CLIMATE CHANGE BRINGS STORMY DAYS: CASE STUDIES ON THE IMPACT OF EXTREME WEATHER EVENTS ON PUBLIC FINANCES

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This paper explores some implications of climate change for fiscal policies by assessing the impact of extreme weather events on public budgets. It presents selected case studies on the basis of available data for extreme weather events in the EU and the US that have occurred since 1990. We derive estimates for the budgetary impact of such events on the basis of the estimated economic damage and with respect to public relief payments. Based on these, we discuss implications for fiscal policy and publicly-provided disaster insurance. Our policy conclusions point to the enhanced need to reach and maintain sound fiscal positions given that climate change is expected to cause an increase in the number and severity of natural disasters.

1 Introduction

It is now widely accepted that man-made climate change takes place and that it is caused by the emissions of carbon dioxide and other greenhouse gases that are accumulating in the atmosphere. The economics discipline is discussing possible consequences that global warming might have for the economy, as well as the effectiveness and efficiency of the large-scale policy intervention that is needed to address the underlying market failure at the root of excessive emissions. Our understanding of these highly complex issues is not yet very well developed. For example, the degree of uncertainty attached to estimates of the "social cost of carbon" based on economic models of climate change is stupefying (see, for example, De Canio 2003). While policy-makers need to act and have started to do so in terms of international negotiations as well as legislation at national and EU levels, the economic debate on policy instruments is still far from conclusive (for an overview, see Helm 2003).

One important consequence of global warming is the increase in the number and intensity of extreme weather events. Extreme weather events are a special type of natural disasters, so called "hydrometeorological" ones, caused by storm and precipitation, including floods, as well as intense heat. The broader concept "natural disaster" is defined as situations or events that cause human and material damage at a scale which overwhelms local capacity and requires national or international assistance. Natural disasters could affect fiscal policies in two ways: first, a "direct fiscal impact" is related to the relief payments and the financing of public disaster response. Second, a drop in output and the negative wealth effect caused by the disaster can be seen to cause some "indirect fiscal impact" through various transmission channels in the economy causing lower tax revenues, increasing public outlays on social payments etc. The overall magnitude of the fiscal impact of natural disasters is not well understood at present.

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This paper aims to contribute to the development of a better understanding of the fiscal dimension of climate change by collecting evidence and by interpreting available data, primarily for six of the most extreme weather events that occurred since 1990 in the United States (US) and in the European Union (EU). On the basis of this fact-finding exercise, we draw some tentative conclusions for fiscal policy. In particular, we note that the fiscal impact of natural disasters, which depends on the severity of the event (and is therefore expected to increase with climate change), the size as well as the resilience[1] of the affected economy, has so far been relatively small in proportion to the GDP of an advanced economy. Nevertheless, we see some need to rethink the role of public and private insurance in the face of climate change. Public disaster insurance could potentially overcome market failures that might impede private insurance but needs be designed carefully to overcome moral hazard effects. One could discuss whether, due to economies of scale, such public disaster insurance should be located at the most federal level of government, *i.e.* at the EU level in the case of Europe.[2] Finally, an increasing likelihood that governments will be forced to muster significant budgetary efforts and accommodate the fiscal impact of an escalating number of increasingly severe weather events underlines the need to reach and maintain sound public finance positions as soon as possible.

The remainder of the paper is structured as follows: the next section presents case studies on the "indirect" and, where available, on the "direct fiscal impact" of six natural disasters for which we were able to collect data. We also present information on disaster funds in Belgium, the EU and the Caribbean. The third section interprets the results and derives policy implications on the basis of the case study information. The final section concludes.

2 Existing information on the budgetary impact of extreme weather events

2.1 Overview

Most of natural disasters that were recorded in the past are related to extreme weather events. In 2006, more than 400 natural disasters occurred world-wide, of which 38 took place in China, 31 in the US and 21 in India. Natural disasters are estimated to have caused around 209.5 bn USD of economic damage on a global scale in 2005 and 34.5 bn USD in 2006 (Below *et al.*, 2007). Aggregated at country level, the highest absolute damage occurred in China at around 13.5 bn USD, whereas the highest relative economic damage was caused in Guyana, which lost close to 17 per cent of GDP in 2006 due to a flood disaster. Based on an average of the years 2000 until 2004, annual global economic damage is close to 60 bn USD, of which about 40 per cent is caused by windstorms, 30 per cent by floods and around 12 per cent by droughts. Hence, less than 20 per cent of natural disasters are related to events that are *not* influenced climate change (such as geological disasters), whereas 80 per cent are so-called hydrometeorological disasters or extreme weather events.

Extreme weather events are expected to increase in number and severity as a result of climate change. Looking at data provided by Munich Re, the past trend shows a significant increase

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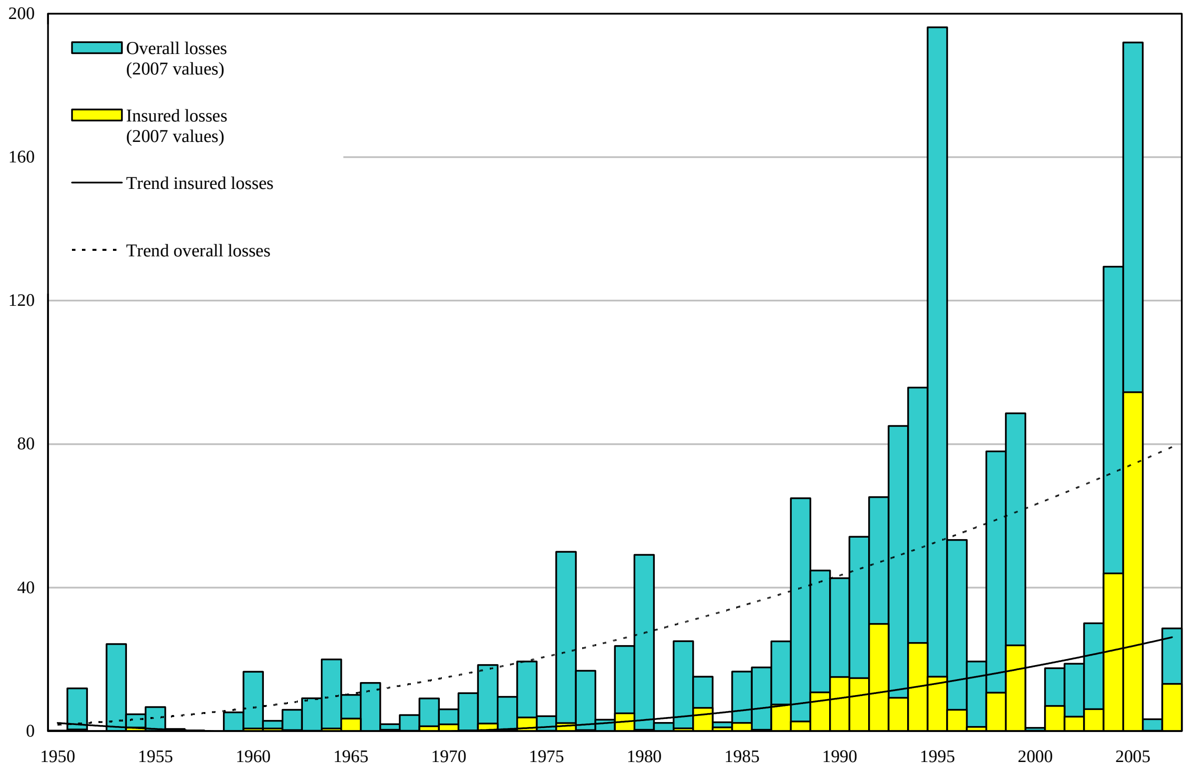
1 Resilience in this context means the ability of a country to deal with extreme weather events. This includes the preparedness of the country in terms of adaptation but also the structural flexibility of the economy such as flexible labour and product markets.

2 This might also be true for other public disaster response measures and equipment, such as helicopters for fire fighting.

Figure 1

Extreme Events, 1950-2006: Overall and Insured Losses
(USD billions)



Source: Munich Re NatCatSERVICE.

in great natural disasters[3] in particular related to extreme weather events (see Figure 1). The Stern report argues that due to the fact that damage from storms scales as the cube of wind speed or more, costs of extreme weather are estimated to reach 0.5 to around 1 per cent of global GDP annually by 2050 (Stern 2007).

While most of the damage caused by extreme weather events occurs in developing countries – which are also the least resilient – developed countries are affected, too. At the same time, the impact of such extreme weather events on the public budgets of advanced industrialised nations is, at best, unclear. This paper is intended as a first enquiry into the ways in which natural disasters affect fiscal policy in advanced economies and the budgetary measures by which governments respond to them. For the purposes of this paper, we broadly distinguish between three different types of fiscal cost that can arise due to the occurrence of extreme weather events like severe storms, abnormally abundant precipitation and the resulting inundations as well as heat waves and tornados.

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[3] According to Munich Re, in line with the UN definition, a *great* natural disasters is an event where "the affected region's ability to help itself is distinctly overtaxed, if one ore more of the following factors apply: Interregional or international assistance is necessary; thousands are killed and/or hundreds of thousands are made homeless; substantial overall losses and/or considerable insured losses". In 2006 only one event out of 850 qualified as a great natural catastrophe in accordance with these criteria.

First, extreme weather events can damage public and private assets alike. Government expenditure related to the protection and repair of public assets would obviously be part of the first-order fiscal cost of such an extreme weather event. This type of expenditure typically occurs at the level of local government, and it should in principle be possible to gather some evidence on the associated magnitude by checking municipal accounts for related spending items. However, we have refrained from doing so for this initial enquiry, not least because of the complication that at least some of such "repair spending" might contain municipal expenditure that in any case would have occurred, at least over time, in order to maintain public buildings and infrastructure. Hence, the additional effect unambiguously related to the incident of a natural disaster would still remain unclear and possibly be equivalent only to a somewhat higher depreciation rate compared to a "business-as-usual" scenario had the disaster not occurred. This is particularly likely if the extreme weather event in question falls short of a major disaster that indeed would destroy considerable public assets. Furthermore, the repair work following an extreme weather event largely consists of public investment, *i.e.* capital spending for accounting purposes. In most cases, it is not unlikely that such investment actually *upgrades* assets that had suffered from disaster-related damage. For example, replacing the heating system of a school after a flooding might in the short run drive up the need for public funds but in the longer run lead to lower maintenance costs thanks to a more efficient installation. This implies that the simple first-order cost would again overstate the discounted fiscal impact of the incident over time.

Second, in addition to such first-order costs accruing to the public sector at the local level, governmental measures in reaction to a extreme weather event typically draw on a broad range of public outlays that are at least partially intended to cater for such events but normally occur independently of any *specific* disaster, such as personnel and equipment of the armed forces or the provision of technical assistance through specialised relief organisations that are publicly funded. However, the current practice of national accounting makes it close to impossible to disentangle, for example, from the defence budget those costs that are specifically linked to a given disaster. Hence, expenditure that arises as part of regular precautionary provisions of the government and therefore is only indirectly related to specific extreme weather events is also generally not considered in this paper.

Third, in the event of a natural disaster, governments typically provide relief in the form of public transfers to private households and companies. Often, these transfers are funded from specific disaster funds that, either, are maintained as a standard component of public budgets (e.g., the EU Solidarity Fund or the disaster fund of the Belgian government) or are set up individually to channel state transfers in reaction to a specific event (such as the German "*Aufbauhilfe*" fund in response to the 2002 flood). Where available in terms of data, we use this information for our enquiry and assume that this type of public transfer together with other, quantifiable direct response measures on the expenditure and revenue sides provides us with a first proxy for the "direct fiscal impact" of a given extreme weather event.

In addition, we try to determine an "indirect fiscal impact" by deriving a rough estimate of the fiscal implications related to the "economic damage" caused by a natural disaster. Given that the real size of the economic damage of natural disasters is usually not known, we take recourse to available estimates.

A first source is model-based estimates of the "economic damage". Very few of these exist and then, obviously, they are subject to the limitations of such underlying growth models as well as to caveats similar to those mentioned above in the context of public first-order costs: the overall economic damage of a extreme weather event is normally defined in terms of lost output, which does not reflect lost assets but only the indirect effects of the disaster on GDP growth. A typical pattern that emerges from most simulations is one where output drops initially due to the negative supply shock caused by a disaster and subsequently recovers and often even over-compensates the initial loss due to a positive demand shock fuelled by increased investment spending in the economy. As the disaster is seen to trigger *additional* investment spending (*i.e.* normal investment activity is not fully crowded out by disaster-related capital formation), its effect, at least in standard models, is often seen to increase output over time by more than the initial loss, which is one reason why model-based estimates of the "economic damage" of a disaster focus on the first-order loss in output. Another caveat of the first order losses is that models as yet do not capture well the long-term impact of disasters on the productivity of an economy: for example, the loss of human capital might have an impact not only on employment but also on labour productivity. The destruction of production facilities not only means a loss in jobs but could also affect long-run capital productivity beyond the cost of a lost factory if critical facilities are hit, such as energy companies. It is conceivable that in fact the overcompensation of initial losses could take a long time or fail to materialise at all. Also other effects of disasters, e.g. on wealth via lost housing, are so far not well captured in the models.

As a second source for the economic damage, we use estimates provided by the reinsurance company Munich Re. These estimates of the *economic* damage are not model-based but derived from official statements and press reports as well as on the basis of judgement in relation to the verified *insured* damage, which is of course much better documented than the uninsured damage, which is usually much larger (for more information on the Munich Re database on natural catastrophes, see Munich Re, 2003).

Relying on model-based estimates as well as on Munich Re information on the economic damage of an extreme weather event, we derive the "indirect fiscal impact" by translating the output loss into a hypothetical increase in the general government deficit ratio of the affected country affected via budgetary elasticities as laid out in Girouard and André (2005). For example, if the first order economic damage was estimated at 3 per cent of GDP, given an assumed budget elasticity of 0.4 this would translate into a (hypothetical) reduction in the budget balance of 1.2 per cent of GDP.

In sum, the complications and uncertainties blurring the first-order fiscal cost of extreme weather events as well as the budgetary burden related to the wider precautionary measures of a government with respect to natural disasters obviously impede a precise definition of the fiscal cost of any given extreme weather event. This, on its own, is already a relevant insight. However, in this paper and as a first step towards a better understanding of the wider problem, we aim to establish at least a "lower bound" or minimum proxy for the fiscal cost of those extreme weather events for which we were able to obtain data. We derive such a lower bound by combining information that we were able to obtain on "direct fiscal effects", which usually relate to expenditure for public relief payments, with "indirect fiscal effects", accruing from a short-run, negative macroeconomic impact of the disaster.

Several caveats are associated with our approach: first, the "direct fiscal effect" in terms of public expenditure for relief funds does not cover all disaster-related public spending and does not necessarily accrue in one single fiscal year. Second, the "indirect fiscal effect" depicts a hypothetical magnitude of the impact on fiscal balances related to a first-order loss in output that is often seen to be reversed over time. Also, the estimated budgetary elasticities refer to long-term averages covering the period 1980-2003, *i.e.* the budgetary impact derived on that basis needs to be seen as only a rough proxy. Nevertheless, we would deem it useful to accept these caveats and the inevitable crudeness of our approach in order to provide some first, indicative answers to our question, which is to develop some understanding of the fiscal impact of hydrometeorological disasters that are expected to increase in size and number as a result of climate change.

The following subsections present by way of case studies the information that we were able to gather and derive on the budgetary impact of the 4 most extreme weather events in the EU since 1990 and of the 2 most extreme events that occurred in the US since 1990, sorted in the order of economic damage: in the US, the 2005 hurricane "Katrina" and the 1992 hurricane "Andrew" and in Europe the 2002 flooding of the Elbe, a heat wave during Summer 2003, the 1999 winter storm "Lothar" and the 1990 winter storm "Daria". In addition, we present a subsection on public relief funds that contains information that we deem relevant for discussing the fiscal policy implications of our findings in Section 3.

2.2 Hurricane "Katrina" in the US in 2005

The hurricane Katrina, which reached the US on 29 August 2005, is considered the costliest extreme weather event so far and, as such, is reasonably well documented. The storm surge caused severe damage along the Gulf Coast, devastating the Mississippi cities of Waveland, Bay St. Louis, Pass Christian, Long Beach, Gulfport, Biloxi, Ocean Springs and Pascagoula. In Louisiana, the federal flood protection system failed and Katrina inundated 80 per cent of the city of New Orleans as well as many neighbouring communities for weeks. More than 1,800 people died and over one million were displaced from their homes.

The macroeconomic impact of Katrina was magnified beyond the great deal of devastation through the long-term flooding of New Orleans and the destruction of energy and port infrastructure, notably oil pipelines. Economic activity in the sectors of energy, refined products, port services, housing, manufacturing, retailing, tourism and other consumer services was depressed for several months in the affected areas. Employment declined significantly – estimates go up to half a million job losses – as a direct consequence of the disaster.

Concerning the "direct fiscal impact" of Katrina, government records suggest that 62.3 bn USD were made available to the disaster relief account of the Federal Emergency Management Agency, which, over time, disbursed these funds for housing assistance, the acquisition of manufactured housing, goods and services for relief activities, the reimbursement of federal agencies, etc. An additional 400 mn USD was disbursed to the Army Corps of Engineers and 1.9 bn USD to the Department of Defence for its disaster response efforts (Congressional Budget Office, 2005b). The total sum of 64.6 bn USD in terms of federal expenditure directly related to the disaster would correspond to 0.52 per cent of nominal US GDP in 2005, although it is likely that more funding was provided for purposes of business development and long-term reconstruction.

In terms of the "indirect fiscal effect" considered in this paper for the budgetary impact accruing from the macroeconomic damage, hurricane Katrina was first estimated to have caused a drop of real GDP growth of around 0.5-1.0 per cent for the second half of 2005 (Cashell and Labonte, 2005; and Congressional Budget Office, 2005a), but estimates were subsequently revised to around 0.5 per cent (Congressional Budget Office, 2005b). Munich Re estimates that Katrina caused an economic damage of 125 bn USD, which would be equivalent to 1.01 per cent of nominal GDP and appears to be at the higher end of the estimations. Taking an average of the available estimates, we assume that the initial loss in output amounted to 0.75 percentage points of GDP. Applying the elasticities as outlined above, this would translate into a deterioration of budgetary balances by around 0.26 per cent of GDP.

Hence, on the basis of available information, it is probably fair to say that the most expensive natural disaster in modern times had an overall budgetary impact of some 0.8 per cent of US GDP. This figure might be seen as pointing to a surprisingly small "fiscal damage", given the size of the disaster. This, in a sense, is true and obviously related to the relative size of the US economy. At the State level, however, the economic impact of Katrina was considerably larger, as well as the impact on the state budgets of Alabama, Louisiana and Mississippi. After major disasters, it is mainly the affected state and local governments that face the dual task of responding to the crisis and absorbing the economic impact. Higher public expenditure and lower revenue mainly occurs at this level and less so at the federal level.

In the case of Katrina, it is assumed that the affected region temporarily lost about half of its economic activity (Maguire, 2005), with the ensuing consequences for tax collection that appear to have dropped in a similar magnitude. However, as a feature of the "balanced budget rules" in place for State budgets in the US, most States maintain so-called "rainy day funds" in which they channel part of the cyclical component of budget revenues during "good economic times". These funds can be accessed in the event of unexpected budget shocks, such as natural disasters. Thanks to this institutional set-up, those State governments affected by Katrina were able to finance the additional expenditure *in part* from their own funds and, in particular, had access to sufficient temporary liquidity immediately following the disaster. In the medium-tem, Alabama, Louisiana and Mississippi all used a combination of "Rainy Day Fund" and federal revenues as well as debt issuance to finance relief and recovery spending. Though these "rainy day funds" help to alleviate the fiscal effects of weather events, in case of extreme events (such as Katrina) they are not sufficient to cover all costs.

2.3 Hurricane "Andrew" in the US in 1992

The second-largest extreme weather event that we consider is the hurricane "Andrew", which occurred from 23 to 27 August 1992 in the US and brought wind speeds up to 280 km/h. Severe flooding was caused in Louisiana with over 28,000 houses being destroyed and well above 100,000 being damaged, putting 86,000 people temporarily out of work. The oil industry incurred major losses and 1.4 million people were subject to severe power outages. 2.6 million people had to be evacuated and the hurricane caused the death of 62.

According to Changnon and Easterling (2000), federal and state relief payments related to Andrew amounted to 6.5 bn USD, which, in terms of the "direct fiscal impact" considered in this paper, would amount to 0.1 per cent of 1992 US nominal GDP. Munich Re estimates the economic damage at 26.5 bn USD, which would be equivalent to 0.42 per cent of GDP and translate into a worsening of budgetary balance, *i.e.* an "indirect fiscal impact" of 0.14 per cent of GDP. Hence, overall, we would assume the fiscal impact of hurricane Andrew in 1992 to have a magnitude of at least 0.28 per cent of GDP at the general government level.

2.4 The floods in Europe in Summer 2002

In the Summer of 2002, the Czech Republic, Germany, Hungary, Austria, Poland, Romania, Slovakia and Croatia suffered from a historic flooding of the river Elbe as well as numerous of its tributaries, caused by unusually intense precipitation in the Alps and lower mountain ranges. The disaster was helped by the fact that extensive precipitation had already occurred during the preceding weeks, rendering the soil unable to absorb additional rainfall. Inundation first occurred in Bavaria and in the Austrian states of Salzburg and Upper Austria. The floods gradually moved eastwards along the Danube and intensified when the rainfall shifted northeast to the Bohemian Forest and to the source areas of the Elbe and Vltava rivers, resulting in catastrophic water levels first in the Austrian areas of Mühlviertel and Waldviertel and later in the Czech Republic and the German *Länder* Thuringia, Saxony and Saxony-Anhalt, causing casualties and extensive damage in several large cities, including Dresden and Prague, as well as in numerous villages.

In Austria, direct measures of the government included discretionary tax exemptions amounting to around 0.1 per cent of GDP and relief-related expenditure with a volume of around 1 bn euros, which would correspond to around 0.4 per cent of GDP as the "direct fiscal impact" of the flood. The macroeconomic first-order damage of the flooding was estimated to amount to around 0.25 per cent of GDP by the Austrian National Bank (Fenz and Prammer, 2002). This is below an estimate of around 3 bn USD proposed by Munich Re, *i.e.* roughly 3.2 bn euros at the time, which would be equivalent to 1.44 per cent of nominal Austrian GDP in 2002. This higher estimate would correspond to an "indirect fiscal impact" on budgetary balances of around 0.68 per cent of GDP. Hence, based on our crude approach to combine direct and indirect contributions to the budgetary impact of a natural disaster, we would deem the flood to have deteriorated Austrian public finances by around 1.08 percentage points of nominal GDP in 2002.

In Germany, the "direct fiscal impact" of the Elbe flooding is mainly associated with the special national relief fund "*Aufbauhilfe*" that was founded jointly by the federal and *Länder* authorities in the aftermath of the disaster.[4] The facility was set up to channel funds to households and private companies that had suffered damage not covered by private insurance as well as to pay for the reconstruction of assets and infrastructure through the federal, *Länder* and municipal budgets. The fund had a volume of 6.3 bn euros, of which 3.5 bn was contributed by the federal government and 2.8 bn by the *Länder*, which in turn split up their contributions according to relative GDP weights. Hence, the "direct fiscal impact" of the flood as a percentage of nominal GDP in 2002 would amount to around 0.3 per cent of GDP. The fund was administered through the Federal Ministry of Finance and reported to Parliament as an appendix to the federal budget. Funds were disbursed according to an allocation key, which earmarked 78.9 per cent of the resources for Saxony. It was dissolved at the end of 2006, small remaining assets being reimbursed to the federal and *Länder* budgets.

Concerning the "indirect fiscal impact" in Germany and short of model-based estimates for the economic damage of the Elbe flooding, we solely rely on the Munich Re estimate, arguing that the flood caused an economic loss of roughly 11.6 bn USD, of which 1.8 bn USD was covered by insurance. The rough estimate of 11.6 bn USD, *i.e.* 12.4 bn euros at the time, would correspond to 0.58 per cent of 2002 nominal German GDP, which in turn would translate into an "indirect fiscal impact" of around 0.3 per cent of GDP. Together with the "direct fiscal impact", this would point to an overall deterioration of the German general government budget balance of around 0.6 per cent of nominal GDP in 2002.

About the same time, heavy storms in northern Italy flooded roads, brought down bridges and raised the water in Venice to record levels. Munich Re estimated the economic damage at around 3.7 bn euros, about 0.3 per cent of GDP, which would translate into an "indirect fiscal impact" of around 0.15 per cent of GDP. Unfortunately there is no information available on the direct fiscal impact of these floods.

The findings of this section are summarised in Table 1. Because the "direct fiscal impact" was not available in most country cases (except Germany and Austria), we only show the insured

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4 Gesetz zur Errichtung eines Fonds "Aufbauhilfe" (Aufbauhilfefondsgesetz – AufhFG) of 19 September 2002, Bundesgesetzblatt I S. 3652, 3652.

Table 1

Estimated Indirect Fiscal Impact of the Floods in Summer 2002

Country	Insured Damage *(million euros)*	Economic Damage *(million euros)*	Economic Damage *(percent of GDP)*	Indirect Fiscal Impact *(percent of GDP)*
Czech Republic	1,275.1	2,587.3	3.23	1.26
Hungary	n.a.	31.9	0.05	0.02
Slovakia	n.a.	3.2	0.01	0.00
Austria	425.02	3,187.7	1.44	0.68
Germany	1,928.5	1,2431.8	0.58	0.30
Italy	10.6	3,718.9	0.29	0.15

Note: Data for Poland, Romania and Croatia are not available from Munich Re.
Source: Munich Re and own calculations.

damage, the economic damage and the resulting indirect fiscal impact. It is worth pointing out that a relatively small country such as the Czech Republic was hit the hardest in relation to its GDP.

2.5 Summer heat wave in Europe in 2003

From July to August 2003, many European countries experienced an extreme heat wave in combination with widespread drought. The situation led to numerous forest fires and record low water levels in rivers, disrupting shipping and power generation as well as land-based transport. Major losses occurred to agriculture and livestock and 70,000 people, especially elderly persons, died. Munich Re estimates the overall economic losses at 13.8 bn USD, of which only 10 mn were covered by insurance. The negative impact on budgetary balances in terms of the "indirect fiscal effect" derived from the macroeconomic damage reached up to 0.28 per cent of GDP in the case of Hungary but was comparatively low in larger, more resilient economies, such as Germany. The estimates are summarised in Table 2.

2.6 Winter storm "Lothar" in Europe in 1999

On 26 December 1999, several countries in Europe were affected by the winter storm "Lothar", particularly Austria, Belgium, France and Germany. Wind speed reached up to 200 km/h and occurred jointly with heavy rain and floods. Several municipalities were cut off and a large number of dwellings and other assets were destroyed. Infrastructure was affected, including road traffic, train services and airports, as well as power supplies, leaving millions without electricity. Casualties numbered 110, of which 90 were recorded in France. According to Munich Re, the overall economic damage amounted to 11.5 bn USD, of which less than half (5.9 bn USD) was insured.

Based on the estimates of the economic damage in individual countries, the indirect fiscal impact of Lothar varied, reaching up to 0.29 per cent of GDP in France, the most heavily affected country. The impact was weaker in Germany and Italy, as summarised in Table 3.

Table 2

Estimated Indirect Fiscal Impact of the Summer 2003 Heat Wave

Country	Insured Damage *(million euros)*	Economic Damage *(million euros)*	Economic Damage *(percent of GDP)*	Indirect Fiscal Impact *(percent of GDP)*
Hungary	n.a.	443.0	0.59	0.28
Italy	n.a.	3,898.5	0.29	0.15
Germany	8.9	1,462.0	0.07	0.03
Poland	n.a.	310.1	0.16	0.07
Slovenia	n.a.	70.9	0.28	0.00
Slovakia	n.a.	132.9	0.45	0.17
Romania	n.a.	385.4	0.73	0.00
Austria	n.a.	248.1	0.11	0.05
France	n.a.	3,898.5	0.24	0.13
Spain	n.a.	779.7	0.10	0.04

Note: Data for Portugal and Greece are not available from Munich Re.
Source: Munich Re and own calculations.

Table 3

Estimated Indirect Fiscal Impact of Winter Storm "Lothar", 1999

Country	Insured Damage *(million euros)*	Economic Damage *(million euros)*	Economic Damage *(percent of GDP)*	Indirect Fiscal Impact *(percent of GDP)*
Germany	610.1	1,501.8	0.07	0.04
France	750.9	7,509.0	0.55	0.29
Italy	n.a.	469.3	0.04	0.02

Source: Munich Re and own calculations.

2.7 Winter storm "Daria" in Europe in 1990

On 25 and 26 January 1990, a winter storm named "Daria" caused havoc across several countries in North-Western Europe, including close to 100 casualties. It produced wind speeds of around 180 km/h and brought heavy rain with floods. Rivers burst their banks and several dykes breached. Damage to buildings and vehicles was extensive, a nuclear power plant in France collapsed, and several others had to shut down. Agriculture and forestry suffered extensive harm; the damage to greenhouse growers alone amounting to 65 mn USD. Natural gas production and power supply was impaired and major traffic connections were severely disrupted across Western

Europe. Munich Re estimates that the overall economic damage caused by Daria in Europe amounted to 6.9 bn USD, of which 5.1 bn USD were covered by insurance.

Data on specific governmental relief payments in the sense of a "direct fiscal impact" in the affected countries are also in this case not available, with the exception of the Belgian disaster fund (see below). In addition, given the lack of model-based estimates of the economic damage, we again need to base our estimates of the "indirect fiscal impact" solely on the Munich Re data for the economic damage caused by Daria. The budgetary impact in this sense was largest in the Netherlands and Luxembourg, with 0.22 per cent of GDP and 0.33 per cent respectively, Luxembourg obviously being affected in particular as a relatively small economy. The results are summarised as follows:

Table 4

Estimated Indirect Fiscal Impact of Winter Storm "Daria"

Country	Insured Damage	Economic Damage		Indirect Fiscal Impact
	(million euros)	*(million euros)*	*(percent of GDP)*	*(percent of GDP)*
Belgium	196.9	275.7	0.17	0.09
United Kingdom	2,402.4	2,678.1	0.34	0.15
Denmark	47.3	94.5	0.09	0.05
Poland	0.0	39.4	0.13	0.06
France	236.3	315.1	0.03	0.02
Germany (west)	472.6	945.2	0.07	0.04
Luxembourg	47.3	70.9	0.71	0.33
Netherlands	630.1	945.2	0.41	0.22

Source: Munich Re and own calculations.

2.8 Belgium, the EU and the Caribbean: examples for disaster funds

In this subsection we discuss to examples of public disaster insurance. Unlike the temporary "*Aufbauhilfe*" fund set up in Germany after the flood in 2002, Belgium has a standing facility that channels disbursements to private sector victims of natural disasters. The "*Nationale Kas voor Rampenschade/Caisse Nationale de Calamités*" pays up to 60 per cent of privately incurred damage, subject to an approval procedure that involves the recognition of the weather event in question as "exceptional" by the government. Payments above 1 mn euros since 1990 are included in the table overleaf.

Table 5

Disbursements of the Belgian Disaster Fund

Year	Date	Event	Disbursements *(euros)*	*(percent of GDP)*
1990	25/01/1990	Storm	74,712,550.2	0.05
1990	03/02/1990	Storm	14,897,271.5	0.01
1990	26/02/1990	Storm with floods	29,504,626.6	0.02
1993	20/12/1993	Floods	12,526,924.2	0.01
1995	20/01/1995	Floods	6,462,544.7	0.00
1998	13/09/1998	Precipitation and floods	38,470,551.3	0.02
1999	04/07/1999	Precipitation and storms	1,174,156.8	0.00
1999	24/12/1999	Strom	2,508,721.1	0.00
2000	02/07/2000	Precipitation	1,126,357.8	0.00
2001	17/09/2001	Floods	8,780,817.1	0.00
2002	23/08/2002	Precipitation	7,317,461.2	0.00
2002	29/12/2002	Floods	3,661,719.5	0.00
2004	15/08/2004	Precipitation	1,330,320.9	0.00
2005	29/06/2005	Precipitation	2,475,543.3	0.00
2005	03/07/2005	Precipitation	25,112,073.8	0.01
2005	29/07/2005	Precipitation	1,177,962.2	0.00
2005	10/09/2005	Precipitation	1,007,162.9	0.00

Source: Belgian National Bank.

Payments through the Belgian disaster fund are well documented and provide a reasonably good indication of the budgetary efforts related to extreme weather events. The most severe disaster in Belgium since 1990 was the above-mentioned winter storm “Daria” on 25 and 26 January 1990. In Belgium, related disbursements of the fund, *i.e.* the “direct fiscal impact” of Daria, correspond to “only” 0.05 per cent of Belgian nominal GDP in 1990. To this, one would need to add the 0.09 per cent of GDP in terms of “indirect fiscal impact”, yielding an overall estimate of around 0.14 per cent of GDP as the minimum fiscal impact of Daria on Belgium, which was the most expensive natural disaster for that country. The records from the disaster fund suggest that other extreme weather events appear to have had significantly less direct impact on public finances in Belgium.

Similar to the Belgian facility, the EU since 2002 has at its disposal a so-called “Solidarity Fund”, which, according to Council Regulation (EC) No 2012/2002, is intended in “a rapid, efficient and flexible manner” to come to the aid of any EU Member State in the event of a major natural disaster.[5] The Fund has an annual budget of 1 bn euros, which, in light of the above, is

5 Related websites are http://europa.eu/scadplus/leg/en/lvb/g24217.htm and http://ec.europa.eu/regional_policy/funds/solidar/solid_en.htm

comparatively small in relation to the damage caused by a major disaster as well as in relation to the budgetary effort that governments have mustered in those cases in the past.

A natural disaster is considered as "major" for the purposes of the EU fund if it results in damage estimated above 3 bn euros (in 2002 prices) or at more than 0.6 per cent of GNI. In exceptional cases, the fund can be mobilised for extraordinary regional disasters resulting in damage inferior to this threshold if they affect a major part of a state's population with serious and lasting repercussions on living conditions and the economic stability of the region concerned. Assistance from the fund takes the form of a grant, without co-financing, complementing the disaster-related expenditure of the government concerned. The financing of the facility occurs outside the normal EU budget, implying that the Commission does not decide on disbursements alone but has to propose to the Council and European Parliament to mobilise the fund. The aid can only be disbursed once the fund has been made available following a budgetary procedure.

The following amounts (annual totals in euros) have been mobilised since the fund's inception in 2002: 728 mn (2002), 107.1 mn (2003), 19.6 mn (2004), 205 mn (2005), 24 mn (2006) and 172 mn (2007). For disasters that classified as "major", individual disbursements were as follows:

Table 6

Disaster Damage and Disbursements from the EU Solidarity Fund

Year	Country	Nature of the Disaster	Reported Economic Damage *(million euros)*	Aid Granted *(million euros)*	Reported Economic Damage *(percent of GDP)*	Aid Granted *(percent of GDP)*	Implied Deficit Increase *(percent of GDP)* [(1)]
2002	AT	Flooding	2,900	134.0	1.31	0.06	0.62
	CZ	Flooding	2,300	129.0	2.87	0.16	1.12
	DE	Flooding	9,100	444.0	0.42	0.02	0.22
2003	PT	Forest fires	1,228	48.5	0.89	0.04	0.41
	MT	Flooding	30	1.0	0.68	0.02	…
2005	SK	Storm (Tatras)	203	5.7	0.53	0.01	0.20
	EE	Storm	48	1.3	0.43	0.01	…
	LV	Storm	193	9.5	1.48	0.07	…
	SE	Storm "Gudrun"	2,297	81.7	0.80	0.03	0.44
	RO	Spring flooding	489	18.8	0.61	0.02	…
	BG	Spring flooding	222	9.7	1.01	0.04	…
	BG	Summer flooding	237	10.6	1.08	0.05	…
	RO	Summer flooding	1,050	52.4	1.32	0.07	…
2006	HU	Flooding	519	15.1	0.58	0.02	0.27
2007	DE	Storm "Kyrill"	4,750	166.9	0.20	0.01	0.10
	UK	Flooding	4,612	162.4	0.23	0.01	0.10
	EL	Forest fires	2,118	pending	0.92	n.a.	0.43
	SI	Flooding	233	pending	0.70	n.a.	…

(1) Damage times budget elasticity. The overall budget elasticity was taken from Girouard and André (2005) and is only available for OECD countries.
Source: European Commission and own calculations.

Based on these 18 cases, it is evident that disbursements of the EU fund mostly amount to a very small proportion of GDP, rarely reaching levels like 0.16 per cent of GDP in the case of the Czech Republic in 2002 or 0.07 per cent of GDP as in Latvia and Romania in 2005. Interestingly, the damage assessments reported by governments to the EU are slightly below the ones estimated by Munich Re and used in our approach to estimate the "indirect fiscal impact" of a disaster. Alternative estimates for the indirect effect are also reported in Table 6.

Another example for a standing facility is the donor-supported Caribbean Catastrophe Risk Insurance Facility (CCRIF). Like the EU Solidarity Fund, the CCRIF is a supranational insurance for Caribbean Community (CARICOM) countries. It aims to make use of recent financial innovations and provides help to governments (and not private households). Established in 2007, the purpose of the CCRIF is to provide governments with index-based insurance against government losses caused by natural disasters. The use of parametric triggers (*i.e.*, meaning that payment is triggered by the intensity of the event, rather than being a function of the damage incurred) is aimed at providing for very rapid payment of claims to the ministries of finance of the affected countries. The insurance was initially financed by donors (Japan, World Bank) but seeks also to access the international reinsurance and capital markets.[6]

3 Implications for fiscal policy

In order to derive policy implications of the case study information presented above, we propose to summarise the results in Figure 2.

We note that apparently the "indirect fiscal impact" of a natural disaster varies with the size of the economy affected and with the severity of the event in question.[7] By and large, the most serious events that have occurred since 1990 have not caused output losses that led to budgetary deteriorations above 0.5 percentage points of GDP. A notable exception is the 2002 flooding and its impacts on Austria and the Czech Republic, *i.e.* on relatively small economies. Information on the "direct fiscal impact" is relatively sparse. Where available, it seems to be pointing to a substantially higher total magnitude of the fiscal impact, the indirect component in some cases making up less than half of the total.

Overall, it also seems that the 2002 flooding has reached a different magnitude of damage compared to the storm events under consideration. This is interesting with respect to the fact that the containment of the damage of flooding is not completely out of governmental control: regulation for residential and commercial construction as well as precautionary preparation in terms of infrastructure (dykes, water reservoirs etc.) can both contribute to reduce the size and thereby also the impact of a flood. By contrast, the damage caused by a storm appears to be much more random and less prone to containment through governmental measures.

Up to now, the budgetary impact of extreme weather events in advanced economies seems to have had a limited magnitude in terms of GDP and, therefore, also limited impact on the sustainability of public finances in the long term or even on the solvency of governments in the short term. This does note exclude that future events might lead to a more serious situation for public budgets, but we can note as one important result of this paper that, up to now, public budgets have been able to accommodate the event of a hydrometeorological disaster fairly well.

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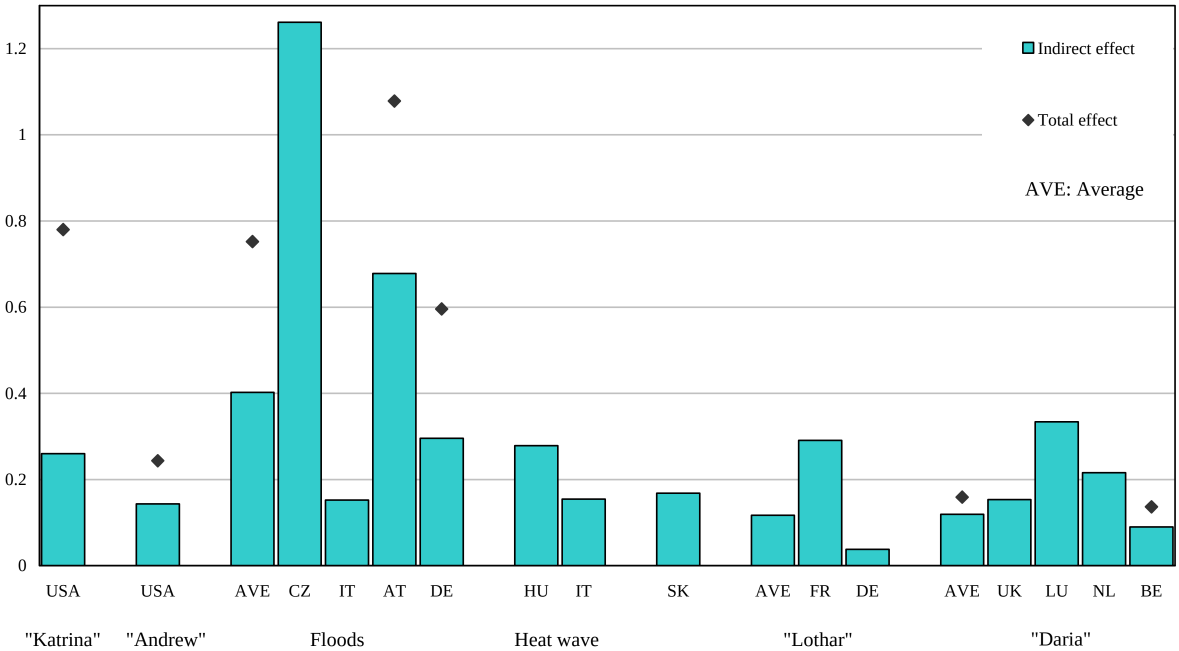
6 For more information please see: http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/LACEXT/0,,contentMDK:20939758~pagePK:146736~piPK:146830~theSitePK:258554,00.html

7 The small number of observations does not permit a deeper econometric analysis.

Figure 2

Summary of Case Study Information(1)

(percent of GDP)



(1) The total effect is the sum of the direct and the indirect effect. Direct fiscal effects were in many instances not available. Averages for floods, the heat wave, Lothar and Daria are calculated on the basis of the data available for all countries mentioned in the text. Because of space constraints only those individual countries were depicted where the fiscal effect was sizeable.
Source: Own calculations.

Given the high cost of the economic damage but the low (albeit rising) probability of the occurrence of extreme weather events, an insurance against the risk might be the preferred solution, especially when adaptation is either not possible or too costly. However, for catastrophes the essential risk is often aggregation, *i.e.* the same event can cause losses to numerous policyholders of the same insurer, so that the ability of that insurer to issue policies becomes constrained, not by factors surrounding the individual characteristics of a given policyholder, but by the factors surrounding the sum of all policyholders so exposed. Therefore the private sector might not be able to issue insurance for all potentially affected households or enterprises. An example is insurance against flooding, where the ability of an underwriter to issue a new policy in certain areas depends on the number and size of the policies that it has already underwritten. In extreme cases, the aggregation can affect the entire industry, since the combined capital of insurers and reinsurers can be small compared to the needs of potential policyholders in areas exposed to aggregation risk. When looking at the data provided by Munich Re for the extreme weather events that we analysed in this paper, we can already now assume a significant private underinsurance (see Figure 1).

The aggregation problem might therefore argue for the use of public funds as a way to provide insurance of "last resort", but this raises further questions/issues that have to be carefully assessed:

1) On the one hand there could be moral hazard through public insurance. For example, if the expectation of public funds in case of a flooding leads to disproportionate location in flood-prone areas, then this excessive risk-taking is an adverse corollary of public insurance. This can only be countered by stringent government regulation. In case of flooding this might imply zoning regulations or the taxing of flood-prone or otherwise hazard-prone land.
2) Another issue to be decided is the level of government. In principle, an insurance fund could be assigned to the regional, the national or the supranational level, and there are examples for each (see section 2.6). Given the nature of extreme weather events, that more than often affect large areas across national boundaries, a supranational insurance might be the first best option. This could also circumvent the aggregation problem that in particular a small country faces if a national insurance fund has to cover for losses in an area that affects large part of the country. A supranational fund would also spread the risk across a wider area. However, correlated shocks limit the benefits from risk-spreading. Take for example the CCRIF: if a hurricane strikes in the Caribbean, many countries/islands will be affected at the same time and in the same manner (IMF 2008). Then even a supranational fund is faced with an aggregation problem.
3) A third issue is the financing of such a fund. We showed that already available specific disaster funds, e.g. the "rainy day funds" in the US, are often insufficiently funded in case of extreme weather events. Therefore other options could be considered: (i) the tapping the bond-market, (ii) using the receipts from selling CO_2 permits, etc. For tapping the bond market, the supranational fund (or the participating governments) could issue some form of catastrophe bonds, which would pass some of the risk on to investors. Investors would buy the bond, which might pay them a coupon of LIBOR plus a spread. If no extreme weather event hit, then the investors would make a healthy return on their investment. But if a extreme event were to hit and trigger the bond, then the principal initially paid by the investors would be forgiven, and instead used by the supranational fund to pay its claims to policyholders. The option to finance the fund by selling CO_2 permits would come into play once carbon permits are not given away for free, as is currently the case of the EU ETS but rather auctioned. It is difficult to estimate the potential revenues that could be made from such auctions, as it is unclear what a "fair" price for a carbon permit is.
4) Finally, the verification of losses has to be made stringent so that fraud is avoided. In the context of the CCRIF the verification has proved more contentious than expected (IMF, 2008).

Though the fiscal effects of extreme weather events have been relatively modest in the EU and the US so far, governments need to recognise and prepare for these random shocks because climate change is expected to cause an increase in the number and severity of extreme weather events. Given that many EU countries already have to cope with the burden of an ageing population, achieving a sound fiscal position now is vital to provide for the necessary safety margin to cope with more and graver weather events.

4 Conclusion

This paper surveyed the impact of extreme weather event on public finances by looking at various country cases and discussed the strategic implications for national but also supranational public finances. We estimate that the impact of extreme weather events depends – not surprisingly – on the severity of the event, which is expected go increase with climate change, the resilience as well as the size of the affected economy. As a percent of GDP the total effect of extreme weather events on public finances varied between 0.3 to 1.1 per cent of GDP. So far, governments have coped quite well with this additional burden. However, this may change if climate change produced more and more extreme weather events and already available disaster facilities might increasingly prove as insufficient. The ability to cope with these events will depend on the starting position of each country: a country with a sound public finance position and a resilient economy will deal with an extreme weather event much better than a country that already suffers from sustainability problems, last but not least because of ageing populations. Given the nature of the problem (high cost/low probability), private and public insurances have a role to play. As it stands, private insurance of extreme weather events is relatively limited and is most likely not to increase much further because of the aggregation problem. Against the backdrop, government assistance is likely to be called more frequently because the public perceives the government as the "insurer of last resort". Because climate change is a global phenomenon that disregards regional or country boundaries an insurance fund at the supranational level could represent a solution, as long as it is carefully designed and properly regulated. However, given the difficulties in setting up supranational insurance funds described in sections 2.8 and 3 this would be a very challenging task.

Finally, as our paper has shown, the quantification of the fiscal impacts of climate change is still underdeveloped. In particular, the link between economic damage and the public budget needs further exploration. Also the data situation is sketchy at the moment and more information on the budgetary consequences of climate changes is needed. Therefore there are still many avenues for further research.

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