essential sectors may be concentrated in megacities (finance, trade etc.). If disrupted by a disaster, "bottlenecks" may result and translate into shifts in aggregate productivity.
are based on intuitive induction from anecdotic evidence or on statements from the humanitarian literature. The conclusions in the insurance literature – that natural disasters lead to significant macro-economic effects in developing countries, in particular on output, growth, development and poverty – will therefore be considered a hypothesis for further discussion in the thesis.

Levels of controversy are low between the insurance literature and the development policy perspective (chapter 3) on the one hand, and the macroeconomic perspective (chapter 5) on the other hand. Relations between the different perspectives may include firstly, humanitarian issues that are, implicitly or explicitly, a concern in most of the catastrophe literature. Secondly, references to economic loss data\textsuperscript{156} from insurance literature abound in both policy and development literature as well as in macroeconomic contributions\textsuperscript{157}.

\textsuperscript{156} Sections 4.1 and 5.1 discuss the concept of economic loss and the related widespread confusions.

\textsuperscript{157} Mechler (2003) and Freeman et al. (2002) propose a methodology, which explicitly links loss simulations by insurance with a macroeconomic model. See detailed review in the next chapter.
Whereas the previous two chapters have surveyed literature at the periphery of mainstream macroeconomic research, the following sections will review macroeconomic concepts applied to the study of natural disasters (figure II-1). The institutional background of this literature tradition is primarily in academia and related research institutions.

Macroeconomic perspectives differ from development policy perspectives (chapter 3) both in their theoretical and analytical viewpoint and by their explicit reference to macroeconomic concepts, models and empirical methods. The contrast to the insurance perspective (chapter 4) lies in the use of analytical frameworks at the macro level rather than at the micro level.

Chapter 5 is organised into four sections, of which three are devoted to analysis and discussion and the last section to summarising the findings – in the form of a provisional answer to the research question.

Section 5.1 continues, in the first part, the discussion of economic loss as this concept is both central and a source of confusion in catastrophe literature. In the second part of 5.1, purely empirical studies (as opposed to theory-guided) on the macroeconomics of disasters are surveyed. The section also includes the author's own empirical excursion.

Section 5.2 reviews approaches inspired by macroeconomic theory, excluding growth theory. Mesoeconomic models will be examined as well as mainstream macroeconomics applied to the problem of disasters. The focus of section 5.2, however, will be a "Keynesian" multiplier model of catastrophes and an accompanying empirical study.

Section 5.3 discusses contributions that explicitly apply growth models to the study of disasters. This includes a review of qualitative neo-
classical arguments as well as simulations based on Harrod-Domar frameworks and Ramsey models. In addition, the largest empirical study on the economics of catastrophes known to the author will be evaluated.

Section 5.4 summarises the findings and concludes. As will be shown, the empirical work (sections 5.1 and 5.2) and the theoretical arguments from section 5.2 combine to a basis for a provisional answer to the research question.

5.1 Empirical approaches

The section on empirical approaches begins with the discussion of a central conceptual problem and continues with a survey of a first part of the empirical literature:

Firstly, the overview of concepts of economic loss, damage and costs is continued from section 4.3. Given the widespread reference to these concepts in the catastrophe literature and the equally widespread confusion a detailed discussion will be in order. Using the ECLAC framework as a guiding example, the main methodological and defining problems of measuring disaster impacts will be outlined – with the primary objective of facilitating the macroeconomic interpretation of statements on "economic losses".

Secondly, the results of studies which directly supply empirical answers to the research question are reviewed. This includes analyses of disaster effects such as on macroeconomic time series. The focus of this section is on "purely" empirical literature inspired by analogous and more general work on economic growth and development (e.g. Barro, 1991; section 1.1). Theory-guided approaches, including further empirical studies will be discussed in the subsequent two sections (5.2 and 5.3).
**Concepts of loss, damage and costs of disasters**

Measuring the economic effects of natural disasters is one of the main unifying problems in disaster literature. However, the objectives of such estimates depend upon their institutional backgrounds: they are different for humanitarian aid and development institutions (chapter 3), for insurers (section 4.3) and for economic researchers (this chapter). Hence the abundance of proposed methodologies for quantifying the losses, damages or costs of disasters. The following paragraphs introduce one of these methodologies (ECLAC, 2003) and illustrate the main difficulties of damage measurements. Implications for the macro-economic interpretation of loss estimated conclude the section.

**The ECLAC Methodology**

In its "Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters", ECLAC (2003) proposes an analytical framework and a practical methodology for estimating disaster impacts, differentiated by direct, indirect and secondary effects. A large proportion of the catastrophe literature refers to the ECLAC approach, either by applying it, sometimes in analogous forms (e.g. Benson and Clay, 2000; Caballeros Otero and Zapata Marti, 1995; UNDRO and DHA, 1994) or by criticising it and by proposing alternative methodologies. Table 5-1 provides an overview.

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158 "The elusive concept of damage and why damage estimates are so poor" is a one of the sections in Cochrane (2004), a paper titled "Economic loss: myth and measurement". These headlines may provide an illustration of the problems and confusions accompanying the concept of economic loss.

159 ECLAC is the UN Economic Commission for Latin America and the Caribbean. The current version of the Handbook is ECLAC (2003) with credit given to Jovel (1989) as one of the main primary sources for the methodology. In total, the ECLAC Handbook comprises several hundred pages and provides detailed instructions for estimations of damages to housing and infrastructure, the analysis of effects on the main economic sectors and on the environment. This includes technical issues from data collection in surveys to the use of geographical information systems (GIS).
Purpose and scope: The ECLAC (2003) methodology is designed for identifying the sectors and societal groups that are most affected by a disaster and for estimating reconstruction requirements. Taking into account local capacities, the need for support by multilateral institutions may be quantified in order "to obtain assistance before international assistance is diverted to other areas" (ibid.: Section 1). The ECLAC approach can therefore be considered, first and foremost, a practical tool for development and disaster experts, rather than a theory-based methodology for economic research.

According to the ECLAC framework, the economic impact of a natural disaster may be described by direct, indirect and secondary effects (see table 5-1). Direct effects are defined as losses or damages to stock variables, that is, to assets. Indirect effects are the consequence of direct effects and include the decrease in flows of goods and services. Also included are changes in operational costs, income and expenditures due to the disaster. Further indirect effects may result from forward and backward linkages in production chains, such as the disruption of supplies of energy and raw materials. The sum of direct and indirect effects gives the total loss. Implications of the disaster for macroeconomic variables are discussed in ECLAC under secondary effects. These include repercussions of the disaster on GDP, growth, public finances, external balances, employment, interest rates and other prices. As these variables provide a different and complementary view of the disaster’s impact, the effects on variables such as GDP are not added to the total loss estimate. Table 5-1 provides an overview of the ECLAC framework, a comparison with the insurance

160 As the title of the handbook states, the scope of the methodology is to "measure in monetary terms the impact of disasters on the society, economy and the environment of the affected country". The focus of the discussion in this thesis remains on the economic aspects.

definitions of economic loss and with the variables from the neo-
classical framework.

In practice, the ECLAC approach is, on the one hand, mesoeconomic: Direct and indirect losses are estimated separately for various types of infrastructure, economic sectors, socio-economic groups and regions. These estimates are then aggregated to a net national total, taking account of potential double-counting. On the other hand, as estimates are undertaken shortly after the event, the methodology is predictive: While direct losses may be visible immediately after a disaster, indirect losses over the recommended time-frame of 2 – 5 years have to rely on a baseline projection (without disaster) and on projections for the indirect effects, such as on the duration of production interruptions and market disruptions. The same applies to estimates of secondary (macroeconomic) effects.162

Table 5-1 illustrates the differences between two examples of loss definitions and the simplistic macroeconomic framework from chapter 2. Direct losses are conceptually similar in all of the three approaches. Indirect losses are defined as net effects in the ECLAC methodology while in the reinsurance literature they are an aggregate of "business interruption" that does not take into account positive effects. In the neoclassical model (basic version), indirect effects are equal to the output effects and are determined by the disaster’s effect on production factors and technology (or productivity).

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162 Appendix XVII of the Handbook (ibid.) refers to two macroeconomic models for "estimating the impact of disasters and forecasting their short- and medium-term consequences". The first model is, similar to the neoclassical model built around a Cobb-Douglas production function and based upon an IMF model (not described in detail). The second model is adapted from the Keynesian approach of Albala-Bertrand (1993b), which is discussed in detail below.

163 See discussion of aggregation problems and other issues of loss estimates in the next section.
Table 5-1: Economic loss concepts. Comparison of insurance definitions (Munich Re, 2001; see section 4.3) and the ECLAC methodology (simplified) with variables from the neoclassical framework (chapter 2, table 2-1).

<table>
<thead>
<tr>
<th>Direct, indirect, and total loss (ECLAC, 2003)</th>
<th>Insured and Economic Loss (Munich Re, 2001)</th>
<th>Neoclassical Framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct effects: Economic</td>
<td>Direct losses</td>
<td>ΔK_d</td>
</tr>
<tr>
<td>Damage to assets and stock of goods, raw materials etc.</td>
<td>The primary (re-) insurance definition of economic loss.</td>
<td>Shock to the capital stock</td>
</tr>
<tr>
<td>Direct effects: Humanitarian</td>
<td>Not included(^{164}). Effects on GDP in some instances estimated from the number of workers affected.</td>
<td>ΔL_d</td>
</tr>
<tr>
<td>Valuation considered impractical.</td>
<td></td>
<td>Shock to the labour force</td>
</tr>
<tr>
<td>Indirect effects</td>
<td>Indirect losses</td>
<td>ΔY_d = f(ΔK_d, ΔA_d, ΔL_d)</td>
</tr>
<tr>
<td>Goods and services not produced due to disaster plus increased expenditure. Time span: 2 – 5 years.</td>
<td>Aggregated &quot;business interruption&quot; (ΔY_d at the micro level).</td>
<td></td>
</tr>
<tr>
<td>Total loss</td>
<td>Economic loss</td>
<td>-</td>
</tr>
<tr>
<td>Direct effects + indirect effects</td>
<td>Direct losses + indirect losses</td>
<td></td>
</tr>
<tr>
<td>GDP, growth, external balances, public finances, gross investment, employment, inflation etc.</td>
<td>GDP, GNP, balance of payments, budget deficits</td>
<td></td>
</tr>
</tbody>
</table>

Total losses and secondary effects are roughly identical in the ECLAC and insurance definition; in the neoclassical framework all variables are determined by the production function and the disaster variables

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\(^{164}\) Note that the insurance literature on natural disasters (chapter 4) addresses, first and foremost, effects on property and businesses; issues of life and health insurance are rarely discussed.
(ΔK_d, ΔL_d, ΔA_d), however, there is no macroeconomic variable corresponding to "total losses".  

Case studies and conclusions derived from the ECLAC approach

Two numerical examples of the ECLAC methodology applied to individual events: For the El Niño cycle of 1982/83 ECLAC (2000) estimates direct losses of US$ 1.3 bn and indirect losses to US$ 2.6 bn. Total damage corresponded to 10% of GDP of the affected countries and 50% of government revenues, respectively. The earthquake of 1985 in Mexico caused direct damages of US$ 2.8 bn and US$ 0.5 bn of indirect damages, corresponding to 2.7% of GDP. Despite capital inflows in the form of insurance payments and other transfers, Mexico’s current account worsened by US$ 8.6 bn and the fiscal deficit increased by US$ 1.9 bn.

As a generalisation (see figure 5-1), ECLAC describes the macroeconomic processes triggered by a natural catastrophe in a small economy as follows. In the year of the disaster (t_d), GDP growth falls. External debt grows faster owing to an increase in import growth and a decrease in export growth. In the first year following the disaster (t_d+1), GDP growth is increased (potentially above its long-term trajectory) by spending for reconstruction. External debt growth falls below pre-disaster level and the other main variables return to their pre-disaster paths. In subsequent years, after a peak in t_d+1, GDP growth and import growth (due to reduced income) slow down below

165 Rose and Lim (2002) expand on this problem and suggest to study primarily flow variables.

166 The estimates include Bolivia, Ecuador and Peru.

167 ECLAC (2003: Section 5: 75); this summary appears to refer to the synthesis of ECLAC disaster assessments in ECLAC and IDB (2000).
their long-term trends\textsuperscript{168}. In large parts, relaxing some assumptions, this line of argument is consistent with the basic neoclassical framework. Figure 5-1 illustrates the GDP trajectories for the above conclusions.

\textbf{Figure 5-1: ECLAC hypothesis on the output effects of a disaster in a small open economy.} Optimistic scenario A with return to the long-term growth trajectory (---) and pessimistic scenario B with permanent effects. Apart from the growth "hike" due to increased reconstruction spending, a neoclassical economy behaves analogously to scenario A. GDP is assumed to be on the Y-axis. From ECLAC (2003: Section 5: 83).

\textsuperscript{168} Okuyama (2004) explains the long-term negative effect on growth by the reallocation of funds from planned investment (that would have increased future output) to reconstruction as a mere compensation for a sudden and unexpected disinvestment.
General problems of loss estimates, alternative approaches to ECLAC

The ECLAC methodology raises a number of questions that illustrate the general difficulties of loss estimates. These have inspired various alternative approaches. The main problems appear to be associated with the level of analysis and aggregation, with the distinction between stock and flow variables, with different cost concepts, and with macro-economic projections\(^{169}\).

Levels of analysis and aggregation: While insurers’ estimates of economic losses are based on damage at the microeconomic level, the ECLAC methodology suggests a mesoeconomic approach with damage assessments starting at the level of sectors and regions. Depending upon the purpose of estimates, various methods of aggregating these losses exist, which yield fundamentally different results for losses to flow variables. As Loubergé (1995) observes, disaster effects at the micro and meso level may disappear at higher levels of aggregation. Cochrane (2004), reversely, points out the risk of double-counting inherent to aggregation.

By summarising business interruption losses\(^{170}\) the insurance approach, in principle, produces the most conservative approximation (largest figure), as "positive" effects on the production side are not subtracted\(^{171}\). Evidently, repercussions on aggregate output or income


\(^{170}\) This may be generalised by including public sector interruption losses.

\(^{171}\) There is no a priori preference for one of the aggregation approaches presented here. By emphasising total negative effects, the insurance approach is analogous to gross output in national accounts. The ECLAC definition resembles an estimate of the effects on net output or GDP; see also Rose and Lim (2002) and the following paragraphs. For the usual assumptions in the neoclassical model, indirect effects according to ECLAC are, in principle, identical to output effects \(\Delta Y_d\).
however, must be estimates of net effects\textsuperscript{172}. A local shock to production may be compensated by spare capacity in non-affected firms or regions, by increased labour input or increased labour productivity – some sectors may experience increased demand due to the shock. The effect on aggregate output could be nil or positive.

Using a graphical apparatus and a loss accounting framework, Cochrane (1997, 2004) illustrates these above problems of definition and aggregation from a regional economics perspective: Losses to a region may be offset to a large degree by transfers\textsuperscript{173} from the nation as a whole. From a macroeconomic perspective, however, these transfers are part of the total loss due to the disaster. In contrast, production transferred from the affected to non-affected regions does not count as a macro loss, whereas it \textit{is} a loss from the regional perspective. Further losses at the national level (beyond the gross regional loss) could result from bottleneck effects and systemic effects, such as in the financial sector\textsuperscript{174}.

In summary, from a macroeconomic point of view, there do not appear to be aggregation problems specific to disaster losses. However, different estimation methodologies and different levels of analysis may lead to fundamentally different conclusions on the aggregate effects, on the welfare effects of disasters and on policy implications. If, for example, a regional disaster does not affect GDP and welfare on average, this does not allow for conclusions with regard to welfare effects, such as related to the redistribution of wealth and income (Loubergé, 1995; Van der Veen, 2004). To be useful for the macro-

\textsuperscript{172} According to the ECLAC (2003) handbook total loss estimates should aim "... at determining the net effect, giving due consideration of both negative and positive results ..." as "... some indirect effects of a disaster might generate benefits to society ...".

\textsuperscript{173} These may include insurance and aid resulting in a rebuilding stimulus as well as unemployment benefits.

\textsuperscript{174} For an analogous argument illustrating the differences between losses at national and global levels see the small open neoclassical economy in chapter 2.
economic study of disasters, loss estimates should therefore include methodological notes on the aggregation methodology used.

Stock losses and flow losses: Total losses or economic losses according to ECLAC and reinsurance practice are the sum of stock losses and flow losses. Any model with a production function of the form \( Y = f(K, ...) \) will illustrate the problem of double counting inherent to this definition. In theory, a disaster’s impact may equally well be quantified by stock measures and flow measures, \( \Delta K_d \) and \( \Delta Y_d \) in the neoclassical framework (Munich Re, 2001; Cochrane, 1997). Given that some stocks such as private residential capital\(^{175}\) may not be reflected in traditional monetary flow measures, practical arguments for summarising the two effects may include the better and immediate availability of stock loss data and the objective of including impacts on both wealth and income. Further methodological complications that may encourage the use of pragmatic loss definitions relate to the absence of deterministic relations between stock and flow effects of disasters at all levels of aggregation. On the one hand, stock losses may not affect the output of a firm significantly if "operating capacity" can be re-established for a small fraction of the replacement costs (ECLAC, 2003). On the other hand, forward and backward linkages as well as bottlenecks in supply chains may disrupt the production of firms that are physically unaffected by a disaster (Van der Veen, 2004; Cochrane, 1997). As a solution to these difficulties, Rose and Lim (2002) propose the exclusive reliance on flow measures rather than effects on stocks or a sum of both. They argue that relying on flow measures only solves the three problems of double counting, of accounting for indirect effects (see next paragraph), and of consistency with the usual welfare indices (income, profits) as well as with economic aggregates such as GDP.

\(^{175}\) And any other type of capital with returns that are not included in traditional measures such as GDP.
While these methodological difficulties entail significant practical problems for loss estimates, which start from a microeconomic level, a number of them disappear with aggregation or if disaster effects are analysed at a macro level. However, the minimum requirement for economic loss data to be useful for the macroeconomic study of disasters is the clear statement of whether they include stock or flow measures or both.

Direct and indirect effects: In catastrophe literature, economic effects of disasters are usually described in the terms of direct and indirect effects. For various arguments, however, the definitions of these concepts may fundamentally differ from one author to the other (Van der Veen, 2003). Moreover, additional descriptive dimensions are sometimes introduced, such as primary and secondary effects or first-round and second-round effects. In addition to the insurance definition (section 4.3) and the ECLAC framework of economic losses, the approaches of Cochrane as well as Rose and Lim are briefly introduced here.176

Cochrane (1997) defines direct loss as "all damages ... due directly to the closure of the damaged facility". In contrast to the ECLAC approach, this may include both stock and flow effects. Indirect losses are all losses other than direct losses, resulting, in particular, from forward and backward linkages or "real ripple effects" as well as banking and insurance systemic risk (insurance bankruptcies, credit and insurance rationing etc.; Cochrane, ibid.). In close analogy to this

176 For further and again different loss frameworks see Dacy and Kunreuther (1969), the examples of West and Lenze (1994) or the FEMA/NIBS earthquake loss methodology outlined in Whitman et al. (1997). Damages to infrastructure (capital stock) are differentiated there into direct damages (earthquake) and indirect damages (e.g. fire triggered by an earthquake). Direct economic losses include both stock and flow losses at the microeconomic level, which is in analogy to Cochrane (1997) and Rose and Lim (2002). Indirect losses are measured at the mesoeconomic (regional) level and refer to variables such as employment, government budgets, supply and demand of products and services etc., – what the ECLAC (2003) methodology defines as secondary effects.
approach, Rose and Lim (2002) consider the ECLAC of little help as both damage to property and business interruption have direct and indirect dimensions. As an alternative suggestion, they consider direct losses as the consequences of physical damage to an entity, while indirect losses include the effects resulting from forward and backward linkages\(^{177}\). For both loss categories, Rose finds flow measures superior to stock measures. However, such estimates require economic modelling, which gives rise to new problems (discussed below)\(^ {178}\).

As observed for the aggregation methodologies and for the stock and flow measurements, any meaningful macroeconomic interpretation or policy discussion of loss figures requires clear distinctions and explicit definitions of indirect and direct effects.

**Cost concepts:** In parts of the catastrophe literature, the "costs of disasters" appears as a synonym for loss, damage or impact\(^ {179}\). Respective definitions may refer to accounting costs (expenditures) or to economic concepts of costs, which include both expenditures and opportunity costs (van der Veen, 2004). Costs or welfare effects of disasters may be discussed at various levels of analysis and aggregation (see above) and they may comprise private costs or social costs and market or non-market costs (Cochrane, 2004). The

\(^{177}\) Alternative terminologies: downstream or supply-side linkages as opposed to upstream or demand-side effects (Rose and Lim, 2002; Van der Veen, 2004).

\(^{178}\) Note that, in the neoclassical framework, direct effects according to ECLAC are \(\Delta K_d\) and indirect effects approximately correspond to \(\Delta Y_d\). In Rose and Lim (2002), the direct losses may be translated into \(\Delta K_d\) and \(\Delta Y_d\), that is, capital and output shocks at the microeconomic level. Indirect effects according to Rose and Lim can not be captured by the neoclassical framework, as they describe exogenous effects on an economic actor. For these, no corresponding variables are available.

\(^{179}\) Examples include: Tucker (1997), climate change; Kramer (1995) and Mechler (2003), cost benefit analyses of disaster risk management and finance; Boswell et al. (1999), the public cost of hurricanes; McCarthy et al. (1995), the growth costs of malaria. Given the macroeconomic rather than welfare economic approach of this thesis, the notes on cost concepts remain superficial. For an early paper on the welfare effects of climate change see e.g. Kokoski and Smith (1987).
main additional requirements for explicit definitions, which result from the variety of concepts, may relate to the difference between accounting perspectives and the economic perspective as well as to the level of analysis\textsuperscript{180}.

\textit{Economic projections as a basis for indirect loss estimates:} ECLAC recommends undertaking the damage assessments after the emergency stage of the disaster, a short time after the actual event\textsuperscript{181}. Direct damages may be approximated by drawing on sources that include surveys and figures published by the private and the public sector. Estimates of indirect losses, however, will be based on simulations of the disaster’s economic effects as compared to a "without-disaster" projection that serves as a baseline. The recommended time frame is 2 years, with a maximum 5 years\textsuperscript{182}.

Estimates of indirect losses and macroeconomic effects that are based on simulations raise the same problems as any economic projection. Ex-ante estimates of indirect disaster effects entail the additional risk of replicating generic assumptions such as that "most losses will be indirect, owing to the impact on economic flows" (ECLAC, 2003; see also figure 5-1). Using ex-post data, on the other hand, gives rise to the problem that figures become only available

\textsuperscript{180} In the words of Cochrane (2004), "it is seldom clear whose losses are to be addressed."
\textsuperscript{181} According to ECLAC (2003), the catastrophe triggers an emergency stage (weeks to months), which is followed by rehabilitation stage and, finally, by a reconstruction stage.
\textsuperscript{182} The Handbook refers to a range of approaches for modelling indirect losses and macroeconomic effects of disasters, including mesoeconomic expert surveys and macroeconomic models developed by IMF and Albala-Bertrand (1993a; see below). Rose and Lim (2002) propose Input-Output models or Computable General Equilibrium models for these purposes (see section 5.2) and Cochrane (1997, 2004) outlines further methods of loss simulations all of which "should be viewed with a healthy dose of scepticism". As an example of macroeconomic projections, the Mechler-Freeman approach is presented in section 5.3. For ECLAC’s generic assumptions on macroeconomic effects from, see the previous paragraph.
several years after the event and that disaster effects cannot readily separated from other economic fluctuations.

Again, a prerequisite for loss estimates and projections being useful in discussions of macroeconomic and growth effects of disasters, is that definitions, methodologies and assumptions are clearly stated.

Conclusions from the review of economic loss concepts

To a certain extent, economic literature on natural disasters centres around concepts of loss, damage and cost. For this reason, the above discussion continues, from a macroeconomic perspective section 4.3 on insurance definitions of economic loss.

The conclusions of the above review relate, on the one hand, to the objectives of loss estimation methodologies, which overlap only to a minor degree with the research question. On the other hand, they relate to problems of methodology, definitions and interpretation.

Scope and objectives: Loss measures may provide a valuable quantitative starting point for economic discussions of catastrophic events. However, the literature based on loss concepts allows only for limited conclusions on the effects of disasters on macroeconomic aggregates. This may have several reasons: Firstly, the approach of most loss assessment methodologies is primarily practical, with the objective of producing an estimate of damages immediately following a catastrophe. While macroeconomic considerations may serve as inputs to such estimates, the focus generally remains on stock effects ($\Delta K_d$). References to macroeconomic repercussions, referred to as secondary effects in the ECLAC handbook, remain marginal. Furthermore, owing to the timing and purpose of disaster impact assessments, macroeconomic statements in loss estimates have the characteristics of medium-term predictions and assumptions rather than of empirical evidence. Secondly, the largest portion of the literature is based on concepts of economic loss studies of individual catastrophic events or
disaster scenarios in a particular (regional) economy. In this literature, only a few cross-country studies or theoretical analyses have been identified that would allow for generalising conclusions with regard to the research question. Exceptions including Cochrane (various years), Mechler (2003) and further scholars that take a macroeconomic approach are discussed later in this chapter.

**Problems of methodology and interpretation:** The comparison of various loss definitions has illustrated the challenges presented by measuring disaster impacts. In the literature, a variety of approaches are proposed for overcoming these difficulties. Designed for contrasting purposes from insurance business practice to humanitarian aid but using similar terminologies, the different methodologies entail considerable risks of misinterpretation. This risk is greatest for figures on flow effects and total losses, while stock losses raise fewer interpretation problems. To the research question, the discussion of loss estimation methodologies supplies additional questions rather than answers. These will be reconsidered in the following chapters from both empirical and theoretical perspectives.

**To summarise:** Considering the variety of definitions and methodologies, statements on economic losses of disasters should be interpreted with due caution – be it in terms of financial costs, in welfare terms or in terms of macroeconomic effects beyond $\Delta K_d$. The conclusion that there is only marginal overlap between the research

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183 The problem of case studies is briefly discussed in the following section; see also section 5.2 for notes on meso-economic models.

184 One of the objectives of this thesis is to provide a translation of the various loss concepts into standard macroeconomic variables and, at the risk of gross simplifications, into the neoclassical framework from chapter 2. While this in the interest of clarity and comparability of theoretical statements and empirical results, it may not provide the author with complete protection against the confusions discussed above.

185 This would also presents considerable problems in meta-analyses based on economic loss figures.
question and the answers provided by economic loss approaches may be surprising. In figure II-1, this finding could be explained by the primarily microeconomic orientation of loss concepts and by their loose relation to macroeconomic theory\textsuperscript{186}.

**The macroeconomic empirics of natural disasters**

In the introductory chapter the empirical growth literature was surveyed for evidence related to the research question (section 1.1). While in a large number of contributions the influence of environmental factors on economic development is studied\textsuperscript{187}, natural disasters were found to receive little attention in mainstream growth research.

This second part of section 5.1 reviews empirical studies of the macroeconomic effects of disasters. Explicit and implicit hypotheses with regard to output, growth and poverty are discussed. The focus is on cross-country analyses that allow for a higher degree of generalisation than case studies of individual events\textsuperscript{188}. A link between mainstream growth research and the empirical studies of macroeconomic disaster effects is presented in Cochrane (1999). With reference to Barro and

\textsuperscript{186} It should be noted, however, that the above comments do not imply a critique of loss estimation methodologies and the respective literature.

\textsuperscript{187} Examples from this research tradition include studies of the determinants of productivity (Hall and Jones, 1999) and growth (Barro, 1991; Barro 1997). Rodrik (1998) looks into the growth effects of exogenous shocks. Influences of environmental factors such as geography, climate, diseases are analysed in Easterly und Levine (2002), Sachs (2003) and Acemoglu et al. (2001).

\textsuperscript{188} Rossi et al. (1978) emphasise the "... chronic problems of case studies. First of all, they focus on events that are quite atypical, usually on the most serious end of the continuum of disaster magnitude." See also Ellson et al. (1984). For this reason, the focus of the thesis is on cross-country studies. Case studies are only referred to for illustration. For excellent in-depth country studies see in Benson and Clay (2004; see chapter 3) and the literature quoted there or the disaster assessments by ECLAC synthesised in Caballeros Otero and Zapata Marti (1995) or ECLAC and IDB (2000). On the meta-analysis of case studies, the concluding remarks in part III contain a number suggestions.
Lee (1993), he hypothesises that most of the factors positively associated with growth are negatively associated with disaster risk: Disasters reduce the investment rate and raise government consumption. They also increase the black market premium on foreign exchange as well as the frequency of revolutions.

In the following sections, a number of cross-country empirical studies is reviewed and complemented with an own empirical excursion. A summary of hypotheses related to the research question concludes section 5.1. The chapter will then continue with a synopsis of theory-guided approaches to the macroeconomics of disasters (sections 5.2 and 5.3).

Macroeconomic impacts as indicators for disaster vulnerability

In the interest of defining indicators for disaster vulnerability, Crowards (2000) compares various measures for the effects of historical natural disasters in the Caribbean\textsuperscript{189}. Most of the countries studied could be classified as small island developing states (SIDS) and are exposed to tropical storms (hurricanes). The geographically small size of these economies, their level of development and the high rates of poverty combine to a high vulnerability to natural hazards (Briguglio, 1995; Pelling and Uitto, 2001).

Empirical results: In macroeconomic time series around disaster events, Crowards finds the following patterns as averaged over all

\textsuperscript{189} Aiming primarily at understanding vulnerability, macroeconomic variables are only one set in an array of potential indicators evaluated by Crowards. They include the number of disaster events, effects on macroeconomic variables, volatility of agricultural production, damage costs, the number of fatalities and affected persons. For approaches to measuring vulnerability and disaster risk in general see also the Munich Re megacity risk index (Munich Re, 2004; section 4.3), the survey of disaster risk indexes (DRI) in Pelling (2004) and the geographically highly detailed approach in Dilley et al. (2005). On the UNDP (2006) website (http://gridca.grid.unep.ch/undp), an interactive disaster risk index for developing countries is available.
countries and all events studied\textsuperscript{190}. Compared to average growth (5.4\%) in the three pre-disaster years, GDP growth decreases in the year of the event (to 2.3\%), rises above its pre-disaster trend in the first year (5.7\%) and then falls below average again (3.8\%). Graphically, this corresponds to the hypothesis presented in ECLAC (2003 see figure 5-1). Growth in exports appears to be reduced in the disaster year only, whereas import growth remains higher for two years and then falls below the pre-disaster average. This results in a widening of the trade deficit, which decreases but persists over the 4 post-disaster years observed. Net foreign assets as a percentage of imports increase in the disaster year (possibly due to transfers of relief funds and insurance payments, according to Crowards) and then fluctuate around zero in the subsequent years. External debt growth rates show a peak in the disaster year\textsuperscript{191}. Statistically, the effects on GDP growth, Import growth and the trade balance are significant\textsuperscript{192}. Individual events, however, are observed to diverge widely from these average patterns.

Discussion and conclusion: For SIDS as a particular group of countries, it is concluded here from Crowards (2000) that natural disasters exert a significant effect on GDP growth\textsuperscript{193}. Except for a reconstruction

\textsuperscript{190} The variables analysed (using data from 21 disasters occurred between 1970 and 1997) are: GDP, consumer prices, exports, imports and balance of trade, net foreign assets, external debt, government capital and expenditure as well as tourist and cruise ship arrivals.

\textsuperscript{191} Croward does not find damage costs an informative indicator for vulnerability as “the initial damage caused by a natural disaster does not represent the full range of economic consequences”. Further drawbacks include the limited availability and quality of historical data as well as the underestimation of relative loses to poorer socio-economic groups.

\textsuperscript{192} Two-tailed t-test, 5\% level of significance; difference between average value of variable in the three pre-disaster years and the individual four years following and including the disaster year.

\textsuperscript{193} Note that the approach of comparing pre-disaster figures with post-disaster figures is considered problematic by some scholars (e.g. Ellson et al., 1984) as this ignores trends. A comparison of economic projections with observed data is recommended.
peak following the event, growth appears, on average, to remain below pre-disaster levels beyond the observed 3 post-disaster years. This pattern is explained in Okuyama (2004) with a reallocation of investments (that would increase output in the long term) to short-term reconstruction. Repercussions on the external balances may be interpreted as the result of adjustments for mitigating the economic impacts of the disaster rather than as an additional negative effect.

Natural disasters and the volatility of aggregate consumption

Auffret (2003a) studies the welfare effects of natural disasters by analysing their macroeconomic effects, in particular on consumption. As with Crowards (2000), he focuses on Caribbean SIDS. In some statistics however, he uses global data sets and produces comparisons with other regions. One objective of his paper is to confront economic data with the hypothesis that individuals smooth consumption if faced with shocks to income\textsuperscript{194}. His second objective is to identify the economic effects of disasters in time series of macroeconomic variables.

Empirical results: In a global comparison of consumption growth and consumption volatility, Auffret finds that while consumption growth rates in the Caribbean (2.45\%) are nearly as high as in the OECD countries (2.5\%), volatility is four times higher (8.6\% and 2.2\%, respectively). In welfare terms, this reduces the "certainty-equivalent of growth" in the Caribbean to 0.8\%\textsuperscript{195}.

\textsuperscript{194} See the theoretical outline in section 4.1.

\textsuperscript{195} This may serve as a quantitative illustration of the risk theory in section 4.1. Period studied: 1960 – 1997. Consumption volatility is measured by the standard deviation of consumption growth and given in \%. At 0.9\% Sub-saharan Africa has the lowest consumption growth rate and the second-highest volatility (8\%), after the Caribbean.
Globally, consumption volatility is higher than income volatility, which is in contradiction to the consumption smoothing hypothesis. On the other hand, more advanced financial markets are associated with higher degrees of consumption smoothing. Finally, more developed (richer) economies and larger economies suffer from lower consumption volatility than small and poor countries\textsuperscript{196}.

Conceptually, Auffret’s analysis of \textit{macroeconomic effects} is analogous to Charvériat (2000; see below) and ECLAC (2003; previous section). The economic mechanisms triggered by disasters are explained along a neoclassical line of argumentation (chapter 2). Cumulated economic losses according to the ECLAC definition are estimated at a country average of 112\% relative to GDP for the Caribbean, 61\% for Central America and 9.6\% for Latin America\textsuperscript{197}. Finally, using equations that include output, consumption, investment and a catastrophe variable, Auffret finds the following macroeconomic repercussions of disasters: In the year of the event, the growth rates of output, consumption and investment are significantly reduced. The most affected variable is investment growth. Private consumption appears to be more sensitive to disaster effects than public consumption. In addition, simulations are reported (without numerical evidence provided) to show a worsening of the current account due to disaster shocks\textsuperscript{198}.

\textsuperscript{196} Circa 100 countries included; The World Bank’s SIMA database is given as a source.

\textsuperscript{197} Includes 14 Caribbean countries and covers the time span from 1970 – 1999. The value of 112\% for the Caribbean includes the extreme case of Montserrat, where Hurricane Hugo in 1989 and volcanic activity in 1996-98 contributed to cumulated economic losses of 900\% (sic) of GDP. This extreme case excluded, the cumulated loss estimate for the Caribbean amounts to a country average of 47\% of GDP.

\textsuperscript{198} The results appear to be similar if a dummy catastrophe variable is used instead of economic losses as % of GDP. Note that the analyses of macro effects is based on a
Conclusions: On the macroeconomic effects of disasters in small developing countries\textsuperscript{199} with a high exposure to natural hazards, Auffret comes to similar conclusions as Crowards (2000; above). That is that the negative effects on output growth are significant. From the global analysis of consumption volatility patterns, two hypotheses may be derived. Firstly, that the effect of disasters on consumption becomes less substantial with development (Albala-Bertrand, 1993a; see section 5.2)\textsuperscript{200}. Qualitatively, this conclusion does not support the three-stage theory of development and vulnerability (Benson and Clay, 2004; Clay and Benson 2005; see chapter 3). Secondly, if volatility of consumption decreases with country size, analogous correlations may be postulated for the macroeconomic effects of disasters\textsuperscript{201}.

Disaster risk in Latin America and the Caribbean

Of the contributions on the macroeconomics of natural disasters in Latin America, Charvériat (2000) gives the most detailed account including a large number of case studies. Starting from summary statistics for the region she draws conclusions analogous to the stylised facts in chapter 1. The conceptual approach follows ECLAC different group of countries (6 Caribbean, 10 Latin American): Barbados, Bolivia, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Peru, Trinidad and Tobago. Period covered: 1963 – 1997.

\textsuperscript{199} This includes the Caribbean SIDS plus Middle American countries, most of which are small and exposed to similar hazards.

\textsuperscript{200} "Richer is simply safer" according to Wildavsky, quoted in Horwich (2000) where a microeconomic explanation is provided of why vulnerability decreases with wealth.

\textsuperscript{201} In neoclassical variables (see chapter 2): A disaster of similar magnitude M will, identical vulnerability assumed, lead to the same shock $\Delta K_d$ to the capital stock in absolute terms. Trivially, both the relative shock ($\Delta K_d/K$) and the output shock ($\Delta Y_d$) decrease with the size of the economy. Further, consumption shocks ($\Delta C_d = (1-s) \Delta Y_d$) and therefore consumption volatility would become smaller with development – if development is associated with higher capital stocks, which implies lower marginal productivities of capital.
(2003) and a detailed qualitative description is given of how natural catastrophes affect welfare and economic aggregates. For an overview and brief description of disasters, for which ECLAC reports are available, see ECLAC and IDB (2000).

*Empirical results:* The typical effects of disasters on GDP are studied semi-quantitatively by calculating the median values of GDP growth in the disaster-year, one pre-disaster year and two post-disaster years. For the 35 events in various countries, median growth falls from 2.5% to 0.74% in the disaster year. In the two post-disaster years, increased growth rates of 3.5% are observed. Charvériat emphasises the wide variation of individual trajectories around the median growth path. As the magnitude of growth effects does not seem to be associated with the loss-to-GDP ratio, differences in vulnerability and other influences on the growth rate than the disaster shock are suggested as explanations. The hypothesis that disasters are related to poverty (with causalities in both directions) is supported with a synopsis of empirical evidence, including studies of El Niño in Ecuador, floods and droughts in Chile and Hurricane Mitch in Honduras (ibid.: 27).

*Conclusions:* According to Charvériat, the "median natural disaster" in Latin America and the Caribbean is characterised by a short term negative effect on GDP growth (as compared to pre-disaster figures) and higher growth rates in the two post disaster years. Typically, macroeconomic repercussions are detectable for up to three years. Moreover, catastrophes seem to be accompanied by an increase in poverty rates and vice versa. Poor regions and socio-economic groups appear to be exposed to higher disaster risk.

The medium-term growth increase is in contrast to Crowards (2000), who found persistent negative effects on growth after a "reconstruction peak" in the second post-disaster year. This may be due to the

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202 Period covered: 1970 – 1999. The approach is analogous to Albala-Bertrand (1993a); see section 5.2.
different characteristics of the country samples. While Crowards focuses on Caribbean SIDS, Charvérait’s study covers also includes the larger countries of Latin America. Following Albala-Bertrand (2006), it might be hypothesised that shocks in large countries tend to be more localised geographically than in small countries, implying faster return of macroeconomic aggregates to pre-disaster patterns. Furthermore, Charvérait finds herself in contradiction to Albala-Bertrand (1993a), who found in many cases neutral or positive effects on GDP growth already in the disaster year. She explains this finding by the different trigger events in the two studies, with Albala-Bertrand’s sample including 50% earthquakes and Charvérait’s 75% hydro-meteorological events. As opposed to storms and floods, earthquakes tend to be more localised, trigger an instant reconstruction peak in growth trajectories and as a result appear macroeconomically less disruptive (Charvérait, 2000; Albala-Bertrand, 1993a).

*Empirical excursion: disasters and economic growth*

As the studies discussed in the above sections have a regional focus and an analogous global study by Albala-Bertrand (1993a; see section 5.2) covers the period of 1960 to 1980, a complementary analysis of data was carried out in this thesis. The objective of the explorative empirical study in this section is to apply the methodologies proposed by the three aforementioned authors to a longer time series and a global sample. Below, the data and the analytical approach are outlined and the results discussed; details are supplied in the appendix.
Data and approach

The analysis aims, first and foremost, at quantitatively illustrating the characteristic medium-term effects of catastrophes on GDP growth. With this in mind, a sample of "large" natural disasters from 1950 to 2005 was compiled from a selection of different sources of large natural disasters (albeit by different criteria). Included were the events studied in Albala-Bertrand (1993a), the list of "major natural disasters in the 20th century" from Munich Re (1999), the "most expensive disasters relative to GDP" between 1974 and 2003 according to CRED (Guha-Sapir et al., 2004) as well as an overview by UN-ISDR (2006) of the "top 50" disasters in terms of economic damages as a ratio to GDP. After eliminating duplicates and accounting for the availability of economic data the sample consisted of 110 disasters that occurred between 1953 and 2005, most of which (101) in developing countries. The total number includes 36 geophysical events, 58 sudden-onset hydro-meteorological events, 4 wild fires as well as 12 droughts and heat waves.

Effects of disasters on real GDP growth were studied by comparing pre-disaster growth with post-disaster rates. Medium-term time series of 7 years, including the year of the disaster (t₀ or t₁) were compiled for

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203 As the effects of disasters on GDP of the affected countries are to be studied, the objective was to identify a sample of events with high loss-to-GDP ratios, rather than the largest disasters in absolute terms. Note that, as Guha-Sapir et al. (2004) find, the largest disasters in absolute monetary terms occur in the USA and Japan while the events with the largest numbers of casualties include primarily droughts in Africa as well as earthquakes and tropical storms in Asia.

204 Events were included if data for GDP growth (constant prices) were available for, as a minimum, two pre-disaster and two post-disaster years. Sources for economic data: IMF Economic Outlook Database (IMF, 2006) which may include projections, Albala-Bertrand (1993a), and, in very few cases, the Penn World Tables, version 6.1 (Heston et al., 2002). For years before 1960, the availability of economic data becomes thin, in particular for developing countries.

205 Geophysical events: 34 earthquakes and 2 volcanic eruptions. Hydro-meteorological events: 39 windstorms, 19 floods and landslides; the full list is given in the appendix.
this purpose. In the interest of comparability, the analytical approach remains largely analogous to Albala-Bertrand (1993a: 56ff), Charvériat (2000) and Crowards (2000).

Results

Table 5-2 and 5-3 provide an overview of the results. As illustrated by figure 5-2, the characteristic GDP growth trajectory around a catastrophe year may be described as follows. In the year of the event ($t_0$) growth rates fall below pre-disaster averages to rise above average levels in the subsequent years ($t_1$ and later). However, on the one hand, as shown in figure 5-2, the variance of individual growth paths around the mean trajectory is large. On the other hand, the number of countries experiencing negative growth rates is only slightly higher in disaster years than in pre-disaster years (table 5-4).

Qualitatively, the different results for the sub-samples A to E suggest that disasters have larger short-term effect in developing countries than in industrialised countries (values for $t_0$ in samples A and B). Primarily droughts (see sample C) and hydro-meteorological events (sample E) appear to influence growth negatively in $t_0$ while earthquakes, as compared to other events, seem to lead to an increase in GDP growth already in $t_0$ and a further and more pronounced rise in $t_1$. It should be noted, however, that none of the differences between post-disaster growth rates and pre-disaster averages are statistically significant at confidence levels of 90% or higher206.

206 Two-sided t-test for paired samples; the P values of the t-statistics are supplied in the appendix.
Figure 5-2: Characteristic effect of large natural disasters on GDP growth paths. Median of GDP growth for 101 events in developing countries over 7 years from \( t_{-3} \) over the disaster year \( t_0 \) to \( t_3 \) (sample B in table 5-2). Upper and lower quartiles are indicated with error bars; maximum and minimum values with + (the maximum value of 44.1% for \( t_2 \) is not depicted).

Table 5-2 (following page): Effects of large natural disasters on GDP growth. Average and median values over all events in the sample indicate the characteristic patterns of growth rates in the years following a disaster (\( t_0, t_1 - t_3 \)). Figure 5-2 illustrates the average growth trajectory and the large variance around the mean. None of the average differences between growth in post-disaster years and the average growth rate in pre-disaster years (\( t_{-3} \) to \( t_{-1} \)) is statistically significant at any level of significance of > 90%. Note that, for reasons of data availability, averages for \( t_3 \) are based on fewer data points and may therefore only qualitatively be compared to pre-disaster averages. Details of the samples and the statistics are supplied in the appendix.
<table>
<thead>
<tr>
<th>Sample Variable</th>
<th>$t_3$</th>
<th>$t_2$</th>
<th>$t_1$</th>
<th>$t_0$</th>
<th>$t_1$</th>
<th>$t_2$</th>
<th>$t_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. All events, all countries (n=110)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>2.70</td>
<td>3.86</td>
<td>3.74</td>
<td>3.52</td>
<td>4.27</td>
<td>4.20</td>
<td>3.83</td>
</tr>
<tr>
<td>Median</td>
<td>3.55</td>
<td>4.00</td>
<td>3.90</td>
<td>3.60</td>
<td>4.70</td>
<td>4.10</td>
<td>4.15</td>
</tr>
<tr>
<td>Average Difference</td>
<td>Pre-event average: 3.64</td>
<td>-0.12</td>
<td>0.64</td>
<td>0.57</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B. Developing countries (n=101)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>2.58</td>
<td>3.89</td>
<td>3.84</td>
<td>3.43</td>
<td>4.32</td>
<td>4.31</td>
<td>3.97</td>
</tr>
<tr>
<td>Median</td>
<td>3.55</td>
<td>4.15</td>
<td>4.00</td>
<td>3.50</td>
<td>4.75</td>
<td>4.30</td>
<td>4.30</td>
</tr>
<tr>
<td>Average Difference</td>
<td>Pre-event average: 3.66</td>
<td>-0.23</td>
<td>0.66</td>
<td>0.65</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C. Developing countries; excluding droughts (n=90)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>2.38</td>
<td>3.72</td>
<td>3.89</td>
<td>3.53</td>
<td>4.27</td>
<td>4.51</td>
<td>3.92</td>
</tr>
<tr>
<td>Median</td>
<td>3.45</td>
<td>4.00</td>
<td>4.00</td>
<td>3.60</td>
<td>4.73</td>
<td>4.30</td>
<td>4.20</td>
</tr>
<tr>
<td>Average Difference</td>
<td>Pre-event average: 3.56</td>
<td>-0.03</td>
<td>0.71</td>
<td>0.95</td>
<td>0.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>D. Developing countries; earthquakes and volcano eruptions (n=32)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.64</td>
<td>3.58</td>
<td>5.07</td>
<td>4.46</td>
<td>6.01</td>
<td>4.49</td>
<td>3.97</td>
</tr>
<tr>
<td>Median</td>
<td>2.95</td>
<td>4.30</td>
<td>4.60</td>
<td>4.60</td>
<td>5.90</td>
<td>5.05</td>
<td>4.45</td>
</tr>
<tr>
<td>Average Difference</td>
<td>Pre-event average: 3.89</td>
<td>0.57</td>
<td>2.12</td>
<td>0.60</td>
<td>0.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>E. Developing countries; storms, floods and other events (n=58)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>2.74</td>
<td>3.80</td>
<td>3.24</td>
<td>3.01</td>
<td>3.31</td>
<td>4.52</td>
<td>3.89</td>
</tr>
<tr>
<td>Median</td>
<td>3.65</td>
<td>4.00</td>
<td>3.70</td>
<td>2.75</td>
<td>4.05</td>
<td>4.10</td>
<td>4.20</td>
</tr>
<tr>
<td>Average Difference</td>
<td>Pre-event average: 3.40</td>
<td>-0.38</td>
<td>-0.09</td>
<td>1.12</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5-3: Effects of large natural disasters on GDP growth. Signs of real GDP growth rates in the disaster year $t_0$ as compared to the pre-disaster year $t_{-1}$. Absolute numbers of positive and negative growth figures in each sample; analogous to Albala-Bertrand’s "simple effect criterion" (1993a); see table 5-4. The composition of the samples A to E is described in table 5-2 with further details provided in the appendix.

<table>
<thead>
<tr>
<th>Sign of GDP growth rate</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$t_{-1}$</td>
<td>$t_0$</td>
<td>$t_{-1}$</td>
<td>$t_0$</td>
<td>$t_{-1}$</td>
</tr>
<tr>
<td>Positive (≥ 0)</td>
<td>96</td>
<td>92</td>
<td>88</td>
<td>84</td>
<td>80</td>
</tr>
<tr>
<td>Negative (&lt; 0)</td>
<td>14</td>
<td>18</td>
<td>13</td>
<td>17</td>
<td>10</td>
</tr>
</tbody>
</table>

Conclusions from the empirical excursion

The explorative statistics carried out for this thesis show that large natural disasters in developing countries appear, as a general rule, not to have statistically significant repercussions on the growth rate of real GDP. In individual cases, falling (or negative) growth rates are observed in the year following a catastrophe – and in subsequent years GDP growth may surpass pre-disaster levels. Pronounced effects, however, in both directions, seem to be exceptions. While there is potential for refinements with regard to the compilation of the sample and the analytical approach, the empirical excursion puts into perspective the, in some cases drastic, generalisations in the literature on the negative effects of natural disasters on aggregate growth and output\textsuperscript{207}. Refinements may involve control variables such as for regions, country size, levels of development as well as the analysis of further variables such as consumption, investment and external balances.

\textsuperscript{207} For examples of such statements see chapter 1 and chapter 3 or, for a critical discussion, Albala-Bertrand (1993a, 2006).
Conclusions from the empirical literature

As a summary of conclusions from section 5.1, the findings of empirical studies are compared and hypotheses are derived in the form of provisional answers to the research question\textsuperscript{208}. For the most part, the reviewed examples of empirical studies appear to focus on growth and further macroeconomic aggregates, while distributional issues as well as differences between industrialised and developing countries receive less attention.

The analytical approach taken in Crowards (2000), Auffret (2003a), Charvériat (2000), Albala-Bertrand (1993a)\textsuperscript{209} as well as in the empirical excursion is analogous for all authors: real GDP growth rates in disaster and post-disaster years are compared with pre-disaster growth rates. It is hypothesised, in the following that different findings of the five studies can be primarily attributed to differences in the samples studied.

For small economies that are exposed to large disasters, such as SIDS in the Caribbean, the effects of catastrophes on GDP growth rates are significant. Crowards (2000) finds a characteristic trajectory analogous to ECLAC (see figure 5-1), with growth falling in the disaster year, briefly increasing in the second year and remaining below pre-disaster levels afterwards. It appears that the disaster shock on output ($\Delta Y_d$) is in part smoothed via changes in external balances. On the one hand an explanation for the significant effect may be the large $\Delta K_d/K$ ratios. On the other hand, a large catastrophe affecting a SIDS may be considered both economically and geographically widespread rather than localised (Albala-Bertrand, 2006; section 5.2).

\textsuperscript{208} For the conclusions drawn from the discussion of "economic loss" concepts and the related literature, see the first part of this section.

\textsuperscript{209} This anticipates the detailed discussion of Albala-Bertrand’s findings in section 5.2. His main findings are summarised in table 5-4.
Expanding the sample to include countries from both Latin America and the Caribbean (Charvériot, 2000; Auffret, 2003a) shows less pronounced, but still significant effects of disasters. However, in contrast to Croward’s SIDS sample, growth rates remain above pre-disaster averages after the disaster year.

Finally, in a global sample of large natural disasters that occurred over 50 years (empirical excursion), the characteristic GDP growth trajectories remain qualitative as described by Charvériot. Quantitatively however, the effects are small and statistically not significant. This contrast to the Latin American and Caribbean samples may to some extent be explained by the inclusion of events that occurred in larger economies, decreasing average $\Delta Kd/K$ ratios and implying a larger percentage of localised than widespread disasters$^{210}$. On the other hand, the samples differ in their distribution of trigger events. Charvériot’s Latin American data set contains predominantly storms and floods, which appear to be macroeconomically more disruptive than the rather localised earthquakes. In a sample consisting of 50% earthquakes Albala-Bertrand (1993a) observes no effects or even increases of GDP growth already in the disaster year. The results of the empirical excursion therefore support both Albala-Bertrand’s and Charvériot’s conclusions.

On development in the long term, on distributional effects and on differences between industrialised and developing countries the review of empirical literature was less fruitful. From the survey of papers on poverty and disasters in Charvériot however, empirical evidence seems to suggest that, on the one hand, the poor are exposed to higher disaster risk and on the other hand, catastrophes are associated with increases in poverty rates.

$^{210}$ As Auffret (2003a) finds, in empirical support of Albala-Bertrand’s (2006) localisation theory, the volatility of consumption with regard to income shocks decreases with both development levels (per capital income) and country size.
To summarise the provisional answer of section 5.1 to the research question: by studying different samples, the five quantitative analyses lead to complementary rather than contradictory findings. As a generalisation, historical natural disasters do not appear to exert dominant influences on GDP growth. Although characteristic GDP trajectories reveal small decreases of growth in the disaster year and a rise above pre-disaster levels after the event, these effects seem to remain within the range of normal macroeconomic fluctuations. Exceptions to this general rule are large disasters occurring in small developing economies – with hydro-meteorological events proving more disruptive than geophysical ones. Note that these findings on GDP as an indicator of aggregate economic performance do not allow for direct conclusions on disasters’ effects on welfare, distribution or poverty (see part III).

5.2 Theory-guided approaches: macroeconomics

This section discusses the first category of theory-guided approaches: macroeconomic concepts applied to the study of natural disasters. A separate section (5.3) will be devoted to growth theory perspectives.

The review begins with a (rare) example of an economist analysing the medium-term effects of an earthquake using conventional macroeconomic concepts. This illustrates the contrast between mainstream economic thinking and the economic arguments developed in the catastrophe literature. After a brief discussion of meso-economic models the section then centres around the Keynesian model proposed by Albala-Bertrand (1993a) as well as his empirical study of historical disasters. The "political economy of large natural disasters"  

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211 By controlling for other influences on growth and using sophisticated econometric methodologies, more subtle effects on macroeconomic aggregates may be discerned. This is attempted in Murlidharan and Shah (2003).
represents not only a landmark in catastrophe literature for its analytical depth and rigour – it is also Albala-Bertrand’s critique of mainstream disaster research and the polemic debates sparked by his conclusions that are valuable source of insights for this thesis. The fourth section draws conclusions with regard to the research question.

**The Kobe earthquake of 1995: an economist’s view**

Dispersed throughout this thesis, a number of analyses of the Kobe earthquake or Great Hanshin earthquake are referred to (see chapter 4)\(^{212}\). The following paragraphs outline Horwich’s (2000) view of the macroeconomic consequences of this event. Both his theoretical argumentation and the (anecdotic) evidence allow for interesting conclusions on the economic mechanisms triggered by disasters. Horwich’s mainstream macroeconomic perspective contrasts with most of the catastrophe literature (e.g. Okuyama, 2004 or Munich Re, 1999)\(^{213}\).

Looking back at the earthquake from the second year after the event Horwich finds that "Although the Kobe earthquake was an urban natural disaster of unprecedented economic magnitude, recovery proceeded with generally unexpected speed". His explanations include substitutions of production factors in the short term, the elasticity of supply due to excess production capacity, the importance of human capital as compared to physical capital, as well as permanent structural effects: “a restored economy will not be a replica of the pre-disaster one”.

\(^{212}\) To date, hurricane Katrina (USA, 2005) with estimated damages of US$ 125 bn and the Kobe earthquake of 1995 (US$ 122 bn) lead the list of most destructive disasters in financial measures (UN-ISDR, 2006).

\(^{213}\) On his approach, Horwich notes: "Though hardly novel, this perspective is seldom applied systematically to natural disasters." and, interestingly, in the 1987 edition of the New Palgrave, a four-volume economics encyclopaedia, Hirshleifer (2006) does not find the keywords „disaster“ or „recovery“ in the index.
In combination, these short-term mechanisms will result in changes of the composition of output and in the use of production factors rather than in a decrease of economic activity. In addition to supply side shifts, the aftermath of a disaster may be accompanied by increased demand resulting from emergency and cleanup activities as well as from the replacement of destroyed capital. In the case of the Kobe earthquake, the observed effects on GDP – no evident effects – are in congruence with these explanations. Real growth in 1995 (1.4%) was slightly higher than in 1994 (0.6%) and quarterly growth for 1995 increases from the first quarter (0.2%) to the fourth quarter (2.3)\textsuperscript{214}. For the regional economy of Kobe, it is found that manufacturing output had reached pre-disaster levels 15 months after the earthquake.

One of the principle arguments in Horwich’s analysis relates to the importance of production factors other than physical capital: While the Kobe earthquake destroyed 0.8% of Japan’s physical capital stock, the total loss ratio amounts only to 0.08% if human capital is included and put into relation to the total value of resources. Although the importance of human capital is emphasised throughout the literature on economic growth, this receives little attention in disaster research. Losses of lives are seen as a humanitarian rather than an economic problem and considerations on the economic value of human life are normally avoided in catastrophe literature\textsuperscript{215}.

Concluding from Horwich, the probability of macroeconomic disasters being triggered by natural hazards\textsuperscript{216} appears to be low, due to a

\textsuperscript{214} Figures as in Horwich (2006); data from IMF (2006) and OECD (2006) lead to the same qualitative conclusions.

\textsuperscript{215} Often for arguments of practicability or "ethics", for example, that an economic valuation may result in lower monetary values of lives in developing countries than in industrialised countries. See, for example, Mechler (2003) or ECLAC (2003: Vol. I). See also part III.

\textsuperscript{216} As further anecdotic evidence the rapid recoveries of cities destroyed in wars is presented (Hiroshima, Aachen). For a discussion of analogies, and the limits of such analogies between wars and natural disasters, see Albala-Bertrand (2000).
variety of market mechanisms that compensate for most of the negative effects. This hypothesis, stated primarily for industrialised countries, stands in contrast to the views of Okuyama (2004) for example, where disasters in general and the Kobe earthquake in particular are assumed to „have significant and intense impacts on a region’s economy. In addition, the impacts from the damages will sustain over time, and will spread serious economic effects to other regions” (see the subsequent section on regional economics).

Although common in economics, Horwich’s inclusive treatment of production factors appears to indicate a set of problems, where the mainstream catastrophe literature only marginally draws upon macro-economic principles. Nevertheless, taking into account disaster effects on all production factors and considering their stocks, scarcities, productivities and elasticities of substitution may allow for new insights into the macroeconomic repercussions of disasters – including the differences between the developing and the industrialising world as well as long-term consequences.

As a hypothesis to the research question, Horwich’s theoretical arguments are considered plausible and the results of the empirical review (section 5.1) can be interpreted in support of his conclusions. Furthermore, his arguments are congruent with the empirical findings of mainstream research on economic growth\textsuperscript{217} and with both neoclassical and Keynesian theoretical approaches (see chapter 2 and the remainder of this chapter).

\textsuperscript{217} See literature quoted in section 1.1.
Regional economics: I-O models and CGE models

Geography, regional science, and regional economics rank among the academic disciplines that contribute the largest share of publications to the economic catastrophe literature\(^\text{218}\). Methodologically, these approaches are primarily inspired by Input-Output (I-O) models or Computable General Equilibrium (GCE) models\(^\text{219}\). This section introduces a selection of contributions from regional economics, with a focus on I-O approaches to the study of disasters. The review remains concise, as the conclusion will be that the research question only marginally overlaps with the regional economics tradition of catastrophe literature.

I-O tables are structural meso-economic models. In the form of matrices, they describe how production in one sector or region is used as input for other sectors or regions (Rose, 2004)\(^\text{220}\). Emphasising the interdependencies between economic entities, I-O models can be used to predict the effects of local shocks on all other sectors or regions of the economy. The results may help identifying the regions, sectors and social groups that are most affected by shocks, thereby allowing for insights into the distributional aspects of disaster risk.

Practical applications include Whitman et al. (1997) where a loss estimation methodology (computer software) for earthquakes in the USA is described that includes an economic module based on I-O frameworks. Furthermore, I-O models have been applied to case studies of individual disaster scenarios and, in addition, to the analysis of shocks to individual sectors and to key infrastructure. Examples for regional case studies include Burrus et al. (2002) and West and Lenze

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\(^{218}\) The selection of articles compiled in the two-volume "The Economics of Natural Hazards" (Kunreuther and Rose, 2004) may illustrate this conclusion.

\(^{219}\) For a more inclusive overview see Cochrane (2004).

\(^{220}\) The input-output approach is originally attributed to Wassily Leontief.
(1994) who model the effects of hurricanes in the USA or the analysis of the Kobe earthquake in Okuyama (2004). Rose et al. (1997) use an inter-industry model for estimating the effect of lifeline-disruptions due to an earthquake in the New Madrid Seismic zone (USA) while Thissen (2004) takes an analogous perspective on the costs of terrorism risk to transport systems. Finally, Kokoski and Smith (1987) study the distributional effects of climate change and climate policies in a GCE framework.

In contrast to Albala-Bertrand’s (2006) localisation hypothesis and to Horwich’s (2000) arguments, it is often concluded from I-O simulations that disaster impacts spread economically beyond the affected entity, leading to large indirect losses (Okuyama, 2004; West and Lenze, 1994) – mechanisms sometimes referred to as ripple effects or knock-on effects. Ellson et al. (1984) or Thissen (2004) note that such generalisations may be exaggerations that can be explained by the static characteristics of I-O models, such as fixed coefficients. Observed effects of disasters rarely appear to be „outside the historical variability of the regional economy in response to more traditional shocks and cyclical fluctuations” (Ellson et al., 1984).

To conclude: Regional economics perspectives on catastrophes have provided, among other insights, a wealth of detailed case studies of disaster scenarios, both historical and hypothetical. Methodologically, these approaches may be considered the meso-economic complement to loss estimation techniques.

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221 For historical accounts of the importance of "lifelines" see Swiss Re (2005) and Winchester (2005) who illustrate how the disruption of water supplies has left the fires after the earthquake of 1906 in San Francisco uncontrollable. Harris (2003) provides a semi-fictional pre-industrial example of the consequences that earthquake damages to a Roman aqueduct may have had for the affected cities.

222 For an explanation of why economic losses due to disasters are not equal to macroeconomic effects see the "Conclusions from the review of economic loss concepts" on page 132.
The overlap of the regional economic literature with the research question is considered small primarily due to the following reasons. Firstly, the level of aggregation and analysis is different in regional economics than in growth and development economics, which define the perspective of the thesis. Meso-economic models are normally not a priori designed for addressing macroeconomic, long-term effects of shocks (static structure and demand side approach in I-O models, long-term equilibrium-shift perspective of GCE models; Cochrane, 2004). Secondly, most regional analyses of case studies are produced for industrialised countries, first and foremost for the USA (Kunreuther and Rose, 2004). As meso-economic models are for specific regions or countries, generalisations are difficult and beyond the objectives of these studies – even more so for structurally different economies, such as in the developing world. Finally, while I-O models and related approaches may incorporate historic structural data, most conclusions on disaster effects are projective. As backtesting of these simulation results is not common (or impossible, due to lack of data), they are not considered as empirical evidence.

For the fundamental differences in scope, focus and methodologies, the regional economics literature on disasters will therefore, in analogy to single event case studies in general, only occasionally be referred to in this thesis.

**Natural disasters in a Keynesian framework**

The Keynesian perspective on natural disasters is primarily due to Albala-Bertrand (1993a, 1993b, 2006). A separate and detailed section is devoted to this approach, firstly, because the 1993 book in particular represents one of the landmark contributions to the

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223 Go’s (2004) GCE analysis of external shocks in the Philippines may represent an exception.
economic disaster literature. This is complemented in the 2006 papers by a discussion of geographic and economic localisation of disaster effects as well as the implications of globalisation. Albala-Bertrand’s critique of the "received view" on the macroeconomics of natural disasters, his contrasting conclusions and the fundamental opposition from other disaster scholars marks one of the most interesting debates in the disaster literature – the second reason for discussing his position in some detail.

The following paragraphs will provide a summary of the empirical evidence presented in Albala-Bertrand (1993a) and outline the Keynesian framework as well as his theoretical explanations of the empirical results. Finally, conclusions and the debate in the catastrophe literature are synthesised.

**Empirical Findings**

The statistics in Albala-Bertrand (1993a) include around 30 large disasters that occurred between 1960 and 1979 in 26 countries, namely floods, hurricanes, earthquakes, volcanoes, and droughts. In a semi-quantitative analysis the signs of disaster effects on macroeconomic aggregates and the respective directions of changes are

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224 To provide an example of Albala-Bertrand’s challenges of the received view: "... most disaster ‘experts’ and other observers, like relief operators and journalists, normally get away with uncheckable and unfalsifiable statements about their [macroeconomic] importance, which then feed back and are repeated by everybody as a buzzword." (Albala-Bertrand, 2006).

225 The usual caveat with regard to the narrow focus defined by the research question: The discussion in the following paragraphs will focus on theoretical arguments, empirical results and further statements on the effects of disasters on GDP, growth and poverty. Albala-Bertrand’s analytical framework takes account of further political, sociological and institutional mechanisms which are beyond the scope of this thesis.
studied. The results for GDP growth are summarised in table 5-4 and were taken into account in the empirical excursion in section 5.1.

Table 5-4: Effects of natural disasters on GDP and growth. "Simple effect" describes the short term effect of disasters in year $t_0$. "Positive" and "negative" indicate the signs of GDP growth rates for the 28 disasters in the sample. Directions of changes of GDP growth are described as "up", "down", and "neutral". Under "longer effect", averages of pre-disaster growth rates are compared with post-disaster growth rates. From Albala-Bertrand (1993a: 64ff).

<table>
<thead>
<tr>
<th>Simple Effect</th>
<th>Longer Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>t$_2$/t$_1$</td>
<td>t$_1$/t$_0$</td>
</tr>
<tr>
<td>Positive</td>
<td>28</td>
</tr>
<tr>
<td>Negative</td>
<td>0</td>
</tr>
<tr>
<td>Up</td>
<td>6</td>
</tr>
<tr>
<td>Down</td>
<td>19</td>
</tr>
<tr>
<td>Neutral</td>
<td>3</td>
</tr>
</tbody>
</table>

For GDP and growth, Albala-Bertrand concludes that, as a general rule, natural disasters do not affect economic performance negatively. The results in table 5-4 suggest that GDP does not fall in catastrophe years (simple effect) and that growth rates rather increase than decrease following a disaster (longer effect). Moreover, averaged over all disasters in the sample, the highest growth rates over the 5-year period studied are found for the disaster year. Qualitative controlling

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226 Analogous analyses are presented for inflation, investment, output of the main economic sectors (agriculture, construction, manufacturing), public finances, and external balances. Selected results are discussed in the text.
for other influences on economic performance, such as oil shocks and political crises, makes the observed patterns rather more robust.

For the further aggregate variables, Albala-Bertrand’s interpretations can be summarised as follows: No significant effects are found on inflation, exchange rates, employment, on public finance (there are small increases in budget deficits). The growth rate of investment appears to increase in the disaster year and afterwards falls to pre-disaster levels. Output growth in manufacturing remains unaffected by natural disasters while construction, particularly in the case of earthquakes, shows increases in output growth. For agriculture, the results are less conclusive, but output growth seems to increase or remain unchanged following disasters. Even for hydro-meteorological disasters no significant negative effects are found. Macroeconomic repercussions of disasters appear to primarily materialise in external balances: both trade deficits and currency reserves rise. The latter Albala-Bertrand explains by an increase in capital flows (a third of which are unrequited transfers).

Natural disasters in a Keynesian model

The outline of the Keynesian framework presented here follows, with a number of simplifications\textsuperscript{227}, the line of argument in Albala-Bertrand (1993b). The first two steps include estimates of the upper and lower limits of the output effects of a disaster. In the third step, a multiplier model is introduced for discussing the output effects of compensatory investment and the minimum reconstruction investment required for keeping output (growth) at pre-disaster levels.

\textsuperscript{227} The outline of the formalism here follows closely Albala-Bertrand (1993b) with a number of simplifications and modifications. As the main simplification, the disaster is described here as a shock to the capital stock ($\Delta K_d$) only. Albala-Bertrand’s definition includes both capital losses and losses to current GDP.
1. **Output effect: upper limits.** As a starting point, Albala-Bertrand approximates the upper limit of the output effects by the shock to the capital stock and the capital output ratio (c): \( \Delta Y_d = \Delta K_d / c \). This is in analogy to the neoclassical approach, where the output effect may be linearised to \( \Delta Y_d = \Delta K_d \times MPK \).  

2. **Output effect: lower limit.** In the interest of a more realistic estimate, Albala-Bertrand relaxes and specifies a number of assumptions made in step 1. Various correction factors are introduced which yields for the lower limit of the output effect:

\[
\Delta Y_d = \frac{\epsilon \pi}{\alpha \beta^\gamma \gamma} \frac{\Delta K_d}{c}
\]

where \( \epsilon < 1 \) is a correction factor for the assumed systematic overestimation of losses to the capital stock, \( \pi < 1 \) takes account of depreciation, \( \alpha, \beta > 1 \) indicate that capital lost due to disasters is less productive than the average capital stock (implying a higher capital-to-output ratio) and \( \gamma > 1 \) implies that output depends on further production factors than on capital alone. For the example of the 1976

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228 Where neoclassical variables are available (section 2.2) the notation follows table 2-1 rather than Albala-Bertrand (1993b).

229 Albala-Bertrand (1993a: 39ff) finds that figures on disaster impacts usually are based on unrevised estimates directly made after the event (see also Charvériat, 2000 and Dacy and Kunreuther, 1969; Munich Re, 2003). To account for systematic overestimation and exaggeration he assumes correction factors (\( \epsilon \)) of 0.5 to 0.25 for the number of victims and of 0.5 to 0.3 for physical damages.

230 For an example of a neoclassical discussion of a disaster’s output effects via its impact on different production factors, see Horwich (2000; see above in this section).
Guatemala earthquake, Albala-Bertrand gives a lower estimate for growth of -0.3% with a supposedly unrealistic upper limit of -3.6%.\footnote{231}

3. "Minimum compensatory" reconstruction investment. Assuming sufficient idle capacity in sectors that supply capital goods for reconstruction, the output effect of an increase in investment $I_r$ is given by $\Delta Y = m \Delta I_r$, where $m$ is the multiplier. Assuming that $m \geq 1$ implies $m > 1/\alpha \beta \gamma c$, that is, the positive output effects of capital replacement more than compensates the output effect of $\Delta K_d$. From this, it follows that the reconstruction investment rate $I_r$, which keeps output at pre-disaster level, is given by:

$$\Delta I_r = \frac{1}{m} \frac{\varepsilon \pi}{\alpha \beta \gamma c} \frac{\Delta K_d}{c} \tag{Equation 5-2}$$

which Albala-Bertrand refers to as "compensatory investment". Again for the 1976 earthquake in Guatemala, he presents a numerical example: Assuming a multiplier of $m = 2$, an increase in the rate $I_r/Y$ of between 0.15 and 1.8 percentage points is estimated to compensate for the potential loss of aggregate output\footnote{232}. Note that this estimate is

\footnote{231} Assumptions for the correction factors are given in Albala-Bertrand (1993b). Dividing both sides of (Equation 5-1 by $Y$ yields the effect of the disaster on the growth rate of GDP as a function of the loss-to-output ratio.

\footnote{232} Or, more generally, as outlined in Albala-Bertrand (2006): A total output-to-capita ratio of $c = 0.4$ may be assumed. Further, if disasters affect, firstly, the less productive types of capital (such as residential capital) and, secondly, the less productive fractions of each capital type, this may imply values of $\alpha = \beta = 0.5$ (see (Equation 5-1). Even if estimation errors $\varepsilon$, depreciation $\pi$, and non-capital inputs $\gamma$ are not taken into account, this implies a ratio of $\Delta K_d/\Delta Y_d$ of 10. With a multiplier of $m = 2$, each unit of reconstruction investment $I_r$ would have a 20 times greater effect on output than the capital loss $\Delta K_d$. For a (huge) disaster with a loss-to-GDP ratio of 10%, an increase of the investment rate by 0.5 percentage points would be sufficient to raise output to pre-disaster levels.

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for the first year after the disaster. Subsequently "the reconstruction effort can be spread over a large number of years with no negative consequences on aggregate income, and thereby with few sacrifices of funds from other developmental projects at any one year"\textsuperscript{233}.

Albala-Bertrand applies this analytical framework to six Latin American case studies and finds it explains the macroeconomic effects of disasters well. In most cases the growth rate of GDP increased in the catastrophe year. For the exceptions, Albala-Bertrand supplies explanations that are unrelated to disasters.

\textit{Albala-Bertrand's hypothetical reply to the research question}

The empirical results and the theoretical considerations lead Albala-Bertrand to the conclusion that "disasters are primarily a problem of development, they are not necessarily a problem for development"\textsuperscript{234} – a quotation that may provide the most concise summary of his hypotheses. Effects of natural disasters on macroeconomic aggregates in general, are found to be short term (2 – 3 years) and hardly observable. Qualitative explanations in addition to his formal arguments include endogenous response mechanisms drawing on local resources. These may even be effective in the case of large direct losses with macro effects depending rather on ongoing social dynamics than on disaster magnitudes. Further arguments include the economic and geographical localisation of most natural disasters as well as the sectoral and socio-economic distribution of disaster impacts: Primarily the poor and the less productive sectors are likely to be affected.

\textsuperscript{233} Formalism not recapitulated here.
Natural disasters are therefore, in the view of Albala-Bertrand, first and foremost a humanitarian and distributional problem in developing countries. While the poorest suffer most from the effects of disasters, there seems to be "no correspondence between disasters victim and disaster beneficiary". On the contrary, it is hypothesised that higher-income groups are less affected and may benefit more from disaster-related assistance.

On the developmental implications of catastrophes, Albala-Bertrand notes that these may involve political changes and technological progress – consequences however, that appear to be insignificant in most cases. Rather, they enforce "inequitable institutional arrangements" and rarely entail improvements for the poor.

Relation to other perspectives and debates in the literature

Albala-Bertrand’s critique of the mainstream position in catastrophe literature – "the received view" – has not been left unanswered. A selection of contrasting positions in the following paragraphs will illustrate the debate, with the main objective of drawing more robust conclusions from the theoretical arguments and the empirical evidence reviewed in this section. This is complemented with a re-examination of the main arguments raised in this debate referring to the neoclassical framework from section 2.2.

The ECLAC (2003) Handbook contradicts some of the main findings in Albala-Bertrand (1993a), arguing that the experience of the institution

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234 Italics in the original (Albala-Bertrand, 1993a) – a classic quotation in the catastrophe literature.

235 No evidence is presented for this hypothesis.

236 The brief review may also indicate that the debate has remained rather intuitive and at the level of views and positions rather than to involve detailed empirical evidence or theoretical arguments.
has shown disasters "are a problem both for and of development" and 
"... that after every disaster the gap between the level of growth 
expected and that achieved grows wider". Apart from the GDP 
trajectory in figure 5-1 and a number of illustrative case studies, no 
sources for this conclusion are given. ECLAC's statement is therefore 
considered here as a hypothesis rather than as evidence. Interestingly 
though, Albala-Bertrand's model (outlined above) is recommended for 
estimating the GDP and growth effects of the disaster in the appendix 
of the ECLAC Handbook.

Charvériat (2000) explains the contradictions between her empirical 
results with the findings in Albala-Bertrand (1993a) by differences in 
the samples, that is, with country and disaster characteristics. The two 
contributions are considered as complementary rather than contra-
dictory as discussed in section 5.1.

Benson and Clay (2004) note that "some economists, in fact, question 
the adverse effects of natural hazards and even argue the opposite — 
that disasters can be a positive shock". They explain Albala-
Bertrand's (1993a) findings with a Schumpeterian model of creative 
destruction, concluding that "careful re-examination of his data" shows 
that positive impacts on growth are mainly observed for geophysical 
disasters (reconstruction boom), while for hydro-meteorological disas-
ters, the impact is negative in most cases. Furthermore, the way that 
Albala-Bertrand treats disasters as isolated events is criticised for not 
taking account of cumulative economy-wide impacts. Benson and 
Clay refer to a study by Benson (2003) where evidence for a negative 
correlation between disaster risk and growth rates is shown. As the 
empirical excursion in section 5.1 suggests, the macroeconomic

\[\text{\textsuperscript{237}}\text{ The paper by Benson and Clay (2004) and comments by Albala-Bertrand (2006) are} 
\text{reviewed in chapter 3. For interpretation problems of "positive" effects of disasters on} 
\text{GDP see part III.}\]

\[\text{\textsuperscript{238}}\text{ The source is not specified and could not otherwise be identified at the time of} 
\text{writing (July 2006).}\]
effects of geophysical and hydro-meteorological trigger events may indeed differ (Charvériat, 2000). However, considering the explicitly stated focus of Benson and Clay on extreme cases as well as the statistical insignificance of the results of the empirical excursion (section 5.1), Albala-Bertrand’s hypothesis of no or positive effects on growth can not be falsified on this basis.

Freeman et al. (2002)\textsuperscript{239} emphasise that "there is much to discuss in Albala-Bertrand’s analysis" but refrain from giving their arguments explicitly. In Mechler (2003), the conclusion of a brief literature review is that "The empirical research literature generally finds macroeconomic effects and considers natural disasters a barrier for longer-term development. The only dissenting view is Albala-Bertrand (1993)."

Mechler, re-examining Albala-Bertrand’s analysis (table 5-4), finds the conclusion of increased growth rates following disasters not convincing and shows that alternative interpretations of the data leads to more ambiguous results – without, however, overturning the conclusions nor rejecting the null hypothesis on these grounds. Emphasising that he does not aim at "establishing some general laws on the economic impacts of natural disasters", Mechler refers to ECLAC (2003) for contradictory examples and to Murlidharan and Shah (2001)\textsuperscript{240} for a quantitative study that finds negative effects of disasters on growth – this can considered the only empirically founded objection in Mechler (beyond case studies) to Albala-Bertrand’s hypothesis. It will be reviewed in the following section (5.3). The paper by Murlidharan and Shah (2003) considers Albala-Bertrand’s sample as small, and notes that his statistics are rudimentary and do not control for other influences on growth than disasters. A valid objection; however, if natural disasters exerted dominant and systematic

\begin{itemize}
\item \textsuperscript{239} The Mechler-Freeman approach, including Albala-Bertrand’s (2006) criticism will be discussed in section 5.3.
\item \textsuperscript{240} Not published; Murlidharan and Shah (2003), reviewed in this thesis, is assumed to contain the same findings.
\end{itemize}

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influences on macroeconomic aggregates, this should be observable in either Albala-Bertrand’s sample or in the empirical excursion.

Finally, whether a neoclassical perspective produces congruent or contradicting predictions to Albala-Bertrand’s hypothesis depends largely on how far assumptions are modified. A textbook version with a focus on physical capital and the assumption of actual output being equal to potential output tends to reproduce the „received view“: a shock to the capital stock translates into an output shock, potentially shifting the economy to a poverty trap. Recovery would be slow, owing to the constant saving rate. However, introducing open capital markets or allowing for insurance suffices for decoupling output from domestic capital, thereby reducing the GDP effects of shocks to the capital stock. Moreover, if following Albala-Bertrand’s model, spare capacity is assumed, various types of capital of different productivity and vulnerability are introduced, the output effects of shocks to the production factors could become insignificant in a Solow-Swan model. Moreover, if following Horwich (2000), labour and human capital as well as substitution of production factors were taken into account, shocks to the capital stock would imply only minor effects on output. Note that the neoclassical framework formalises a supply-side approach. Demand-side arguments that play a key role in both Albala-Bertrand’s and Horwich’s considerations are difficult to accommodate in such a model. In brief, customary modifications of the basic (supply-side only) neoclassical framework are sufficient to plausibly explain Albala-Bertrand’s findings.

Conclusions from the review of Albala-Bertrand’s contributions will be synthesised with the overall conclusions in the following section.

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241 Where the effects of disasters on external balances are analysed, the results could be interpreted in support of such a model; see evidence in the literature quoted throughout this chapter.
Conclusions from section 5.2: macroeconomic theory-guided approaches

Section 5.2 discussed approaches to the study of natural disasters that draw upon macroeconomic theory. Covering disciplinary backgrounds from regional economics to mainstream macroeconomics and disaster risk finance, the review centred around Albala-Bertrand’s critique of the majority of disaster scholars "... that there are no such things as ‘national calamities’, ‘long-term stagnation’, ‘formidable obstacles to economic growth’ due to natural disasters or ‘that [they] can significantly retard the growth of developing countries’.”

Could this null hypothesis provide an answer to the research question? On the one hand, Albala-Bertrand presents both rudimentary empirical evidence and a theoretically consistent argumentation for his findings. Horwich, though not explicitly, corroborates and complements the theoretical underpinnings of Albala-Bertrand’s conclusions with additional economic arguments.

Quantitatively the results of the review in section 5.1, including the empirical excursion, can not be interpreted as to reject the null hypothesis. On the other hand, Albala-Bertrand is more often contradicted than agreed with in catastrophe literature. This criticism, however, is based in most cases on individual case studies (anecdotic evidence) or simulations of disaster effects that are not empirically backtested. No formal review of the theoretical frameworks of either Horwich or Albala-Bertrand was found in the literature, nor were theoretical arguments against the null hypothesis. The only empirically founded study that comes to contrasting findings is Murlidharan and Shah (2003), which will be discussed in the subsequent section. In conclusion, postponing the review of the latter paper, Albala-Bertrand’s

242 Albala-Bertrand (1993a: 86)
null hypothesis can therefore not be rejected on the basis of the arguments summarised in section 5.1.

The provisional answer to the research question remains, as in section 5.1, that natural disasters do in general not have discernible effects on economic growth. Exceptions to this rule may be large catastrophes affecting SIDS, in particular floods and storms as well as geographically widespread events in poor countries, particularly droughts in Africa. On issues beyond macroeconomic aggregates, the debate is less intense in the literature. There appears to be broad consensus that the poor are most vulnerable to disasters and that adverse shocks may result in increased poverty rates. In other words: Disaster risk is both unequally distributed and may lead to more unequal distribution.

5.3 Theory-guided approaches: growth economics

The third section of this chapter reviews approaches that explicitly draw upon theories of economic growth. Beginning with a survey of neoclassical perspectives on catastrophes, the review covers examples of a Harrod-Domar model and of Ramsey models. Analogous to the all previous sections of part II, the objective of the discussion is to scrutinise the literature for empirically and theoretically founded answers to the research question.

Issues of growth and development were found to be central primarily to the humanitarian and normative perspectives (chapter 3). The following paragraphs will illustrate elements of formalised growth theory that may be assumed behind the intuitive and normative lines of arguments widespread in that literature category. In the insurance literature (chapter 4) development aspects were discussed in a theoretical context of markets for risk. The practical insurance literature, on the other hand, makes few explicit references to growth issues, with the exception of qualitative arguments, illustrative case studies and a
singular excursion into a theory of growth and disasters. In contrast, the following review will identify a number of instances where growth theory approaches explicitly refer to the risk and insurance literature.

**Natural disasters in neoclassical growth frameworks**

A neoclassical framework for discussing natural disasters was introduced in chapter 2 and serves as a benchmark for definitions and comparison throughout the text. The basic neoclassical model reproduces the widespread intuition in the catastrophe literature that shocks to the capital stock translate into shocks to output. Customary refinements of the model, such as open capital markets or differentiating between various types of capital, including human capital, qualify this prediction (see also the preceding section 5.2).

The following paragraphs review three contributions that take neoclassical models seriously and apply them to the analysis of the macroeconomic impacts of natural disasters. This includes the seminal Alaska case study by Dacy and Kunreuther (1969), a neoclassical analysis of investments in disaster management by Tol and Leek (1999) and, finally, the deliberations of Okuyama (2003) 243.

*The economics of the Alaska earthquake of 1964*

Aiming at suggestions for disaster insurance in "alternative to the current paternalistic ... policy", Dacy and Kunreuther (1969) provide an economic view of the Alaska earthquake of 1964. The analytical part of their book includes a microeconomic perspective based on supply

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243 In economics teaching, natural disasters and analogous shocks to production factors supply popular illustrations of the mechanics of neoclassical growth models and a source of inspiration for exercises (e.g. Gärtner, 2006).
and demand considerations for the short term\textsuperscript{244}. Long-term recovery is discussed in a neoclassical framework. For this theoretical perspective and the comparison of the Alaska case study with an analogous event in a poorer country, the main arguments of Dacy and Kunreuther on growth and development are discussed in the following passage.

A production function with three types of capital summarises the neoclassical part of their analysis:

\[
Y = P(K_p, K_b^*, K_r^*, L, K_{aid})
\]

Here $K_p$ is public capital including infrastructure, $K_b$ is business capital such as production facilities and $K_r$ is residential capital. $L$ is the fixed stock of labour\textsuperscript{245} and $K_{aid}$ is a fixed amount of transfers from outside of the affected region. The superscript * indicates capital stocks that are held constant at their post-disaster levels, so that the above equation becomes a partial production function of $K_p$, public capital. This formulation from Dacy and Kunreuther illustrates their view of the optimal allocation of labour and aid to the reconstruction of the different capital stocks\textsuperscript{246}. Assuming that public capital has the highest marginal productivity and residential capital the lowest, it is proposed to begin

\textsuperscript{244} For economic views on human behaviour in disaster situations see also Douty (1972) and for an ethical discussion of respective price movements: Samuels and Puro (1991).

\textsuperscript{245} Labour is assumed to remain largely unaffected by natural disasters in industrialised countries, however, migration of working and non-working population to and from the disaster region may be relevant; see also West and Lenze (1994). This aspect is not discussed here.

\textsuperscript{246} An accompanying graphical apparatus is also presented – analogous to the textbook neoclassical model in section 2.2.
reconstruction with $K_p$ as there is "no reason for residential damage to severely impede the economy." Moreover, the equation serves the authors' aims by emphasising the importance of foreign aid for the speed of recovery towards pre-disaster aggregate output.

The hypothesis of "... recovery to be painstakingly slow in a relatively poor nation that could not afford to divert large amounts of capital at one point in time for rebuilding a disaster-torn community ..." (ibid.) is illustrated with a comparison between the Alaska earthquake and the earthquake of 1963 in Skopje, former Yugoslavia. In Alaska, substantial transfers from the federal government allowed for rapid economic recovery. In Skopje, however, damages were higher in per capita terms and as a ratio to macroeconomic aggregates. In addition, central government funds were more limited and in combination these factors explain, in the view of Dacy and Kunreuther, the observed slow pace of reconstruction in Skopje.

On the other hand, Dacy and Kunreuther hypothesise that "... a disaster may actually turn out to be a blessing in disguise" (ibid.). Emergency situations may encourage innovation, the replacement of destroyed capital may be accompanied by technological improvements and large scale damage in cities may entail unique opportunities for the modernisation of urban structures. In support of this hypothesis, the historical example of the 1917 Halifax explosion, the Alaska earthquake and the expected development of Skopje are presented.

**The neoclassical economics of disaster management**

Tol and Leek (1999) use the basic neoclassical framework to explain the effects of disasters on output growth\textsuperscript{247}. Their simulations yield predictions as illustrated using the textbook model in chapter 2:

\textsuperscript{247} The focus of the paper is on weather disasters and their expected increase owing to climate change. Tol and Leek's theoretical treatise, however, remains generic.
disaster entails a shock to the capital stock ($\Delta K_d$) which translates into an output shock ($\Delta Y_d$) but does not affect steady state growth rates. Introducing insurance allows for fast reconstruction of the capital stock. The rate of technological progress temporarily increases, thereby shifting the output growth trajectory upwards.

On the other hand, the authors emphasise that the investments in risk management may reflect more appropriately the economic implications of disasters than the effects of shocks on aggregate output. With this objective, the neoclassical framework is applied to a discussion of the costs and benefits of ex-ante disaster management including investments in protective measures and insurance. Introducing a stochastic function for damage and "defensive capital" that reduces the risk of damage, the output function becomes $Y = C + I + I_d$, where $I_d$ is investment in protective capital. The same argument is developed for insurance or precautionary savings: $Y = C + I + P$, where $P$ is the annual premium. As with Arrow (1996; section 4.1) diminishing returns of wealth or risk aversion, respectively determine the optimal level of investment in disaster management. The benefits of reduced variance of output however, come at the cost of lower average output. From these theoretical considerations, Tol and Leek conclude that regions or sectors with a higher investment in disaster management generally attract, ceteris paribus, more investment. Assuming that "capital is the engine of economic activity and growth" they further imply that the development of markets for risk are an essential prerequisite for economic growth. Finally, Tol and Leek apply their model to climate change, a situation where disaster risk varies with time. Result: investment into risk management is optimal if expectations on disaster frequencies are ex post correct.

248 For analogous considerations see chapter 4 on insurance and the small open economy model in chapter 2 for post-disaster credit on global capital markets.

A regional economics update of Dacy and Kunreuther (1969)?

Okuyama (2003) finds that since Dacy and Kunreuther (1996) disaster research has primarily been empirically oriented whereas theoretical progress has been slow\textsuperscript{250}. For the analysis of long-term effects of disasters he proposes a neoclassical model (basic version from chapter 2) with a temporarily higher post-disaster saving rate. In addition, he assumes that less productive capital is likely to be affected by disasters and that reconstruction leads to a temporary increase in the rate of technological progress.

\textit{Conclusion from neoclassical approaches}

In contrast to the widespread implicit references to neoclassical intuition, formal Solow-Swan models appear not to be extensively used for the study of natural disasters. Firstly, where they are adapted for this purpose, they serve for illustrating how shocks to the capital stock – other production factors are normally not considered\textsuperscript{251} – translate into shocks to output. Secondly, they are used for demonstrating that reconstruction of the capital stock may temporarily accelerate technological progress. The former is normally seen as an undesirable impact whereas the latter is sometimes interpreted as a positive economic effect of disasters in the long term. A third common topic of neoclassical perspectives is the sources of funds for reconstruction. Dacy and Kunreuther emphasise foreign aid, while Tol and Leek focus their analysis on investments in disaster risk management, precautionary savings and insurance.

\textsuperscript{250} The main gaps, according to Okuyama, relate primarily to the understanding of stock effects and reconstruction investments. Flow effects, however, in his opinion, can be appropriately captured using I-O models – on which this thesis, in section 5.2, comes to contrasting conclusions.

\textsuperscript{251} See Horwich (2000), discussed in section 5.2.
The emphasis on capital inflows as a prerequisite for economic recovery is in congruence with ECLAC (2003) and more formally with the Mechler-Freeman approach (see next section) as well as with Murlidharan and Shah (2003; also discussed below). Dacy and Kunreuther's arguments on the primacy of public infrastructure in reconstruction are shared with the meso-economic literature (section 5.2). For contradictory arguments to both of these views see Albala-Bertrand (1993a, section 5.2), who would agree, however, to the introduction of various types of capital as a refinement. It is also important to note ECLAC's (2003) comment that many facilities affected by disasters may be temporarily repaired at costs far below their replacement value – an assumption in contrast to Dacy and Kunreuther. Moreover, as Tol and Leek underline, focusing the analysis of disaster effects on aggregate output may lead to deceptive conclusions. While disasters are a negative shock to wealth and will decrease the flow of services from capital goods, reconstruction of the capital stock will materialise as an increase in GDP. This argument is in line with Albala-Bertrand, however Tol and Leek do not formalise it in their neoclassical approach.

Conclusions with regard to disaster effects on GDP, growth and poverty remain difficult from the neoclassically oriented literature. On the one hand, this is due to the lack of empirical evidence available on the hypotheses derived from Solow-Swan models. Dacy and Kunreuther supply detailed and comparative case studies, which remain more illustrative examples than evidence. On the other hand, the sophistication of neoclassical models in the catastrophe literature rarely goes substantially beyond the framework developed in chapter 2 for purposes of definition. In summary, the neoclassical literature on natural disasters does not allow for generalisations in form of a hypothesis or answer to the research question.
Mechler (2003) and Freeman et al. (2002, 2004)\textsuperscript{252} analyse the macro-economic implications of natural disasters in a modelling framework that combines an insurance approach to loss estimation with an economic growth model. In the dimensions of figure II-1, the approach includes elements from both microeconomics (the insurance perspective) and macroeconomics (a growth model) while the overall perspective is primarily normative.

The main objective of the Mechler-Freeman model, which was developed in cooperation between experts from The World Bank, the IIASA and Swiss Re, was to present a practical methodology for addressing natural disasters in macroeconomic planning. Policy recommendations in the above publications are addressed at governments of disaster prone developing countries as well as at international finance institutions and at the private insurance sector. At the risk of oversimplification, the key conclusion of Mechler (2003) is that for developing countries, characterised by both high expected losses due to natural disasters and high economic vulnerabilities, ex-ante disaster insurance may increase welfare as compared to reliance on ex-post aid and credit. Potential welfare gains are related to reduced volatility of output while costs include insurance premiums that translate into lower growth rates\textsuperscript{253}.

In the following paragraphs, the framework developed in Mechler (2003) and its main predictions on the effects of disasters on output are discussed.

\textsuperscript{252} The project is documented in most depth and detail in the PhD thesis of Mechler (2003) with excerpts, additional case studies and summaries of provided in previous and later publications such as Freeman et al. (2002, 2004).

\textsuperscript{253} These policy implications rely on cost-benefit analysis. For related approaches to comparing alternative disaster insurance schemes, see Jones-Lee (1984).
Outline of the Mechler-Freeman approach

The macroeconomic model consists of two elements: Firstly, a methodology for estimating the effects of disasters on the capital stock in the form of loss-frequency distributions, aggregated over all types of disasters considered. Drawing on established reinsurance practice (section 4.3), this methodology yields estimates of average expected losses per year and of the losses that are expected every 100, 500 and 1000 years, respectively. In the neoclassical framework this definition of loss or damage corresponds to $E[\Delta K_d]$, an expectancy value for shocks to the capital stock. A linear correlation with the effects of disasters on the labour force ($E[\Delta L_d]$) is assumed.

Secondly, the expected shocks to the production factors, and in particular to the public infrastructure, are stochastically simulated and the results entered into the Revised Minimum Standard Model (RMSM-X) of the World Bank. Originally, this macroeconomic planning model was designed around a Harrod-Domar growth framework. The primary purpose of the MSM was to estimate the amount of external aid, referred to as the financing gap, required to achieve a given growth target. One of the main conclusions of this class of models is that output growth depends primarily upon investment in previous periods (Easterly, 2002). Mechler uses the RMSM to simulate the effects of disaster losses ($\Delta K_d$, $\Delta L_d$) on macroeconomic variables, primarily on the government budget, which yields an estimate of the "natural disaster financing gap". This equals the required, but not domestically available, government expenditure for disaster relief and reconstruction of the infrastructure capital stock. Furthermore, the financing gap is proposed as a measure of vulnerability of economies to natural disasters.

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254 The model was widely used as a policy tool in the 1960s and 1970s. The first programmed version of 1971 was referred to as the Minimum Standard Model (MSM) and later revised and refined to the RMSM (Easterly, 2002).
A number of strong assumptions characterise the Mechler-Freeman approach, which are implicit to the Harrod-Domar type model or concern the role of the public sector\textsuperscript{255}. Disaster relief by the government is assumed to keep private consumption constant after a shock and public investments at a level that ensures the reconstruction of the infrastructure to pre-disaster levels.

\textit{Discussion of the predictions on the growth effects of disasters}

In a Harrod-Domar economy as defined by the above model, GDP decreases after a disaster. In analogy to the neoclassical framework, the immediate effect on output ($\Delta Y_d$) depends upon the size of the shock to the production factors ($\Delta K_d, \Delta L_d$) and on the characteristics of the production function. A neoclassical economy exhibits a growth maximum in the period after the disaster with growth rates gradually decreasing to their steady state value. In the MSM the growth trajectory following a shock depends upon investment for reconstruction and therefore, in the case of poor countries, primarily upon foreign aid and credit. If the capital stock is not rapidly and completely rebuilt for reasons such as the disaster finance gap, protracted negative effects on output may result\textsuperscript{256}. In developing countries therefore, the macroeconomic effects of disasters primarily depend upon the availability of external finance. Here, the developers of the Mechler-Freeman approach locate the main difference in disaster

\textsuperscript{255} The behaviour of government in this framework resembles that of a "social planner" or "benevolent dictator". Easterly (2002; see also literature quoted there) discusses the relation between the economic history of planned economies, the history of thought on Harrod-Domar growth models, and the application of these models in development policy design.

\textsuperscript{256} From a comparison of projected GDP trajectories with and without catastrophe risk considered, Freeman et al. (2004) conclude in one of their case studies that "if access to foreign savings is limited post-event, catastrophes could stagnate GDP for Honduras over the next eight years."
vulnerability between industrialised and developing countries. Developed economies can absorb shocks to their capital stocks, principally by resorting to domestic savings, while in developing economies no such resources are available. Note that, as opposed to the neoclassical model, the RMSM does not predict an unconditional return to a balanced growth path and no significant capital imports via the international capital markets are taken into account.

Mechler applies the financing gap approach to two case studies (Honduras and Argentina). In Freeman et al., (2002) a third case study on Nicaragua is presented. On the (potential) macroeconomic effects of disasters, the authors conclude as follows from these three sample simulations\textsuperscript{257}. Honduras is, of the above three countries, most exposed to natural hazards and the most vulnerable economy. Expected losses are estimated at 0.5% of capital stock annually and at 31% for a 500-year event. According to the stochastic simulations, this could translate into a maximum shock to GDP of circa -16% with an average predicted effect of -0.5%, for the case that no external finance is available\textsuperscript{258}. A financing gap and the associated negative effects on GDP and growth may result already from 50 year events, such as hurricanes with an occurrence probability of 2% per year.

Hurricane Mitch of October 1998 may serve as a quantitative contrast for discussing the above lines of argumentation. According to an estimate by ECLAC and IDB (2000) 18% of Honduras’ capital stock was destroyed in this disaster with an estimated return period of less than 100 years. Economic losses amounted to 70% of GDP\textsuperscript{259}. Mechler

\textsuperscript{257} No empirical study of the general predictions derived from the case studies was available at the time of writing.

\textsuperscript{258} The percentages given relate to net present values of GDP over a five-year period from 2003 – 2008, compared to a baseline (projected growth rate) of 5.2%. With 100% external financing (of the public sector financing gap), the respective average effects on GDP are estimated at 0.2%, with a maximum of 5.7% (Mechler, 2003: 157ff).

\textsuperscript{259} ECLAC definitions; Charvériat (2000).
(2003) follows that "the effects of this catastrophe were enormous and will have a long-lasting impact on the economy."


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<tr>
<td>GDP growth (%)</td>
<td>4.1</td>
<td>3.6</td>
<td>5.0</td>
<td>2.9</td>
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<td>5.7</td>
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As an illustration, GDP for the years from 1995 to 2003 is given in table 5-5: In 1999, the year following Mitch, output of Honduras contracted by 1.9% and subsequently returned to positive growth rates from 2000 onwards. Medium-term growth averages were 3.9% for the 6 years pre 1998 (3.7% if 1998 is included) and resumed 3.9% for the 6 years post 1999. Including the years in which the disaster supposedly affected GDP growth, the average rate in the period of 1992 – 2005 is 3.4%. In relation to the undoubtedly huge shock to the capital stock, the effects on GDP and growth appear short-term and small. In Mechler (2003) this is explained by the inflow of large amounts of foreign aid and credit as well as a worsening of the trade balance. In the neoclassical small open economy (section I-2), this explanation would correspond to the increase in foreign debt ($\Delta D_d = \Delta K_d$ in perfect capital markets and $\Delta Y_d = 0$).

The example of Mitch indicates, in contrast to the projections of Mechler and Freeman, that the macroeconomic aggregates of GDP

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260 The IMF growth projections before Hurricane Mitch were 5% for 1998 and 1999 (Charvériat, 2000).
and growth may appear only somewhat vulnerable to even large shocks to the capital stock – the economic consequences of natural disasters may have to be located in other variables such as consumption, government budgets, poverty rates and the distribution of disaster effects.

For Argentina, the stochastic simulations in Mechler (2003) give no indications for a catastrophe financing gap. Expected losses due to natural disasters are low for Argentina and sufficient domestic savings are available for covering the government’s relief and reconstruction budgets.

The case study on Nicaragua in Freeman et al. (2002: 28ff) explores the implications of disaster risk for the poor. Starting from the assumption that the effects of disasters on income are equal in percentage terms for all income groups, changes in poverty rates are derived from the GDP projections generated by the RMSM. Simulations that take into account natural disaster risk predict lower growth rates than for "risk free" output trajectories as well as a reallocation of government spending and foreign aid from poverty alleviation to disaster finance. Both factors translate into lower incomes and consumption and, as a consequence, into higher poverty rates or a higher percentage of households with consumption possibilities below the poverty line. As expected, assuming that the incomes of the poor are particularly vulnerable to the effects of shocks results in stronger effects of disaster risk on poverty rates.

*Debates in the literature*

Problems related to the concept of economic loss (see detailed discussion in section 5.1) may be considered as solved in the

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Poverty rates in Nicaragua are estimated at around 50% for 1998 (ibid.).
Mechler-Freeman model as clear definitions of the respective variables are provided.

That the Mechler-Freeman approach relies on strong assumptions regarding the importance of investment for output in periods following a disaster, is a general characteristic of Harrod-Domar or financing gap models. Some scholars, however, see this as a weakness (Easterly, 2002) and consider the models as obsolete from a theoretical perspective, as falsified from on empirical grounds and therefore a dubious basis for policy recommendations\textsuperscript{262}.

Albala-Bertrand (2006) criticises the Mechler-Freeman approach from a theoretical point of view as "failing in its realism" as their model "heavily relies upon fixed coefficients, an actuarial concept of losses and an inert conception of society." He sees the actuarial or insurance perspective as non-applicable at the macro level and the fixed coefficients as too strong for both temporary disaster situations and long-term projections. Additionally, the model ignores, in Albala-Bertrand’s view, endogenous reactions, which are "bound to produce adaptations, substitutions, economic shifts, migration, diversification". As discussed in the above section on the Keynesian perspective on natural disasters (section 5.2), Albala-Bertrand also empirically challenges the Mechler-Freeman generalisations from the case study simulations.

\textit{Conclusions regarding the research question}

The financing gap approach advocated by Mechler, Freeman and co-authors provides, first and foremost, policy recommendations for financial disaster risk management rather than a macroeconomic

\textsuperscript{262} Mechler and Freeman make strong and very specific assumptions on the role of the public sector. Governments are modelled as welfare-maximising social planners; they are considered the main actors involved in ex-ante and ex-post disaster management.
analysis of disaster risk. Statements on the macro effects of catastrophes are based on a cursory review of disaster literature (Mechler 2003: 25ff) and on case studies of macroeconomic projections.

Taking into account the criticism of financing gap models (RMSM), the difficulties of generalisations from case studies and that no empirical tests of the projections are available, the Mechler-Freeman allows for few reliable insights into the macroeconomic effects of natural disasters. As Freeman et al. (2004: 339) emphasise, this was not a main objective of the project as the "RMSM’s strength lies not as much in its predictive power as in its guarantee that the projections it generates are internally consistent". In contrast to the macroeconomic hypotheses, however, the general policy conclusions may be less exposed to the objections of Easterly and Albala-Bertrand. Estimates of expected disaster losses in terms of damages that draw upon reinsurance expertise, simulations of the potential consequences for government budgets and evaluations of options for disaster finance will remain invaluable elements of disaster management.

In summary, it is concluded that the Harrod-Domar approach as discussed in the above passages neither provides a theoretical nor an empirical basis for generalisations on the growth effects of natural disasters. Cautiously interpreted, the model and the simulation results could support the hypothesis that disasters are more likely to have macroeconomic repercussions in small developing countries as opposed to geographically large or developed economies.

*Natural disasters in a Ramsey growth model*

The last example of growth theory applied to catastrophes is the paper by Murlidharan and Shah (2003). Their study includes an explorative empirical survey and an econometric analysis for detecting "empirical regularities in the behaviour of economies affected by catastrophes". In order to explain the observed patterns, various versions of a
Ramsey growth model as well as simulations are presented\textsuperscript{263}. It will be argued that for this thesis, it is primarily the empirical results that are of interest – both for the large data set and for the extensive quantitative analyses.

\textit{Three Ramsey models}

Ramsey growth models differ from neoclassical approaches primarily in the microfoundation, which is operationalised by the assumption of a utility-maximising representative agent. Saving and consumption is intertemporally optimised rather than exogenously determined and constant. Nevertheless, in most central aspects the Ramsey approaches and Solow-Swan approaches yield by and large congruent predictions on the economics of growth and its determinants.

Murlidharan and Shah\textsuperscript{264} introduce three model variants that "simulate the behaviour of a typical economy when perturbed by an unanticipated and large change in the capital stock followed by an arbitrarily complex change in the affected region’s productivity." There are two types of capital: productive capital and maturing capital that gradually becomes productive capital. Further, it is assumed that less productive capital is more likely to be affected by disasters and that the recovery involves capital goods of the latest technology. Both assumptions imply an increase in productivity; firstly, due to the impact of the disaster which improves the average productivity of the remaining capital stock; and secondly due to reconstruction using more productive capital. Inflows of aid, it is further assumed, provide the main funds for reconstruction.

\footnote{263}{For the arguments explained in section 5.2, the projective regional simulations for disasters in the USA remain out of the scope of the review.}

\footnote{264}{ibid., chapter 3.}
Model 1 depicts a closed economy. After a disaster, output and consumption fall whereas growth rates increase. With reconstruction of the capital stock (financed by aid) productivity increases and output surpasses its pre-disaster steady state level after around 3 years. Consumption, however, remains at permanently lower levels, which is reflected in overall negative effects of the disaster on welfare. Note that owing to the assumptions regarding the higher productivity of reconstructed capital, the larger the disaster ($\Delta K_d/K$), the higher the increase in output. Qualitatively, and apart from a permanent decrease in consumption, these predictions are in congruence with the basic neoclassical model (chapter 2).

Figure 5-3: The growth effects of natural disasters in a Ramsey model. Simulation results of model 2 from Murlidharan and Shah (2003: 109) for five disasters of different magnitudes ($\Delta K_d/K$ given in percentages from 0% to 20%). The disaster occurs at time 0.5, indicated with a vertical bar.

In model 2 the two types of capital are introduced. Following a disaster, the trajectories for capital, output and the growth rates of
these two variables remain similar to model 1. However, for scenarios with large shocks, both capital stocks as well as the growth rates of output may permanently remain below their pre-disaster levels and even become increasingly negative. These results, illustrated in figure 5-3, may be considered analogous to a poverty trap at K=0 in the neoclassical framework.

Model 3 studies two open economies, one of which is affected by a disaster. If a disaster occurs in region 1 it is assumed that "region 2 tries to mitigate the situation in region 1 by diverting some of its output for relief and reconstruction". This is primarily reflected in increased imports in the affected region and in a share of region’s 2 output made available for aid. For a large disaster (ΔK_d/K = 20%) this results in a rapid recovery of the affected region 1 with growth rates remaining positive after a growth peak in the disaster year (analogous to the neoclassical case). If no disaster occurs, however, growth rates become increasingly negative after year 2^{265}.

Murlidharan and Shah draw three conclusions from their simulations. Firstly, a model should include the distinction between maturing and productive capital as otherwise "the fact that post-event growth is negatively correlated with the magnitude of loss cannot be explained", (an empirical finding, see next section). It is concluded, secondly, that "... the models consistently demonstrate the importance of investments in the disaster region" and finally, disasters are seen to "... offer an opportunity to rebuild and convert vulnerable communities into robust ones" and to "make the region more productive than before the event".

265 As this result is in contradiction with the customary assumptions on (undisturbed) growth patterns, such as balanced growth paths, it is attributed here to a simulation artefact. Further, it may be noted that the simulated growth trajectory in the non-affected
**Empirical results**

The objectives of the quantitative analyses in Murlidharan and Shah (2003) are twofold: On the one hand, the socio-economic characteristics are studied which may determine vulnerability, and thereby the economic effects of disasters. On the other hand, the macroeconomic repercussions of disasters of different magnitudes are investigated. Their data set includes more than 150 disasters that occurred in 43 countries between 1970 and 1998.266

The analysis of *socio-economic determinants of vulnerability* is based on regressions of loss ratios \( \Delta K_{it}/Y \) with a number of development indicators267. Findings include that both loss ratios and the affected population are negatively correlated with per capita income. This observation is explained, as it is throughout the catastrophe literature, by the higher vulnerability of poor countries and poor individuals to natural hazards. In addition to per capita income, loss ratios are then correlated (individually) with a large number of further development indicators ranging from population growth to secondary school enrolment and daily protein intake.268 It is assumed here that all of these development indicators are strongly correlated with per capita income in region 2 exhibit strong variations even for the non-disaster case but becomes permanently negative in the long term if a large disaster occurs in region 1.

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266 Included are 24 earthquakes, 62 floods, 57 storms, 20 droughts and 6 other events such as volcanoes. Of the 43 countries studied, 13 are classified as high income countries, 5 as upper middle income, 15 as lower middle and 10 as lower income countries.

267 For this part of the analysis, no levels of significance are given in their paper; the results remain illustrative.

268 The full list includes: Balance of trade, government repudiation of contracts, population growth, urban population growth, forest depletion, electric power consumption, bureaucratic quality, rule of law, corruption, uncertainty of economic growth, volatility in inflation, secondary school enrolment, density of physicians, infant mortality, number of hospital bed, daily calorie intake, daily protein intake, aid as a percentage of government expenditure. The correlation between (negative) trade balances and loss ratios is explained, for example, by the detrimental effects of globalisation and "unequal trading arrangements between rich and poor countries".
income – and that this indicator provides an appropriate, if highly aggregated, proxy for the level of development, particularly considering the low quality of disaster loss data\textsuperscript{269}. The causal speculations on each of the individual correlations provided in Murlidharan and Shah are therefore not recapitulated. Literature on the determinants of development and growth in general has been reviewed in section 1.1.

The \textit{economic repercussions of disasters} are analysed for aggregate variables including GDP growth in the short term and in the long term, consumption, investment, inflation and real interest rates as well as government expenditure. Specifications\textsuperscript{270} of the following form are used for the estimates:

\begin{equation}
    y_{t+1} = b_0 + b_1 \log(\Delta K_d / Y) + b_2 \log(\Delta L_d / L) + b_3 \log(y_{avg}) + b_4 E_i + ...
\end{equation}

where $y_{t+1}$ is the post disaster output, $\Delta K_d / Y$ and $\Delta L_d / L$ the loss ratio and the affected population, respectively. $y_{avg}$ is the pre-disaster average of output and $E_i$ stands for a series of control variables such as the standard deviation of inflation or average gross capital formation. A dummy variable is introduced for different trigger events: droughts, storms, floods and earthquakes. For details of econometric methodology see Murlidharan and Shah (2003: 159ff).

\textsuperscript{269} Loss figures are only available for a fraction of all natural disasters and should be considered, owing to methodological difficulties, as indications of orders of magnitude. Sections 4.3 and 5.1 give a detailed account of the problems related to loss estimates and comment on the economic data available on natural disasters; for an overview of EM-DAT used by Murlidharan and Shah (2003) see Guha-Sapir et al. (2004).

\textsuperscript{270} An illustrative example of a specification adapted from Murlidharan and Shah (2003).
It is found that post-disaster growth is significantly and negatively correlated with the loss-to-output ratio of disasters (ΔK_d/Y), both for the short term and for the medium term\textsuperscript{271}. In the long term, beyond the third post-disaster year, no significant effects are observable. The coefficient for the percentage of affected population also enters significantly, however, suggesting a positive effect on post-disaster growth. In addition, the growth effects of disasters appear to depend upon the trigger event: Droughts are significantly and negatively associated with post-disaster growth, while the coefficient for earthquakes has a positive sign. The results for floods and storms are not reported. Whereas the positive coefficient for the affected population is explained by the larger influx of aid triggered by larger number of disaster victims\textsuperscript{272}, it is hypothesised for earthquakes that reconstruction activities and the resulting productivity increases lead to higher post-disaster growth rates.

\textit{Discussion and conclusions}

The approaches developed by Murlidharan and Shah appear promising as they include theoretical advancements, such as the adaptation of a mainstream growth model to the study of disasters and for their use of sophisticated econometric techniques in the analysis of a large data set. It was, however, found difficult to follow the authors in their generalisations on the growth effects of natural disasters. An outline of problems with the models and the empirical study will illustrate these difficulties:

\textsuperscript{271} Short term: pre-disaster year compared to disaster year; medium term: average growth rates of 3 pre-disaster and 3 post-disaster years, respectively. The correlation is reported to remain significant for a number of specifications.

\textsuperscript{272} In other instances (p 70 ff) Murlidharan and Shah argue that "there is little hard evidence that disaster aid results in net benefit"
Their Ramsey models, while formally elegant, incorporate strong assumptions some of which are based on intuition rather than on theoretical arguments or empirical evidence. Examples include the influx of aid for reconstruction as well as aggregate productivity that decreases due to the disaster and increases with the reconstruction of the capital stock. Furthermore, on the output side the models generate a number of results that are difficult to explain economically such as the significant effects of disasters with zero damages and the permanently negative growth rates of countries unaffected by disasters. Whether these unconventional findings may relate to minor imperfections or not, they cast doubt on the consistency of the model. Finally, some of the simulation results, such as typical growth trajectories are presented as insights gained with the model while, in fact, they may merely reflect the assumptions used for designing it. In summary, it remains difficult to draw robust conclusions from the simulations.

The empirical analysis raises a number of questions that imply a considerable scope for reinterpretation of the results\(^{273}\). Firstly, Murlidharan and Shah assume that disaster loss ratios \(\Delta K_d/Y\) are not correlated with the growth determinants that are used as control variables. In fact, however, this correlation is one of the few areas where widespread consensus exists in the catastrophe literature as is illustrated by figure 2.2 in Murlidharan and Shah (2003: 27). The question of whether the highly significant coefficients of the loss term may be statistical artefacts remains therefore open\(^{274}\). Secondly, while the loss ratios are negatively correlated with post-disaster growth, the

\(^{273}\) A thorough review of the empirical work of Murlidharan and Shah would have to include the (electronic) appendix to the study, which was not available at the time of writing (June 2006).

\(^{274}\) In other words: An alternative explanation for this finding could be that the disaster loss ratio represents primarily an aggregate proxy for other growth determinants; see correlations provided in Murlidharan and Shah (2003: 27ff). The coefficient of the loss ratio might then appear significant in a specification, which already contains other explanatory variables for growth.
correlation with affected population is positive. However, loss rates and affected population (percentage) appear to be positively correlated in figure 1.6 (Murlidharan and Shah, 2003). No plausible quantitative explanation is provided for these contradictory findings from the same sample. Finally, earthquakes are positively associated with growth, but droughts negatively. As results for floods and storms are not reported, it is assumed here that the respective coefficients are not significant. The overall negative correlation between loss ratio and growth would therefore be explained largely by droughts and a number of extreme losses related to floods and storms.

To conclude, the findings of Murlidharan and Shah remain inconclusive for a number of material inconsistencies. What the results would be if the main problems of statistical analysis and interpretation were addressed remains open; possible alternative outcomes are outlined above. Conservatively interpreted from a perspective of the research question, the results may at best allow for cautious conclusions in support of previous studies (sections 5.1 and 5.2): Droughts as well as large and sudden disasters in small developing countries appear to have significant macroeconomic repercussions\(^{275}\). Large effects on economic growth, however, remain exceptions rather than the rule.

**Conclusions from section 5.3: Growth theory perspectives on natural disasters**

The previous passages illustrated that the literature contains examples of various growth models applied to the study of natural disasters. As this thesis focuses on growth aspects of catastrophes and takes a neoclassical analytical perspective, this category of the literature was considered central at the outset of the research project. The following paragraphs summarise the review of growth theory ap-

\(^{275}\) Murlidharan and Shah do not report results differentiated by country income groups.
proaches. The next section (5.4) will draw the overall conclusions from the discussion of macroeconomic perspectives.

The common characteristics of growth perspectives on natural disasters may be stated as follows. Firstly, most approaches that explicitly refer to growth models emphasise the importance of damages to the capital stock and the resulting (negative) consequences for aggregate output and growth. Working hypotheses, assumptions and conclusions are in many cases analogous to "neoclassical intuition" based on a Solow-Swan model, possibly a poverty trap version. Secondly, the normative implications of this intuition include the fact that economic recovery depends primarily upon the reconstruction of the capital stock. The respective funds may involve domestic resources, foreign aid or insurance. Thirdly, the need for reconstruction is often seen as an opportunity for technological advancement or structural changes – with positive long-term effects on productivity and welfare. In the words of Mechler (2003), the conclusions from growth theory perspectives on catastrophes may be summarised as follows: the "... literature generally finds significant short- to medium-term macroeconomic effects and considers natural disasters a barrier for longer-term development."

Theoretically, various contributions go beyond the simplistic neoclassical framework outlined in chapter 2. Most growth models differ between several types of capital. Furthermore, refinements are proposed to depict not only the effects of shocks but also the opportunity costs of ex-ante disaster management. The purpose of these frameworks remains primarily illustrative – with the exception of two quantitative models that are used for simulating the macroeconomic effects of disasters. These, however, incorporate highly specific assumptions, are applied to case studies and yield projections as results. None of the models are backtested with historical disaster data, explicitly
empirically tested or used for studying generic cases\textsuperscript{276}. Finally, an empirical analysis of the macroeconomics of disasters has met with difficulties that make its results seem inconclusive.

In summary, the literature which addresses catastrophes from a growth theory perspective allows for few robust generalisations on the growth effects of natural disasters. Hypotheses abound but await theoretical or empirical underpinnings in most cases. The widespread thesis of "natural disasters as obstacles for growth" is not tenable on the basis of the theoretical arguments and the empirical evidence provided. Conservatively interpreting the literature reviewed in this section\textsuperscript{277}, it can be concluded that natural disasters may have repercussions on growth in small developing economies and that disaster magnitudes decrease with development. This finding may also be valid at the regional or household level. Droughts as well as large floods and storms may affect output negatively whereas disasters triggered by earthquakes may be followed by increased growth.

\textsuperscript{276} Generic examples might include: Developing versus industrialised countries, large versus small economies, earthquakes versus droughts etc.

\textsuperscript{277} Note that these conclusions with regard to the research question in some cases contradict the original statements in the reviewed sources.
5.4 Summary of conclusions from the Macroeconomic Perspectives

The concluding section of the review of macroeconomic perspectives begins with a revised topography of this diverse literature – referring back to the missing stylised fact from the first chapter and to the framework of dichotomies from the introduction to part II. An overview of the main positions will be presented including the various theoretical arguments and the types of evidence offered in support of these contrasting views. The conclusion will be presented in the form of a provisional answer to the research question. Note that the discussion is continued and expanded in part III to a synthesis of findings from all three review chapters, including the development policy perspectives (chapter 3) and the insurance perspectives (chapter 4). Chapter 5, however, constitutes the analytical core of the thesis.

A topography of perspectives, hypotheses, arguments and evidence

Table 5-6 summarises the findings of the review in this chapter as abstracted to two main positions. The first position considers natural disasters as obstacles to economic growth while the second position defends the hypothesis that such effects are not discernible. The lines between these positions run primarily between the macroeconomic perspectives (section 5.2) and growth perspectives (section 5.3). Contributions from the empirical literature (section 5.1) and meso-economic approaches (section 5.2) take the middle ground and cannot generally be associated with one of the two main positions outlined in more detail below.
Table 5-6: Synopsis of macroeconomic perspectives on natural disasters. Main positions (top row), relation to the disciplinary organisation of chapter 5, selected prominent authors, arguments and evidence.

<table>
<thead>
<tr>
<th>Position 1</th>
<th>Intermediate positions</th>
<th>Position 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Natural disasters are setbacks for economic growth.&quot;</td>
<td>Meso-economic approaches (5.2): Cochrane, Rose, West and Lenze</td>
<td>Macroeconomic perspectives (5.2): Albala-Bertrand, Howards</td>
</tr>
<tr>
<td></td>
<td>Empirical approaches (5.1): Auffret, Charvériat, Crowards</td>
<td></td>
</tr>
<tr>
<td>Growth theory perspectives (5.3): Mechler, Freeman, Murlidharan and Shah, Okuyama</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neoclassical intuition: supply side focus</td>
<td>Regional models and simulations</td>
<td>Macroeconomic theory: Supply side and demand side</td>
</tr>
<tr>
<td>Case studies</td>
<td>Case studies</td>
<td>Empirical evidence</td>
</tr>
<tr>
<td>Models, projections</td>
<td>Empirical evidence</td>
<td>Case studies</td>
</tr>
<tr>
<td>Empirical evidence</td>
<td></td>
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</tr>
</tbody>
</table>

Discussion of position 1: "Natural disasters are setbacks for growth"

Measured by the number of publications and authors that implicitly or explicitly support this hypothesis, position 1 is the dominant view in the catastrophe literature. Although the institutional background of the contributions is primarily academic, the focus is often normative and aims at policy recommendations rather than exclusively at macroeconomic analysis. Position 1 is related more closely to the development policy perspective rather than to mainstream economic research. However, some contributions from development institutions were
found to be closer to position 2 while most regional economics contributions can be associated with position 1.

The intuition behind the view of natural disasters as setbacks for growth is hypothesised here to be twofold: On the one hand, the assumption that humanitarian tragedies imply negative effects on macroeconomic performance seems to be widespread. On the other hand, the position appears to be inspired by theoretical concepts of growth where capital is a limiting production factor: shocks to the capital stock translate into shocks to output, "throwing back development".278

Arguments in support of position 1 include country and event case studies, macroeconomic simulations of catastrophes as well as individual empirical contributions. The difficulties of generalising from case studies and from projections have been discussed in various instances above (sections 5.1 and 5.3). Further empirical evidence referred to in relation to corroborating position 1 was found either to be based on specific samples or to suffer from significant methodological difficulties. The former issue was addressed by careful interpretation of samples and provided further support to position 2. The latter point relates to the inconclusive results of a large empirical study, which was therefore not considered as evidence here.

From position 1, position 2 is usually criticised for its hypothesis rather than its theoretical arguments and for its rudimentary empirics drawing on small samples. However, anecdotic evidence, untested projections and reference to the views of a majority were demonstrated not to be sufficiently strong objections to position 2 – and they are not considered here as a sound basis for generalisations on the macroeconomic effects of disasters.

278 A view labelled "capital fundamentalism" in Easterly (2002). Note however, that where Easterly briefly touches upon the macroeconomics of disasters, his illustrations closely resemble to position 1.
To conclude: Literature associated with position 1 illustrates the specific circumstances under which natural disasters may have macroeconomic repercussions. Furthermore, it presents a wealth of hypotheses on the economic mechanisms that may determine ultimately the effects of disasters on growth and development. It does however, neither provide theoretical arguments nor empirical evidence sufficient for rejecting the null hypothesis supported by position 2.

Discussion of position 2: "Disasters have no effects on growth"

Institutionally and within academic disciplines this position can be located where development economics and macroeconomics overlap with disaster research. It is a minority position, defended most fiercely by Albala-Bertrand but it can be traced back to John Stuart Mill (1848). However, contributions on natural disasters remain few and far between in mainstream macroeconomic research, with Hirshleifer and Horwich as two further representatives.

Theoretically, position 2 is characterised by the explicit use of basic concepts from economic theory. Where the argumentation is formalised, this serves primarily for illustrative purposes: the frameworks remain mathematically less sophisticated than the models developed for macroeconomic projections discussed under position 1. The main theoretical arguments for the null hypothesis include the geographic and economic localisation of most natural disasters, the compensatory effects of reconstruction on output, the importance of human capital for output and for substituting capital, and the large fraction of capital that is not directly related to output. Rudimentary (but transparent) empirical evidence is provided to quantitatively illustrate the absence of disaster effects on macroeconomic indicators.

Position 1 is criticised from position 2, on the one hand, for its focus on extreme cases that do neither allow for generalisations nor provide the evidence for rejecting the null hypothesis. On the other hand, the
ignorance of economic principles is emphasised in both qualitative arguments and the static or mechanistic modelling approaches.

To conclude: Although position 2 is a minority position, the review of the macroeconomic literature on disasters could not find theoretical arguments or compile empirical evidence sufficient for rejecting the null hypothesis. On the contrary, the results of the empirical excursion in section 5.1, although as rudimentary as those of Albala-Bertrand, provide support to position 2. As a general rule however, position 2 is only considered tenable if a number of exceptions and qualifications are allowed for.

Provisional answer to the research question based on chapter 5

On the macroeconomics of natural disasters a diverse research tradition flourishes. Literature which entails answers to the research question, supported by sound theoretical arguments and empirical evidence, is thin, however. Moreover, the largest share of contributions containing statements on the macroeconomic repercussions of disasters are more closely related to the development policy perspective than to academic macroeconomics and growth research that define the perspective of this thesis (see figure II-1).

In summary, the conclusions from the review of theoretical deliberations and empirical evidence in this chapter are the following:

1. Natural disasters do not have, in general, systematic, dominating effects on economic growth. This is supported by the empirical evidence and theoretical reflections. In other words, the null hypothesis supported by position 2 can not be rejected. Several exceptions qualify this rule.

279 Note that in contrast to theory and evidence, there is no lack of confident statements on the macroeconomic implications of disasters.
2. Large natural disasters may have repercussions on economic growth in developing countries, particularly in small or little diversified economies. Only then may extreme events in the natural environment trigger disasters that are economically or geographically widespread\textsuperscript{280} and entail macroeconomic repercussions. Characteristic example: storms in Caribbean SIDS and droughts in sub-Saharan countries.

3. Droughts as well as floods and storms are macroeconomically more disruptive than earthquakes. Earthquakes and volcanic eruptions, on the other hand, are both geographically and economically more localised and, in addition, involve faster reconstruction activities. A primarily empirically supported result.

4. Natural disasters have undesirable implications for distribution of income, wealth and risk: Poverty tends to increase vulnerability to disasters (both physically and economically) while additionally adverse shocks may increase poverty rates and perpetuate poverty. This hypothesis applies to all levels of aggregation from country over region to households and individuals\textsuperscript{281}.

The final chapters of the thesis, part III, will synthesise these conclusions with the findings from the review of development policy perspectives and insurance perspectives.

\textsuperscript{280} For the concept of localisation see chapter 3. In brief: if non-affected regions or sectors can compensate for the economic disruptions in the affected region or sector, a disaster will not be discernible at the macro level.

\textsuperscript{281} The empirical evidence for this point is thinner than for the macroeconomic findings; see also chapter 3.
"... what has so often excited wonder, the great rapidity with which countries recover from a state of devastation; the disappearance, in a short time, of all traces of the mischiefs done by earthquakes, floods, hurricanes, and the ravages of war. An enemy lays waste a country by fire and sword, and destroys or carries away nearly all the moveable wealth existing in it: all the inhabitants are ruined, and yet in a few years after, everything is much as it was before."

John Stuart Mill, 1848\textsuperscript{282}

### III Synthesis and Conclusions

In the introductory chapter to this thesis, it was found that positions on the macroeconomic implications of disasters were in fundamental contrast. Summarised in the form of a missing stylised fact, this observation implied a research question with a focus on the growth and development aspects of catastrophes.

Part III concludes the thesis with a synthesis of the findings. Chapter 6 will begin with the overall conclusions from the review of theoretical arguments and empirical evidence as detailed in part II. This will include a revised topography of competing positions in disaster research. On this basis, chapter 7 will discuss how robust these

positions are and propose answers to the research question. Moreover, a number of qualifications and complementary arguments will be presented that have not yet been discussed in the analytical section. Chapter 8 concludes with an evaluation of the thesis and with suggestions for further research.

6 Synopsis: competing positions

For the macroeconomic perspectives, the main positions were already detailed in the concluding section to chapter 5. Centred around figure 6-1, the following paragraphs propose an overall topography of positions in the catastrophe literature – providing a viewpoint complementary to the chart of analytical perspectives and approaches in the introduction to part II (figure II-1). As a gross simplification these graphical representations may primarily serve for structuring the analysis. However, they cannot give due credit to more differentiated argumentation in individual contributions to the literature.

A topography of positions on the research question

In summary, the various perspectives or "schools of thought" in the literature can be related to two contrasting positions (x-axis in figure 6-1). From position 1 disasters are considered to entail material negative effects on economic growth and setbacks for development. Position 2 is the null hypothesis of disasters having no discernible implications on aggregate growth.

It was found that these positions in the literature diverge, first and foremost, on the macroeconomic dimensions of disaster effects. On issue of poverty however, the consensus appears to be broader. This may explain why the debate on the former is more intense with a wider range of literature available. In contrast, with regard to the latter aspect, there is very little literature and debates are virtually non-
existant. Therefore, in accordance with the results of the analysis, the conclusions will focus on issues of growth.

According to the analyses in part II, position 2 is mainly represented by the development policy perspectives (chapter 3) as well as by approaches drawing on concepts from growth economics and regional economics\textsuperscript{283} (sections 5.3 and 5.2, respectively).

Figure 6-1: A topography of positions on the macroeconomics of disasters. Typical positions of perspectives and approaches as discussed in part II. Measured by numbers of publications, the position to the left is backed by a majority of primarily normatively oriented contributions. Literature in support of the null hypothesis (to the right) is rather thin and based, first and foremost, on mainstream macroeconomic analysis.

\textsuperscript{283} The association of positions with specific economic theories should be seen as a coincidence and as a result of specific “schools of thought” on disasters rather than on economics in general. There is no a priori reason for growth theory leading to systematically different positions than a Keynesian approach.
Position 2, on the other hand, is supported in most macroeconomic approaches (section 5.2) and was found to be supported by the largest share of empirical studies. It is the macroeconomic perspectives from chapter 5 that dominate the overall findings of the thesis and therefore receive most attention in part III. For arguments that will be detailed below, the conclusions of this thesis corroborate position 2, the null hypothesis.

The insurance literature is less easily associated with either of the two positions. Theoretical contributions on the microeconomics of risks, on the one hand, tend to emphasise the welfare gains of risk sharing arrangements and the optimal allocation of risk over time and economic actors, respectively. Analyses of the special problems of catastrophic risk, that is, of low-probability and high-consequence scenarios, primarily address reasons for market failures and the respective consequences. While this includes distributional aspects of disaster risk, macroeconomic effects of catastrophes receive less attention in this literature. In business publications by reinsurers, on the other hand, both positions are represented, depending on the context. In some cases, the potentially substantial macroeconomic effects of natural disasters are referred to for illustrating the benefits of insurance. In other cases, it is argued on the basis of quantitative case studies that historical disasters in industrialised countries appear not to have implications at the macro level. However, for developing countries and for the future the question remains open: Scenarios of disasters with macroeconomic effects are outlined for developing countries on the grounds of structural differences. Scenarios for the future are based on projected changes in both exposure to hazards (e.g. megacities) and the frequency of extreme events (e.g. climate change). Therefore, the locus of the theoretical insurance literature in figure 6-1 should be interpreted with caution and some contributions from the applied insurance literature could as well be associated with position 1.
Discussion of the two positions

Continuing the conclusions from the review of the macroeconomic perspectives (section 5.4) and synthesising them with the other two main perspectives in the disaster literature, the robustness of the main positions will be examined. It will be demonstrated that neither the theoretical arguments nor the empirical evidence is sufficient for rejecting the null hypothesis supported by position 2.

Overall lines of arguments and theoretical approaches

The two positions may be characterised by fundamentally different approaches to the problem of natural disasters. Contributions related to position 2 draw upon elementary macroeconomic concepts and take an analytical perspective. This literature aims at understanding and describing the effects of disasters in customary economic variables. A typical proponent of position 1 may be thought of as a macroeconomist studying natural disasters as one economic problem among many others. In contrast, literature supporting position 1 generally aims at normative conclusions with regard to disaster management, development policies or humanitarian aid. The theoretical intuition behind position 1 appears to be inspired by a Solow-Swan model with a decrease in economic activity in case of a shock to the capital stock. Moreover, concluding by analogy, the (local) humanitarian consequences of natural disasters are in many instances assumed to imply negative effects on macroeconomic aggregates. Advocates of position 1 tend to criticise these assumptions as "myths." A representative of position 2 may be described as

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284 To recapitulate the most prominent scholars among a minority representing position 1: Albala-Bertrand (1993a, 2006), Horwich (2000), Hirshleifer (2006). Cochrane (various years) and Mill (1896) may also be included.

285 See Cochrane (various years) and Albala-Bertrand (various years).
a disaster expert studying economic implications as one among many aspects of the adverse effects of disasters.

**Empirical evidence and simulations**

In conclusion, the empirical literature was found to support position 2. In other words: Evidence for rejecting the null hypothesis is not sufficient. The contradiction of this conclusion with the reviews of empirical studies presented by proponents of position 1\(^{286}\) can be resolved for most cases by examination of the samples. Studies that find systematic effects of disasters on growth are usually based on data sets that include a large share of extreme cases\(^{287}\). According to position 2, these may be considered exceptions to a general rule. Attempts to reject the null hypothesis on the grounds of country specific or event case studies raise the same problem: They allow for profound insights into exceptional cases rather than provide the basis for generalisations\(^{288}\).

The use of simulations for studying the macroeconomic (or regional) effects of disasters were found in this study to give rise to analogous objections. Most of the models are designed in specific contexts, for specific regions and applied to specific disaster scenarios. Moreover, as the simulations generally remained projections they were not considered to produce evidence as sound as historical figures – in parti-

\(^{286}\) Examples include the literature surveys in the introductory sections of Mechler (2003) or Murlidharan and Shah (2003).

\(^{287}\) This is not considered here to make these studies less valuable; see section 5.1.

\(^{288}\) On the problem of case studies see, among others, Rossi et al. (1978) and, from a development policy perspective, Benson and Clay (2004).
cular if they incorporate strong assumptions and are not corroborated with data\textsuperscript{289}.

\textit{Institutional background}

Disaster literature is characterised by wide variances in its target audience and the purposes of economic arguments. In academic approaches, which prevail among the supporters of position 2, disasters represent primarily a subject of basic research: catastrophes are considered as "natural economic experiments" (Hirshleifer, 2006). Apart from the greater attractiveness of significant and spectacular findings\textsuperscript{290}, an analytical, positive perspective entails no a priori bias towards one of the two positions.

The other end of the spectrum of institutional backgrounds overlaps, to some degree, with literature associated with position 1. ECLAC (2003)\textsuperscript{291}, for example, explicitly states that disaster damage assessments serve for mobilising international aid. Consequently, it may be assumed that loss figures tend to incline towards higher rather than lower estimates. Analogous arguments may be made on publications by institutions that are specialised on disaster risk management or insurance. In contributions with such institutional backgrounds, the macroeconomic relevance of catastrophes is often referred to for underlining the benefits of policies, projects or products

\textsuperscript{289} On regional models see section 5.1; examples of growth models for macroeconomic simulations of disaster effects are outlined in section 5.3. See also Albala-Bertrand (2006).

\textsuperscript{290} It may be assumed likely that empirical studies of the macroeconomic effects of natural disasters have been carried out but not published as the finding of no effects did not appear interesting.

\textsuperscript{291} The ECLAC "Handbook for Estimating the Socio-Economic and Environmental Effects of Natural Disasters" is discussed in section 5.1.
and the urgency of action, respectively\textsuperscript{292}. This is not to imply that the normative conclusions and the humanitarian imperatives related to position 1 are flawed, quite the contrary. However, if economic figures on disasters from this category of sources are to be used in analytical and empirical approaches, it appears advisable to account for the institutional background.

\textit{In summary}, the literature in support of position 2 (the null hypothesis) was found to draw on more consistent theoretical arguments from macroeconomics, to argue on a more solid empirical basis and to be less exposed to institutional bias. As will be detailed in the subsequent chapter, the findings of this research therefore corroborate position 2.

7 Conclusions: the missing stylised fact

Considering the analytical approaches, the empirical evidence and the economic explanations, the following sections will synthesise the findings of the thesis with regard to the missing stylised fact. The conclusions will be presented as two answers to the research question (section 7.1) and in the form of a general rule on the growth effects of natural disasters. Qualifications in addition to the exceptions to the rule will be discussed in section 7.2. These are found to be equally relevant as the overall finding. Finally, section 7.3 will outline a number of policy implications.

\footnotetext{292}{For the problem of exaggerated disaster estimates at all analytical levels see Dacy and Kunreuther (various years), Charvérit (2000) and, of course, Albala-Bertrand (various years). The role of the media and their influence on disaster research is not discussed here; see e.g. Bennet and Daniel (2002), Russel (1970), Zeckhauser (1996), or Zemp (2006).}
7.1 Two answers to the research question

In brief, the answer to the research question is that aggregate output and growth normally remain unaffected by natural disasters. Macro-economic explanations\textsuperscript{293} for this empirical finding include the economic and geographic localisation of most disasters as well as the compensatory effects of emergency and reconstruction activities. Furthermore, a large fraction of the capital stock may not be essential for aggregate output: Human capital is considered more important for output in general and may substitute for part of the capital lost due to a disaster.

As will be shown, however, there are numerous exceptions to this stylised fact. Moreover, the finding is related in various ways to problems of development and poverty. These causalities are reflected in the explanations of the general rule, in the exceptions to the rule and in the qualifications to the findings. One of the main hypotheses derived from the synthesis will be that the absence of macroeconomic effects can only be understood in connection with the distributional aspects of disasters.

\textit{Growth effects of disasters}

As a general rule, it was found that natural disasters do not significantly affect trajectories of aggregate output and growth. This conclusion is in congruence with position 2 outlined above.

It will be argued, however, that this stylised fact does by no means imply the economic irrelevance of catastrophes – as a number of exceptions and qualifications will illustrate. As interesting as the general rule itself, these will provide insights into the specific circumstances, under which disasters do have macroeconomic implications. In ad-

\textsuperscript{293} The concluding section of chapter 5 provides an overview of these explanations.
dition, the exceptions may facilitate a more precise location of the economic repercussions of disasters other than macroeconomic effects.

**Geographic size of economies:** Ceteris paribus, a disaster is more likely to have macroeconomic impacts in a small than in a large economy. A catastrophe affecting a small island state will be more economically and geographically widespread than localised, with most regions, sectors, markets and other economic actors being affected. Although a trivial observation, this is rarely accounted for in the interpretation of empirical findings even though it may lead to distorted conclusions, in particular on the welfare effects of disasters. The interpretation of macroeconomic indicators in welfare terms will be discussed below.

**Levels of development:** Natural disasters in developing countries are more likely to have macroeconomic effects than similar events in industrialised countries. Development in general is associated with decreasing vulnerability to shocks from the micro to the macro level, with greater economic diversity as well as with increasing capacities for more rapid recovery. With development, the vulnerability of physical structures becomes smaller, the vulnerable (poor) proportion of the population decreases, ex-ante and ex-post disaster manage-

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294 The convention in cross-country studies is, per definition, to use nations as the unit of analysis. In the special case of natural disasters this entails the risk of distortions and misinterpretations, as the absolute magnitude of events investigated remains similar but country sizes vary over a large scale. Note that these problems do not arise in the analysis of intensive measures such as of global commodity prices, human capital per capita, or the density of physicians. Using relative measures such as loss-to-GDP ratios (\(\Delta K/Y\) or \(\Delta K/K\) in the neoclassical framework) is not a sufficient solution; as opposed to an earthquake in Nicaragua an earthquake in India will remain unlikely to be discernible at the macro level. If, as in part of the catastrophe literature, GDP effects are interpreted in welfare terms, a disaster in a large country will appear "preferable" to a disaster in a small country. A promising approach indicated in Dilley et al. (2005) may be to use, in lieu of countries, analytical units of similar geographical size, wealth or population.
ment (including the respective institutions) advance, and both formal and informal insurance arrangements become more developed 295.

From the preceding two specifications it becomes evident that disasters may have macroeconomic repercussions primarily (or exclusively) in small developing countries, referred to as SIDS in the case of islands 296.

**Different trigger events:** Droughts as opposed to sudden-onset disasters are more likely to give rise to macroeconomic effects – owing to their long duration and the large geographical areas affected. It is generally found that floods and storms negatively affect growth more than earthquakes and volcanic eruptions. Hydro-meteorological events tend to be both geographically and economically more widespread thereby entailing a greater risk of disruptions of supply chains, transport infrastructure, agricultural production etc. Geophysical triggers of disasters, on the other hand, are generally more localised in both dimensions allowing for rapid reconstruction that may be reflected in increased economic activity.

**Distributional aspects of disaster risk**

As on the relation between poverty and disaster risk there is a broader consensus in the literature than on macroeconomic implications, the distributional aspects of disasters have been discussed in less detail. Here, a large theoretical research tradition exists (chapter 4) as well as a number of country or regional case studies. Cross-country studies, however, that could be synthesised with the empirical

295 Note, however, that in absolute monetary terms, disaster risk is higher in rich than in poor countries owing to the exposed wealth. No evidence was found for the hypothesis in Benson and Clay (2004) that vulnerability first increases with development before it begins to decrease.

296 On small island developing states (SIDS) see Adrianto and Matsuda (2002), Briguglio (1995), Crowards (various years), and Pelling and Uitto (2001).
research on the macroeconomic effects, were not found in the literature.

The current consensus on the distributional aspects of disasters may be outlined by the following two hypotheses\textsuperscript{297}:

*The poor are more likely to suffer from the effects of natural disasters.* Income distribution is inversely correlated with the distribution of disaster risk. From individuals and households over socio-economic groups, regions and sectors to countries vulnerability decreases with wealth, income and development. The poor are more likely to live in areas exposed to natural hazards, have less access to formal insurance markets and less options for self-insurance such as precautionary savings. Both residential and business capital of the poor tends to be physically more vulnerable to natural hazards.

*Disaster risk increases poverty.* In a neoclassical framework disaster risk both increases the probability of a poverty trap to exist and increases the risk of an economy (or individual) being caught in a poverty trap. More generally, the poor are exposed to greater disaster risk and have fewer options for consumption smoothing, resulting in higher variabilities of consumption with regard to income shocks. Adverse shocks are therefore more likely have irreversible consequences on income or health. In combination, these factors imply that disasters (and disaster risk) may both increase poverty rates and perpetuate poverty – constituting a vicious circle or a poverty trap.

### 7.2 Qualifications

A critical discussion of the above answers to the research will underline the robust aspects of the findings and identify the less robust ones. In the following sections, different points of view will be

\textsuperscript{297} See section 4.1 and, in particular, Hoogeveen (2000).
taken on the concept of GDP, on the relations between macroeco-
nomic disaster effects and poverty, as well as on historical data and
projections.

**Aggregate output and welfare**

Using GDP as an indicator for the economic effects of disasters gives
rise to a number of questions. This is particularly the case in
normative interpretations, such as in welfare terms. These problems
are to a large degree inherent to the concept of GDP rather than
special problems of the analysis of disasters. The following comments
underline the due caution required when interpreting the GDP effects
of disasters. In addition, they may facilitate the understanding of the
main contradictions or confusions in the disaster literature – which
defined the research question for this thesis.

GDP is an indicator of aggregate economic activity and measures
flows of goods and services\(^{298}\). Although widely used in per capita
terms as a crude proxy for average material well-being, it is, by defi-
nition, not a welfare measure. GDP does not include a number of
important aspects of welfare such as equity, the input of labour, paid
or unpaid (and thereby leisure). Moreover, flows of non-traded
services from capital goods such as from residential capital are not
included in GDP. Also excluded are external effects on health and on
the environment. The following two caveats may therefore be truisms,
however they appear to be considered counter-intuitive in many contri-
butions to the disaster literature and may explain part of the argu-
ments made against the null hypothesis.

\(^{298}\) Expenditure, income, or output – depending upon the definition and estimation
methodology used. The points made here apply to any measure for aggregate output
(GNP, GNI etc.); GDP is used for convenience. See e.g. the Economist Guide on
Economic Indicators (Economist, 1997) or any advanced macroeconomics textbook.
An increase of GDP following a disaster does not imply a socially positive outcome. As Tol and Leek (1999) discuss in detail\(^{299}\), GDP neither reflects the loss of lives, nor the ill effects on health or the loss of wealth due to disasters. In contrast, it does include economic activity for emergency measures and reconstruction. This may include increased spending (financed by savings, insurance payments or foreign aid) as well as increased inputs of labour (at the cost of leisure).

That economic effects of disasters disappear at higher levels of aggregation does not imply that they are economically irrelevant. Output lost in an affected region may be compensated for by unaffected regions. There may be no discernible aggregate effects of disasters on GDP. This is firstly the consequence of the localised nature of most disasters and secondly, the flexibility of economic systems. On the one hand, this does rather indicate than rule out redistributive effects with regard to wealth, output, income or welfare\(^{300}\). On the other hand, the adjustments that lead to a "smoothed" GDP trajectory may, as has been demonstrated, have repercussions on other aggregate variables such as in the external balances.

In summary, it appears advisable for discussions of disaster impacts to consider GDP exclusively as an indicator of aggregate economic activity. Interpretations in welfare terms will in most cases prove misleading. Vice versa, it should not be concluded from the welfare effects of disasters and their inequitable distribution that disasters entail macroeconomic effects.

\(^{299}\) See also Ellson et al. (1984).

\(^{300}\) For a discussion of disaster effects at different levels of aggregation see Loubergé (1995).
Distribution and poverty

The relevant literature indicates a broad consensus on the hypothesis that natural disasters affect primarily the poor, both in terms of lives lost and in economic terms. If the distribution of disaster risk is inversely proportional to the distribution of wealth and income, this implies two qualifications. The first point supports the null hypothesis but receives no attention in the catastrophe literature. The second point puts the findings of this thesis into perspective and both lead to suggestions for further research.

That natural disasters primarily affect the poor, may be an explanation for the absence of macroeconomic repercussions. Poverty implies low incomes and few assets. If disasters have effects primarily on the poor and the informal sector, the distribution of disaster risk may supply a sufficient explanation for the observed macroeconomic patterns. In absolute monetary terms, damages suffered by the poor and the output lost in the informal sector may be negligible in economic aggregates. On the other hand, the formal sector and the higher-income groups in developing countries may be considered similar to industrialised countries in terms of exposure and vulnerability to hazards and in terms of disaster management, including preparedness and insurance. In such a "dual economy" disaster effects would remain indiscernible in macroeconomic aggregates.

Macroeconomic repercussions of disasters may not be detectable because assets of the poor as well as economic activity and production factors of the informal sector are not included in economic statistics. Freeman et al. (2002), proponents of position 1, note on economic statistics in developing countries that "because the poor are not well represented in a country’s formal economy, examining the macroeconomic statistics for a country hides the cost of catastrophes to them". The assumption is shared by Charvériat (2000) who argues, specifically for disaster situations that damage estimates rarely include assets, income and output lost by the poor. This adds a problem of
data availability to the distribution issue mentioned above. Different macroeconomic effects of natural disasters may be found if more inclusive statistics were available.\(^{301}\)

**Future disasters: projections, scenarios and historical evidence**

The arguments in this thesis have been primarily developed along arguments from macroeconomic theory and based on empirical evidence gained from the study of historical data. Projections available in the literature were considered too specific with regard to assumptions and scenarios to allow for conclusions on a general research question.\(^{302}\) For discussions of disaster risk in the future, however, this rigorous approach may have to be relaxed.\(^{303}\)

*Owing to the low frequencies of disasters, catastrophe risk may be changing faster than insights can be produced on the basis of historical data.* The processes behind the observed increase in catastrophes globally (see section 1) will continue to transform disaster risk patterns. These include structural changes related to economic growth and development; such as urbanisation, globalisation, as well as the move of settlements and economic activities to coasts. On the other hand, changes in the natural environment, in particular climate change, are expected to increase the magnitudes and frequencies of extreme events. Neither for rapid environmental change nor for

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\(^{301}\) For the developing world, De Soto (2000) estimates that 50% - 75% of employment is in the informal sector, which contributes between 20% and 65% to total GDP. Further, between 40 – 85% of property (number of parcels or dwellings) in the developing world is considered "extralegal" with no property rights assigned.

\(^{302}\) See arguments discussed in section 5.3.

\(^{303}\) Various publications by reinsurers are available on global trends in catastrophic risk (Munich Re, various years; Swiss Re, various years). See also literature quoted in chapter 1 as well as Tol and Leek (1999), Kokoski and Smith (1987), or Kobayashi and Yokomatsu (2000).
disasters in predominantly urban economies are there historical records that could allow for reliable predictions.

7.3 Policy implications

Studying the economic implications of disasters from an analytical perspective, the thesis only marginally discussed policy implications and practical recommendations. The current trend in strategies for disaster risk management may be captured by the catchword of "vulnerability reduction" and, from an implementation perspective, by the twofold concept of "mainstreaming". On the one hand, the achievements of development policies and projects in general are seen as more sustainable if the risks of extreme events are taken into consideration. On the other hand, in many instances disaster risk management is recommended to take a more preventive and long-term development perspective. From this point of view post-event humanitarian relief and fast reconstruction is considered by some scholars to entail the risk of reconstructing vulnerability to further disasters\textsuperscript{304}.

The finding that natural disasters are not a dominating influence on macroeconomic performance may imply two general policy conclusions.

*Firstly, the belief that natural disasters entail significant macroeconomic shocks should be critically examined.* By providing new insights this may allow for a more accurate and finely resolved

\textsuperscript{304} For a selective overview of disaster risk management see the literature quoted in chapter 1 and chapter 3 as well as Russel 1970 and his analysis of optimal levels of adjustment to disasters or Rossi et al. (1978) who discuss, at which levels of administration or aggregation disaster policies have a raison d'etre at all. For theoretical and applied discussions of the concept of "mainstreaming" in disaster risk management, see the publications and websites of international finance institutions, regional development banks or development institutions.
understanding of disasters’ macroeconomic repercussions. Moreover, it may facilitate the mesoeconomic and microeconomic localisation of disaster risk and disaster effects in terms of geography, socio-economic groups, sectors and industries, and public goods. This may involve revisions of long-standing beliefs and topoi in the disaster literature – with the primary objective of basing policies on a more solid understanding of problems. While such policies may well involve institutions at the national or international level, concerns about macroeconomic performance appear not to provide the most useful guidance for disaster policy design.

Secondly, if disaster risk is primarily relevant for the poor, policies for disaster risk management should focus on the poor, the exposed and the affected. Catastrophe policy at the meso and microeconomic level may create the greater welfare gains in terms of vulnerability reduced, lives saved and economic shocks "smoothed". As argued above, this implies that macro policies ought to be scrutinised from a micro perspective. The disaster literature proposes a wide array of meso and micro approaches to disaster risk reduction305, including among many others the development of insurance markets for the poor, settlement planning for exposure reduction, disaster resilient engineering from shacks to large-scale infrastructure, awareness raising and capacity building in high-risk areas, emergency planning at all institutional levels, as well as warning systems.

305 Interestingly, while discussing in some cases well-proven and in other cases innovative policy approaches at the meso and micro level, part of this literature illustrates the relevance of disaster risk management and its benefits with macroeconomic considerations.
8 Evaluation and outlook

The final chapter presents a brief evaluation and lists a selection of suggestions for further research. It will become evident that the thesis, as most research projects, raises more questions than it provides answers.

Evaluation

In retrospective, the contributions of this thesis to the catastrophe literature comprise the following four points:

1. A set of structuring dichotomies that facilitates orientation in a diverse literature. The framework included three dimensions: the institutional background of contributions (including business, the public sector and academia), the overall perspective (normative or positive) as well as the level of analysis (micro or macro). The two main positions with regard to the null hypothesis or with regard to a general reply to the research question may be considered a fourth dimension. Measured by the objectives of this thesis, the framework proved valuable as an analytical tool and for providing an overall structure. Whereas it is by no means claimed to be generally applicable, explicitly characterising statements according to the above and further dimensions may facilitate a debate, in which a problem is addressed from fundamentally different perspectives.

2. A neoclassical framework that provides unambiguous macroeconomic definitions of disaster variables. The Solow-Swan model served for reducing complexity, for purposes of definition and as a point of reference for the synthesis of a wide spectrum of conceptual approaches. Although entailing the risk of oversimplification, the neoclassical perspective proved helpful for orientation in a literature where idiosyncratic definitions of disaster, cataclysm, loss, damage, economic impact, etc. proliferate – leading to widespread confusion of
interpretations, both noticed and unnoticed\textsuperscript{306}. For a qualitative discussion of the macroeconomic effects of disasters, the Solow-Swan framework appears to provide an intuitively accessible and (for pragmatic purposes) sufficiently comprehensive framework. This is for both its strengths and its weaknesses: On the one hand, a textbook version may reproduce position 1 or "the received view". On the other hand, by relaxing a number of assumptions, the model can accommodate the null hypothesis supported by position 2. Owing to its high level of aggregation, fixed coefficients and further characteristics, the Solow-Swan model has its limits, which have become evident throughout the text\textsuperscript{307}. It has therefore been applied where it provided clarifications – without, however, arguing for its validity beyond supplying a rudimentary defining framework of macroeconomic disaster variables.

3. A transect through the catastrophe literature. The analytical approach to the catastrophe literature was inclusive in terms of contributions covered and highly selective with regard to the aspects studied. Referring to the analogies from geography, the thesis should therefore be seen as a two-dimensional transect rather than as a comprehensive multi-dimensional topography. The combination of a broad perspective and narrow focus, however, may have allowed for a contribution that complements the existing disaster literature in two aspects. On the one hand, it allowed for a review that covers a wider range of literature than the, by definition, brief and selective reviews of "previous research" in the traditional introductory sections to publications. On the other hand, as the discussion was narrowly focused, the analysis could be devoted to a detailed review of theoretical arguments and empirical evidence – rather than to argue at the level of

\textsuperscript{306} For this reason no new terminology for describing the macroeconomics of disasters was proposed besides the basic neoclassical variables.

\textsuperscript{307} Note that the validity of the Solow-Swan framework as a model of growth and development in general is not discussed in this thesis.
contrasting views and to dismiss contributions as irrelevant for its positions.

4. A hypothesis to one of the key debates in the disaster literature. As has been summarised in the previous chapters of part III, the overall findings of the thesis clearly support one of the two main positions on the macroeconomics of disasters. Note that the hypothesis in the form of a general rule is complemented with a number of exceptions and qualifications. These draw largely upon the theoretical arguments and empirical evidence supplied by literature associated with a contrasting position. Whether the reader follows these lines of argumentation or not, the objective of the inclusive and analytical approach remains to supply an answer to a research question related to an economic debate in the catastrophe literature. In contrast to the results expected at the outset of the project, the study finds itself in support of a heretical position – however, for the findings of an analysis of research rather than in defence of a position.

In summary, the thesis should be considered as a contribution to one of the fiercest controversies in the catastrophe literature. If it provides a few new analytical perspectives, a number of insights and a multitude of debatable points to a discussion that leads to a better understanding of the economic implications of catastrophes, the project has, in the view of the author, achieved its objective. The fundamental motivation of this work, however, remains that these debates may ultimately translate into more effective policies for disaster risk reduction.

Suggestions for further research

Findings and limitations of the thesis, problems encountered in the literature, questions that were raised throughout the paper as well as anticipated objections may inspire a plenitude of further research. A selection of four suggestions is outlined here:
Analytical approaches may prove more productive than debates centred on positions and views. Intuitive statements on the economic effects of disasters are widespread over the whole spectrum of the catastrophe literature – from newspapers to scholarly journals. Part of the contributions, including this thesis, come to conclusions that are considered counter-intuitive by a majority of disaster experts. Both out of purely scientific curiosity and in the interest of a sound basis for policy design, future discussions may prove more productive if led from analytical (or positive) perspectives rather than at the level of beliefs, myths, views or topoi\textsuperscript{308}.

Natural disasters indicate a field of research which is yet to be discovered by economics. As has been emphasised in various instances in this thesis, natural disasters are only marginally covered in the mainstream macroeconomic literature (Horwich, 2000). Considering the wealth of theoretical concepts and empirical methodologies that could be applied to the study of disasters, the finding that economic disaster research is in its infancy appears surprising. It may, however, imply a large and interesting field of research. Examples of disaster-related problems that are rarely studied from economic perspectives include:

- The microeconomic mechanisms that determine the macroeconomic outcomes\textsuperscript{309}
- The role of labour, human capital, and social capital
- The welfare economics of disasters, including aspects such as lives lost and ill effects on health

\textsuperscript{308} These four derisive terms for the respective opposite position are compiled from original debates in the catastrophe literature and listed here to illustrate the polemic – and admittedly highly entertaining – character of some contributions.

\textsuperscript{309} As discussed in chapter 4, there is a large tradition of research on the microeconomics of risk, which could, in principle, serve as a starting point for a microfounded macroeconomics of catastrophic risk.
- The political economics of disasters\textsuperscript{310}
- The long-term and structural effects of disasters and disaster risk
- The generic differences of disasters with different trigger events in developing and industrialised countries, in urban and rural environments, in small and large countries.

\textit{Theories and models from mainstream economics may facilitate the communication and synthesis of results. Research on disasters could make faster progress on the basis of common terminologies.} Kroll-Smith (1998) reflects on the "untidy character of disaster studies" in the social sciences. For the arguments detailed in the preceding chapters the author tends to agree with this conclusion. At the risk of drawing criticism with regard to "economic imperialism" (Kirchgässner, 1997) mainstream economic theories are suggested here as among the most promising analytical approaches for the study of natural catastrophes – in particular for the study of economic aspects of disasters\textsuperscript{311}.

In general, explicit use of economic theory may promote analytical rigour, reduce complexity and make lines of arguments more transparent. This may contribute to solving central problems of current disaster research such as those related to ad-hoc analytical frameworks and to amalgamates of economic concepts with theories from other disciplines. Such approaches may be innovative and provide novel insights. However, if methodologically idiosyncratic, they are likely to encounter difficulties of interpretation. Presenting economic


\textsuperscript{311} This may appear a trivial statement, however, as has been demonstrated in part II, transdisciplinary approaches to economic problems are widespread in disaster research. Note that the suggestions here are not meant as implicit arguments for the superiority of economics but as suggestions towards more productive communication in research from various disciplines on a unifying problem.
statements in customary economic terminology could facilitate communication. The results would then become more accessible to both examination and synthesis. Moreover, this might contribute to less fragmented discussions and more productive research that could be related to existing traditions of research.

More specifically, basic economic concepts could inspire solutions for the methodological difficulties resulting from the diversity of "economic loss" concepts\textsuperscript{312}. In lieu of introducing definitions, which are specific to the field of disaster studies, common definitions could draw on macroeconomics, national accounting or welfare economics. The potential benefits are analogous to the point above: communication, interpretation and syntheses could be facilitated, thereby advancing an emerging field of research\textsuperscript{313}.

The preceding two suggestions (in italics) may also be relevant to an aspect of disaster effects that is usually avoided in economic considerations (including this thesis) because of reservations with regard to potential cynicism as well as methodological problems, that is, the valuation of human life, health and well-being. It is hypothesised here, however, that integrating an economic perspective with a humanitarian perspective on disasters could provide a more profound understanding of catastrophic risk and more relevant cost-benefit analyses of policies and projects for disaster risk reduction.

\textit{If disasters are primarily "a problem of development" and the poor suffer most from the effects of catastrophes, research should more systematically address the distributional aspects of disaster risk. Firstly, this suggestion points back towards the central problems of development economics, including, for example, the little-studied...}

\textsuperscript{312} See discussion in chapters 4 and 5.

\textsuperscript{313} This could also make the abundance of valuable single-event and single-country case studies accessible to meta-analyses. The current state of methodological advancement has precluded such attempts in this thesis.
economics of the informal sector. Secondly, the suggestion succinctly summarises the key implications of this thesis for both disaster research and for policies of disaster risk management.
Appendix

The appendix supplies details of data and results of the empirical excursion – the quantitative contribution of the thesis to the catastrophe literature. Results are summarised and discussed in section 5.1.

Appendix A.1 lists GDP growth data and gives the respective sources. Appendix A.2 provides detailed results of the empirical excursion. For a description of the approach and methodology, see section 5.1.

A.1 Disaster list and GDP growth data

The table below lists the events that were included in the empirical excursion. For every disaster, the country and year of occurrence is indicated. Australia, Italy, Japan, The Netherlands, and the USA are considered as industrialised countries and excluded from some samples (see section 5.1 and appendix A.2).

Column "T" indicates the trigger event of the disaster: Ws: Windstorm; Fl: Flood; Dr: Drought; Eq: Earthquake; Vo: Volcanic eruption; Ls: Landslide; Et: Extreme temperature; Wf: Wildfire.

GDP growth data were compiled for the disaster year $t_0$ (see column "year") as well as three preceding and three subsequent years.

Column "S" gives the sources of the event data and the sources of the GDP growth data. Sources for disaster events are indicated with numbers: 1: Munich Re (1999: 123); 2: Guha-Sapir et al. (2004); 3: Albala-Bertrand (1993a: Appendix A); 4: UN-ISDR (2006). Sources for GDP growth data are indicated with letters: a: IMF World Economic Outlook database (IMF, 2006); c: Penn World Tables (Heston et al., 2002); b: Albala-Bertrand (1993a). Empty fields in the growth data columns indicate that no growth data were available from the respective sources.
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A.2 Empirical Excursion: Detailed results

The following four tables supply details on the statistical analyses that were carried out for this thesis. Results are summarised and discussed in section 5.1. For a description of the overall approach, the methodology and the samples see the explanations there. With exception of the P-value, all figures have the units of the GDP growth rates (% per year) as given in appendix A.1.

The pre-event average is the arithmetic mean of t₃, t₂ and t₁. For t₀ to t₃ the mean of the differences to this pre-disaster average is given. The discrepancy for t₃ is due to the non-availability of data for some events.

For studying the differences between post-disaster growth rates and pre-disasters average, a t-test was carried out. The last row provides the P-value of a two-sided t-test for paired samples. A value of < 0.05 would indicate a significant difference (confidence level of 95%) between the respective post-disaster growth rate and average pre-disaster growth rate. A P-value of < 0.1 would correspond to significance at a confidence level of 90% etc.

The statistics were carried out by the author and using Microsoft Excel 2004 for Mac, Version 11.2.5 (060620).
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<td>3.24</td>
<td>3.01</td>
<td>3.31</td>
<td>4.52</td>
<td>3.89</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5.61</td>
<td>5.36</td>
<td>4.91</td>
<td>5.91</td>
<td>4.58</td>
<td>6.73</td>
<td>2.88</td>
</tr>
<tr>
<td>Lower quartile</td>
<td>1.08</td>
<td>2.30</td>
<td>0.43</td>
<td>0.85</td>
<td>1.28</td>
<td>1.78</td>
<td>2.30</td>
</tr>
<tr>
<td>Median</td>
<td>3.65</td>
<td>4.00</td>
<td>3.70</td>
<td>2.75</td>
<td>4.05</td>
<td>4.10</td>
<td>4.20</td>
</tr>
<tr>
<td>Upper quartile</td>
<td>5.90</td>
<td>6.10</td>
<td>6.18</td>
<td>6.05</td>
<td>5.88</td>
<td>5.80</td>
<td>5.60</td>
</tr>
<tr>
<td>Maximum</td>
<td>13.90</td>
<td>15.80</td>
<td>14.00</td>
<td>14.40</td>
<td>13.10</td>
<td>44.10</td>
<td>9.90</td>
</tr>
<tr>
<td>Average Difference</td>
<td>Pre-event average: 3.40</td>
<td>-0.38</td>
<td>-0.09</td>
<td>1.12</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>0.58</td>
<td>0.89</td>
<td>0.18</td>
<td>0.31</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


314 Copy made available by the Natural Hazards Unit at Converium, Zurich in 2003. Conference date and location not known, year of publication estimated by the author;


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About the Author

Oliver Zenklusen was born in Ilford, UK in 1971. He studied environmental sciences at the Swiss Federal Institute of Technology (ETH Zurich) specialising in chemistry, theory of risk and risk management. In 1997 he completed his studies with a master's thesis on environmental and safety issues in the design of production processes in the pharmaceutical industry.

From 1996 to 1999 he worked for an engineering consultancy where he led investigations, assessments and oversaw the cleaning up of contaminated industrial areas.

In 2000 he joined Ecofact, a financial sector consultancy, assuming a general management position in 2003. At Ecofact his work centred around the management of environmental, social and reputational risk. This included the development of policies, strategies, management systems software tools, and training programmes as well as overseeing the due diligence team. Clients were primarily large commercial banks, the World Bank Group, multilateral institutions such as UNEP as well as Swiss governmental institutions.

He returned to academia as a part-time doctoral student in 2001 completing the doctoral programme in economics at the University St. Gallen one year later and submitting a thesis on natural disasters and economic development in 2006.

Parallel to his consultancy and academic work he is co-founder and curator of station21, a Zurich-based project and space devoted to the support of young artists.

In 2007 he will start his first series of lectures at the Swiss Federal Institute of Technology (ETH Zürich) on the economics of development and sustainability.