Introduction

In recent decades, the economic damage caused by natural disasters has increased considerably worldwide. It has been projected that extreme weather events will become more frequent and harmful in the future as a result of climate change and socio-economic trends. An important question that arises in this context is how to design effective policies that limit the expected increase in natural disaster risks and reduce the impacts of extreme weather events on human societies. The book addresses this question by examining the role that insurance arrangements can play in increasing economic resilience to natural disasters.

The approach followed involves dealing both with the effects of climate change on natural disaster risks and with the implications of these effects for insurers. The contribution that insurance arrangements can make to societies' management of the risks of natural hazards in the context of a changing climate is analysed, paying particular attention to the complex nature of insuring low-probability/high-impact risks. Public–private partnerships are explored as a possible solution for such complexities. The important role of insurance for individuals in preparing for disasters and purchasing natural disaster coverage is recognized, as well as aspects of the 'bounded rationality' of individuals in dealing with infrequent risks. In particular, material is included about individual risk perceptions, risk aversion, willingness to pay for natural disaster insurance, and applications of utility theories to insurance demand, including prospect theory. The book presents empirical case studies from the Netherlands, which are complemented by international perspectives, studies and examples. The book will appeal to readers from a broad range of disciplines that study aspects of natural disaster risk management, while the material is accessible for both academics and practitioners.

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1 Climate change and natural disaster risk management

1.1 Background

Recent natural disasters have demonstrated the vulnerability of various countries to extreme weather events such as floods, storms and droughts (Munich Re 2012). The economic losses caused by such disasters can be of such great magnitude that individuals and businesses may be unable to carry them, which could cause major financial distress and bankruptcy unless there is compensation available. In the face of a projected rise in the frequency and severity of natural disasters as a result of socio-economic developments and climate change, the question arises of how to design policies that limit exposure to, and ameliorate the impacts of, natural disasters. The role of financial arrangements for natural disaster risk is important in this respect, since an often raised question is who should pay for the elevated risks faced (Kunreuther et al. 2011). Apart from providing financial relief after a disaster has struck, financial arrangements such as insurance may contribute to adapting societies to rising risk and may enhance economic resilience to disasters by providing incentives for risk reduction (Mills and Lecompte 2006). This is not an easy task for the insurance sector, given the challenges associated with insuring low-probability, high-impact (correlated) disaster risks. As an example of such problems, Kousky (2011) reports that in ten states of the USA, state-run natural disaster insurance arrangements have been established because private insurance at affordable premiums is unavailable for many homeowners.

During the last few decades, a considerable increase in the frequency and economic damage caused by natural disasters has occurred worldwide (Höppe and Pielke 2006; Kunreuther and Michel-Kerjan 2007). Figure 1.1 shows an upward trend in overall and insured losses caused by great natural disasters since 1950. Natural disasters, such as major

Some parts of this chapter have previously been published as Botzen and van den Bergh (2009a). All of these parts have been updated and extended in this chapter.

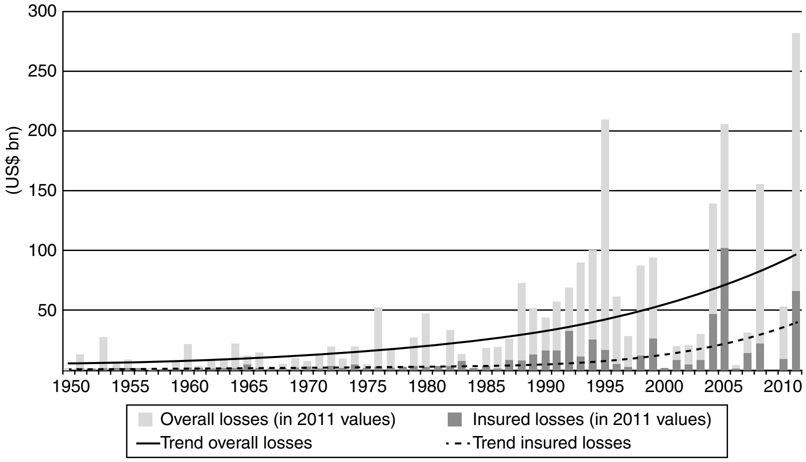

Figure 1.1 Overall and insured losses caused by great natural disasters between 1950 and 2011 (in 2011 values)
Source: Munich Re NatCatService (2012).

storms, floods and earthquakes, have devastating consequences for societies around the world, with especially severe impacts on developing countries, while the consequences for insurers are concentrated in developed countries (Freeman et al. 2003). Specifically, natural disasters may cause many deaths with a single event, result in the spread of diseases in affected areas, and have substantial adverse economic consequences by causing direct damage to property and infrastructure as well as indirect damage, such as business interruption and productivity losses. Some examples of major events in the last decade indicate the diversity of threats posed by nature and their global character. Destructive catastrophes that have exposed the challenges that modern societies face in managing natural disaster risks include the tsunami in Asia in 2004 that caused more than 283,000 deaths; the earthquake in Haiti in 2010 that killed 222,500 people; floods in 2010–11 in Australia with $10 billion of losses, as well as in Pakistan where floods affected 20 million people and put one-fifth of the country under water – resulting in $10 billion of damage; flood damage costing $40 billion in Thailand in 2011 of which only a small portion was insured; and the large earthquake and tsunami in Japan in 2011 which could amount to over $200 billion.

Damaging wildfires occurred in Greece in 2008 and 2009, and major forest fires in Australia in 2009 killed over 200 people and damaged large tracts of land, with devastating effects on wildlife. Summer heat in Russia killed over 55,000 people in 2010. Europe has also experienced severe floods and winter storms in recent years, such as the 2002 floods in central Europe incurring, in total, $15 billion worth of losses, two major floods in the UK in 2007 that caused about $4 billion of damage per event, and the storm Xynthia in south-west Europe in 2010 that caused 63 deaths and €6 billion of damage, as well as destructive flash floods in France (€1.5 billion) and flooding in Germany in 2010 (€1.3 billion).

The USA was hit by a series of very destructive hurricanes in 2005 – hurricanes Katrina, Rita and Wilma killed over 1,500 people and resulted in $180 billion in compensation payments – followed by Hurricane Ike in 2008 with $38 billion of damage (Kunreuther et al. 2011; Munich Re 2009). Hurricane Irene, which hit New York in 2011 as a tropical storm, served as a reminder that huge values of assets are exposed to potentially destructive hurricanes in the USA (Aerts and Botzen 2012a).

The sharp increase in frequency and severity of the recent disasters has made some leading academics suggest that we have entered a new era of natural catastrophes (Kunreuther et al. 2011). Because of their dramatic impacts[1] natural catastrophes are often well publicized in the media and are an important issue for governments, international organizations, such as the World Bank and the United Nations, and the broader research community. An important question that arises as a result of these recent destructive disasters is how to design effective policies that limit the increase in natural disaster losses expected to be caused by climate change and reduce its impacts on human societies. This book provides insights into this subject from an economics perspective and elaborates upon the role that financial arrangements can play in limiting vulnerability and exposure to natural disasters. The insurance sector, which is the world's largest industry in terms of revenue, could be a major partner in managing, spreading and providing incentives for reducing natural disaster risk and, thereby, could promote adaptation to climate change (Mills 2009a). In this respect,

[1] Some authors argue that the effects of catastrophes are minor in macroeconomic terms, even though natural catastrophes have considerable local impacts (Albala-Bertrand 2006). The macroeconomic impacts of disasters may be larger in small countries.

climate change not only poses a threat to insurers, but also entails the development of new business opportunities (Mills 2007).

The remainder of this chapter is structured as follows. Section 1.2 outlines the influence of socio-economic developments and climate change on natural disaster risk. Section 1.3 discusses expert assessment of risk and households' perceptions and behavioural responses to risk. Section 1.4 describes several strategies for managing extreme weather risks. Section 1.5 examines the role that financial arrangements can play in natural disaster risk management. Section 1.6 provides an outline of this book.

1.2 Future natural disaster risks under climate and socio-economic change

1.2.1 Impact of socio-economic developments on natural catastrophe damage

Human actions are a major determinant of the occurrence and consequences of natural disasters. Although natural hazards such as storms, floods, heat waves and storm surges are natural phenomena, the damage caused by these natural hazards is to a great extent influenced by human activities. A natural disaster is usually defined as the impact of a natural event on human societies, for example in terms of loss of life or economic costs (Bočkarjova 2007). Commonly, a certain threshold of economic damage or loss of life needs to be exceeded before an extreme weather event is defined as a natural disaster. Also important in this respect is the ability of societies to prepare for, and manage, the economic disruption caused by a disaster, and this depends on each country's level of economic development (Rose 2003). A major part of the increased damage caused by natural disasters around the globe can be explained by socio-economic developments, such as the increased population and concentration of wealth in areas that are vulnerable to natural hazards (Bouwer 2011; Changnon 2003a; Crompton and McAneney 2008; Miller et al. 2008; Muir-Wood et al. 2006; Pielke et al. 2005). For example, the large rise in hurricane damage in the USA that has been observed in recent decades is mainly due to increased human settlement at coastal locations where hurricanes often make landfall, such as Florida (Pielke et al. 2008; Schmidt et al. 2009b). Also, in a flood-prone country like the Netherlands, the amount of urban area that can be flooded increased six-fold during the twentieth century, and it has been projected that it may double again in the twenty-first century (de Moel et al. 2011). In the future, urbanization in hazard-prone areas, such as coastal agglomerations, is projected to continue, which heightens exposure to extreme weather events, posing challenges for the management and insurability of natural disaster risk (Bouwer et al. 2007).

1.2.2 Climate change and the frequency and severity of natural disasters

In addition to socio-economic developments, climate change may increase the intensity and severity of extreme weather events and contribute to an increasing loss burden of natural disasters in the future (IPCC 2007; Mills 2005). Anthropogenic climate change is caused by the emissions of carbon dioxide and other greenhouse gases, such as methane, that have accumulated in Earth's atmosphere since the industrial revolution (mainly since the late nineteenth century), predominantly due to the burning of fossil fuels, deforestation and other land-use changes. These rising concentrations of greenhouse gases result in increases in surface air temperature, because the greenhouse gases in the atmosphere trap heat (see, e.g., Pierrehumbert 2004). The Intergovernmental Panel on Climate Change (IPCC) projects a rise in global average surface temperatures between 1.1 °C and 2.9 °C by 2100 for a low-emission scenario, and between 2.4 °C and 6.4 °C by 2100 under a high-emission scenario (IPCC 2007). The decay rate of greenhouse gases is very slow, and therefore their presence in the atmosphere,[2] with the accompanying negative consequences, will continue in future decades (IPCC 2007; Matthews and Caldeira 2008). Even if current climate policy were to be able to stabilize greenhouse gases to 2000 levels, then a further warming of about 0.2 °C would occur in the next two decades, while warming would be much higher if emissions increase in accordance with the common projections (SRES scenarios) of the IPCC (2007). This implies a clear need for climate change adaptation policy to reduce the vulnerability of human systems

[2] Montenegro et al. (2007) state that 'about 75% of CO_2 emissions have an average perturbation time of 1,800 years, and the remainder have a lifetime much longer than 5,000 years'.

to climate change (Pielke et al. 2007; Stern 2007). Several positive feedback mechanisms of climate change may increase greenhouse gas concentrations in addition to human-induced emissions, and thus result in even more warming than anticipated by some climate models (Stern 2007). Examples are the release of methane due to the melting of permafrost and a reduced uptake of carbon as a result of the weakening of natural carbon sinks, such as the Amazon forest[3] (Heimann and Reichstein 2008; Kennedy et al. 2008).

According to the recent state of knowledge in climate science, which is summarized in the latest IPCC report (2012), it is very likely that climate change will increase the length, frequency and/or severity of warm spells, or heat waves, over most land areas in the twenty-first century. Moreover, climate change is likely to result in an intensified water cycle, which implies that existing regional patterns of scarcity and abundance of water will be amplified, increasing the risk of droughts and floods. In particular, rainfall and floods are likely to increase in high-latitude regions, while southern arid regions are expected to have considerable reductions in rainfall in both hemispheres (Meehl et al. 2007). According to the IPCC (2012), it is likely that the frequency of heavy precipitation will increase in the twenty-first century over many areas of the globe. In other parts of the world, warmer air and oceans could cause more intense storms, such as hurricanes and typhoons. In addition, climate change is expected to cause a rise in mean sea level due to the expansion of warmer oceans and the melting of glaciers and ice caps. The IPCC (2007) projects a global rise in sea levels between 0.2 and 0.6 metres by 2100. An irreversible melting of the Greenland Ice Sheet[4] or the collapse of the West-Antarctic Ice Sheet, which both have a low probability of occurring, could cause a substantial rise in sea level of about 5–12 metres globally, although this is very uncertain and could only occur over the course of several centuries (Alley et al. 2005; Rapley 2006; Wood et al. 2006). The IPCC (2012) estimates that it is very likely that sea level rise will contribute to an upward trend in extremely high coastal water levels in the future. Sea level rise

[3] Deforestation may also increase the vulnerability to disasters caused by climate change, for example because of soil erosion and landslides resulting from more frequent and severe rains and floods.

[4] The surface mass balance of the Greenland Ice Sheet may turn negative at a global average warming larger than 1.9–4.6 °C, which could result in its complete elimination over a very long time period (IPCC 2007).

could result in the inundation of many unprotected low-lying areas, and may increase the likelihood of flooding due to storm surges, which could have considerable consequences for Small Island States and countries with extensively populated deltas and coastal areas, such as the Netherlands, Vietnam and Bangladesh.

The IPCC (2007) states that global temperatures have already increased by approximately 0.76 °C since 1900, while sea levels have risen by about 20 centimetres during that time. There is also evidence that some of the expected effects of climate change on extreme weather events have already materialized. The IPCC (2012) indicates that it is very likely that there has been an overall decrease in the number of cold days and nights and an increase in the number of warm days and nights. There is medium confidence that the length and/or number of warm spells, or heat waves, has increased in many regions. It is likely that anthropogenic climate change has caused these trends. Moreover, there have been significant trends in the number of heavy precipitation events in some regions, and it is likely that more of these regions have experienced increases in these events. There is medium confidence that the increase in heavy precipitation has been caused by anthropogenic (human-induced) climate change. Furthermore, it is likely that an increased incidence of extremely high sea levels has been observed and it is likely that humans contributed to this trend. According to the IPCC (2007) there has been evidence of an increase in the average intensity of tropical cyclones, such as hurricanes and typhoons, in the North Atlantic and some other regions since the 1970s. It is more likely than not that this trend has been influenced by anthropogenic climate change. However, this statement was weakened to 'low confidence' in the latest IPCC report (2012) due to uncertainties concerning tropical cyclone records, incomplete understanding of the physical mechanisms linking tropical cyclone metrics to climate change, and the degree of natural tropical cyclone variability.

There is, however, debate in the scientific community about whether or not the observed upswing in hurricane activity is caused by anthropogenic climate change, meaning that it is likely to persist in the future, or whether it can be attributed to natural climate variability related to the Atlantic Multidecadal Oscillation (Kerr 2006a). Some research suggests that global warming has already resulted in an increased intensity or frequency of hurricanes, and that this may have been caused by higher sea surface temperatures (e.g. Emanuel 2005; Hoyos et al. 2006; Webster et al. 2005). A study by Elsner et al. (2008) shows that an upward trend for wind speeds of strong hurricanes can be observed in each relevant ocean basin. Saunders and Lea (2008) studied the contribution of sea surface temperature to hurricane frequency and activity for the USA and concluded that a 0.5 °C increase in sea temperature is associated with a 40 per cent increase in hurricane frequency and activity. However, it has been argued that current observational databases are insufficiently reliable to analyse trends for hurricane activity, due to subjective measurements and variable procedures over time. Also, the time periods used may be too short to draw definite conclusions about climate change (Landsea et al. 2006; Michaels 2006). This is likely to remain an active and very relevant area of research in the near future, given the high insurance and economic costs that hurricanes can cause (e.g. Höppe and Pielke 2006). Even though it is difficult to attribute past hurricane activity to climate change, several studies have projected that climate change will increase the frequency of severe hurricanes in the future (e.g. Bender et al. 2010). According to the IPCC (2012), it is likely that average tropical cyclone maximum wind speed will increase, although these increases may not occur in all ocean basins.

While most of the future projections for climate change, including those considered in this book, anticipate gradual changes in climate over time, several studies have indicated that abrupt changes in climate, with large impacts on human societies, are possible (Lenton 2011). The possible existence of tipping points in the climate system implies that small perturbations can switch the climate system into a different mode of operation. This means that at one point in time a small change (e.g. more greenhouse gas emissions) could have large long-term consequences. Lenton et al. (2008) made a shortlist of various elements of tipping points,[5] which includes, among other elements:

- large losses of Arctic summer sea ice, which would amplify global warming

[5] Tipping elements are those large-scale components of the Earth system that could be forced past a tipping point and subsequently undergo a transition to a different state.