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Climate change and natural disasters: macroeconomic performance and distributional impacts

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Abstract Commonly occurring natural events become natural disasters when they affect the population through death and injury, and/or through the destruction of natural and physical capital on which people rely for their livelihood and quality of life. Climate change plays a role in that it tends to increase the frequency and intensity of weather-related natural disasters. Additionally, climate change may put people at risk by influencing access to water, coastal flooding, disease and hunger, and leaving them with a more degraded environment, leading, in turn, to increased vulnerability. The purpose of this paper is to present a review and synthesis of the literature and case studies addressing differential impacts of climate change-related natural disasters on a society and its economy. Developed and developing countries show different vulnerabilities to natural disasters. Even within countries, impacts vary significantly across population and economic sectors. When losses from natural disasters are large, their cumulative effect can have notable macroeconomic impacts, which feed back to further pronounce existing income inequalities and lower income levels. Impacts tend to be most pronounced for women, the young and elderly, and people of ethnic or racial minorities.

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1 Introduction

Every year, a large number of potentially damaging natural events take place in the world—windstorms, floods, droughts, cold spells and heat waves, landslides, and earthquakes, among others.[1] However, in recent years, the frequency and intensity of climatological events have increased, which may be related to global climate change (Easterling et al. 2000; IPCC 2001). In the near future there may be more devastating effects of these weather events. At the same time, population growth and *unsustainable* economic growth put ever larger numbers of people and their assets at risk, while reducing environmental buffering capacities, such as those associated with appropriate vegetation cover on steep slopes, intact wetlands in coastal zones, or coral reefs.

The purpose of this paper is to present a review and synthesis of the literature and case studies addressing differential impacts of climate change-related natural disasters on a society and its economy, i.e., the distributional implications of disasters. Figure 1 describes the central arguments of the paper. Climate change may increase the probability of natural hazards by enhancing the frequency and intensity of extreme weather events. Climate change may also increase biophysical vulnerabilities that result from temperature and precipitation modifications, as well as environmental, location, and geophysical conditions. Natural hazards occur, but they become disasters when there is some sort of vulnerability.

Two aspects of vulnerability are distinguished here—biophysical and social. Ultimately, vulnerability may be reflected through the macroeconomic performance, and this in turn may affect social and biophysical vulnerability as well (e.g., subsistence agriculture on marginal lands will further degrade the land, increasing both aspects of vulnerability). Macroeconomic performance is altered basically because people and/or economic activity are affected to some relatively large extent. The economy and particular groups within society are more affected when they are least prepared to face the effects of natural disasters. We therefore explore the effects of natural disasters on two macroeconomic indicators, poverty and income distribution, and then disentangle the effects on particular social groups. We also investigate potential feedback loops between macroeconomic performance and vulnerability, which are linked through a series of complex relationships.

In the following section we begin by describing what natural disasters are, where they typically occur, and how they affect different regions. Special attention is given to the changes in frequency and intensity of extreme weather events that may result from climate change and the vulnerability those events impose. Section 3 concentrates on macroeconomic impacts of natural disasters (mainly GDP, fiscal and external balances), and their effect on income level and income distribution within and across countries. In Sect. 4 we analyze in more detail which members of society are likely affected by natural disasters and climate change. We refer back to the concepts of vulnerability and resilience addressed in Sect. 2, and use these concepts to frame the discussion of specific-group vulnerability. We then give some insights of how socioeconomic destitution affects macroeconomic performance and how this feeds back into more vulnerability to natural disasters. Section 5 draws conclusions and policy implications.

[1] In the remainder of this paper we will not address earthquakes when discussing natural disasters because they are not related to climate change. However, they do impose a high toll of death and injury, and have similar macroeconomic implications; specific group vulnerabilities typically hold.

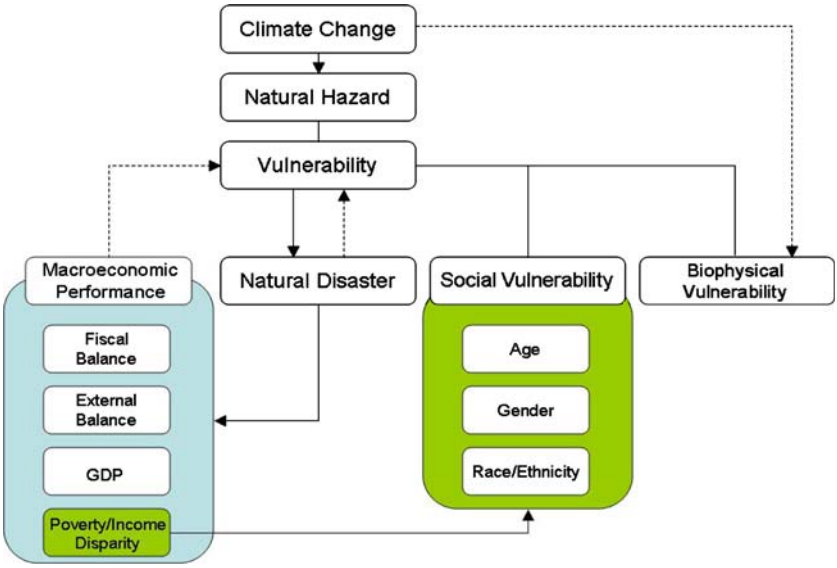

Fig. 1 Natural disasters, group-specific vulnerability, and macroeconomic performance

2 Natural disasters

Natural disasters happen when large numbers of people or economic assets are damaged or destroyed during a natural hazard event (Dilley et al. 2005). The strength of the event, the vulnerability of the people and their economic activity, and their ability to cope with the disaster determine the severity of the disaster's effect. Hence, one may find moderate natural events that map into severe natural disasters due to the vulnerability of a particular population, as well as severe natural events that result in moderate natural disasters due to preparedness of people and institutions.

According to the Centre for Research on the Epidemiology of Disasters (CRED), natural disasters are defined as events that have natural causes and lead to 10 or more fatalities, affect 100 or more people, or result in a call for international assistance or the declaration of a state of emergency (CRED 2004). Natural disasters are usually discussed in terms of their relative destructiveness and are compared in terms of human fatalities, injuries and displacement, direct economic losses, and indirect costs from infrastructure loss and capital needed to replace it. These latter costs refer to the foregone production derived as a result of disasters. Secondary costs, namely the macroeconomic implications of such disasters, are rarely calculated, and non-monetary costs—beyond loss of life or health—are hardly ever assessed. Non-monetary costs include stress to individuals and communities, deterioration of family relationships, and damage to the social fabric.

Geographic differences in the occurrence of weather-related and geophysical hazards are used to map the expected effects on different regions of the world. For example, the Hazard Management Unit (HMU) at the World Bank determines risk levels for individual countries and regions from hazard exposure and historical vulnerability for population and GDP per unit area. Countries are likely to be hurt by natural events if a significant proportion of their land area is expected to be affected, causing both population and economic losses (Dilley et al. 2005). In general terms, there is a broad pattern to the

occurrence of these events: most of the hydro-meteorological hazards happen on the Eastern coast of the Pacific Ocean; droughts are more prevalent in the semiarid regions North and South of the Equator; and regions with coastlines experience more tropical storms and hurricanes than inland locations.

While natural processes determine the occurrence and severity of hazards, human activities may exacerbate or ameliorate their ramifications. Certain patterns of economic behavior can aggravate hazards, such as deforestation in Haiti triggering landslides (Lonergan 1998; Homer-Dixon 1994; Bilsborrow 1992), rural-to-urban migration and increasing urbanization in the Caribbean leading to severe water shortages, or urban encroachment along the coastlines of the United States making ever larger amounts of infrastructure prone to sea level rise (Ruth 2006). For example, 13 million now live on coastline counties in Florida, as opposed to 200,000 a century ago; this aggressive coastal development is increasing vulnerability to natural disasters (De Souza 2004). Conversely, mitigation and adaptation efforts may reduce the level of risk exposure and vulnerability. The United States Geological Survey jointly with the World Bank estimated that natural disaster-related economic losses worldwide could have been reduced by $280 billion had $40 billion been invested in mitigation and prevention (Benson and Clay 2003). Finally, institutional development may also be seen as a form of increased capacity to cope with natural disasters and reduce vulnerability (Kahn 2005).

On a larger scale, Webster et al. (2005), Emanuel (2005), and Trenberth (2005) have all found a positive relationship between increase in atmospheric temperature and the intensity of hurricanes, at least for the North Atlantic Basin. Recent unpublished research is hinting that higher temperatures may also increase the frequency of such events. Higher atmospheric temperatures, in turn, have been attributed to anthropogenic releases of greenhouse gases into the atmosphere related to economic activity (IPCC 2001), and this is certainly expected to continue into the future. Thus, extreme weather events that lead to natural disasters are likely to be more common in the years to come (Easterling et al. 2000). Hence, the urgency to mitigate climate change is justified to prevent an increase in the frequency and severity of natural disasters and their negative consequences.

To assess not just the risks associated with climate change but also the vulnerability of a society and its economy requires consideration of scenarios for all anticipated significant changes to socio-economic and environmental systems (Rayner and Malone 2001). Vulnerability is then often interpreted as the "potential for loss" (Cutter et al. 2003), "the capacity to be harmed" (Rayner and Malone 2001), a combination of "exposure to contingencies and stress, and difficulty coping with them" (Chambers 1989), or "the capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard"(Blaikie et al. 1994). Resilience, in turn, is viewed as the ability of the social or economic system to absorb the impact of changes and continue to function (Dow 1992).

Additionally, climate change has a clear regressive effect on world development, impacting poorer countries more than rich ones, for reasons that will be discussed below. Thus, questions arise also as to the adequacy of mitigation efforts by rich nations, in terms of their historical responsibility for greenhouse gas emissions and their current paying capacity.

3 Macroeconomic effects of natural disasters

Natural disasters have direct economic effects, in addition to the short and long-run traumatic impacts on individuals, households, and communities. These disasters may set

back development goals and achievements. In the case of Central America, for example, natural disasters have caused more than 56 million deaths and $22 billion dollars of economic damage over the last 30 years, the equivalent of 37% of the current aggregate GDP of those countries (Martine and Guzman 2002).

Comparison of the effects of natural disasters on different countries is difficult because of their differences in population, income level, and the number and intensity of events they suffer. For example, monetary damages tend to be higher for industrialized and larger countries because of the accumulated value of monetarized assets at risk there. The highest overall average cost is reported for the U.S. followed by China and India (see Appendix 1). However, the average number of deaths for all events is higher in developing countries. For particular events, average deaths from earthquakes are highest, followed by those related to floods and land slides (see Appendix 2). Over roughly the last 30 years, damage for developing countries was on average 0.69% of GDP, compared to 0.08% for advanced economies. However, for particular Latin American and Caribbean countries the losses as a share of GDP range anywhere from over 1% in most cases to 20% on Barbados, 32% in Nicaragua, and 85% in St. Kitts & Nevis (Charveriat 2000). Similar variability in losses is seen throughout Asia and Africa.

In the remainder of this section we analyze the macroeconomic impacts of natural disasters within and between countries. Even though GDP is regarded as a problematic measure, we employ it here to facilitate inter-country and inter-sector comparisons. In the subsequent discussion, we address specific effects of natural disasters on poverty and income distribution, and discuss feedback effects between poor macroeconomic conditions, mainly reflected in poverty, and environmental degradation.

3.1 Within country effects

Natural disasters tend to deteriorate or destroy physical and social infrastructure, change the environment, and cause economic stress. To the population, they cause loss of property and impacts on livelihoods, and disruption to family and social relationships. Moreover, natural disasters affect the performance of the economy by changing the level and structure of public expenditure, usually hurting the current level of public services and future public investment, and reducing transfers, particularly to the disenfranchised and poor. Sometimes this sets back long-term development projects that ultimately affect those with lower income levels.

Overall, macroeconomic studies have found that natural disasters may lead to an immediate contraction in economic output, a worsening of a country's balance of trade, a deterioration of the fiscal balances, and an increase in poverty, usually accompanied by an increase in income disparities (Rasmussen 2004). Each of these macroeconomic impacts are closely related to each other.

Reductions in the growth of GDP typically take place in the year that the event occurs, with the potential for sharp increases in subsequent years (Charveriat 2000). For the Latin American and the Caribbean region (ECLAC), the median real decline in GDP growth typically is on the order of 2% in response to an average disaster, followed by an annual increase of 3% during the two subsequent years. Worldwide, the size of the effect on output growth depends in part on the overall size of the economy, the degree of integration of an affected area or sector with the rest of the economy, and the ability to adapt to varying production conditions (Benson and Clay 2004).

The growth rate of GDP falls because there is usually a significant fall in production, particularly in the case of hurricanes, floods, or droughts. These events are typically

perceived to primarily affect the agricultural sector, in addition to other primary activities such as forestry and fisheries. However, hurricanes and floods may have effects on other sectors such as tourism that rely heavily on the existence of natural capital. The manufacturing sector may be affected as well, in part because of a decrease in activity due to the disruption of transportation and a reduction in production capacities. Transportation is commonly affected because natural disasters tend to hurt roads and bridges. Production capacity falls because of a delay in inputs such as water, energy, and materials, and because of direct effects on workers and their productivity. Finally, the export sector is hurt because of the effects that both the primary and secondary sectors suffer (Charveriat 2000; Albala-Bertrand 1993; Downing et al. 1999).

Gross formation of capital tends to fall in the year of the disaster but then increases due to new investment for reconstruction. Inflation tends to increase since the prices of goods and services go up due to disruptions in production and transportation.

If countries have access to additional resources and room to increase or reallocate expenditures, the fiscal balance suffers because of necessary diversions of government expenditures for aid and reconstruction (Benson and Clay 2003). At the same time, tax revenue typically falls. IMF (2003) found that particular natural disasters in Africa caused an increase in the fiscal deficit of 3% of GDP in the year of the disaster.

Trade balances often suffer for at least two reasons. Exports may fall if either the production of exports is affected or if the infrastructure to put the products into the international market is damaged. Furthermore, imports of reconstruction materials and consumption goods usually rise in response to falling domestic production. ECLAC (2000) found that for the case of Latin America the deterioration of the balance of payments was equivalent to a third of the estimated damage (Crowards 2000). Balance of payment impacts are particularly large for countries with high dependence on the primary sector for exports and domestic consumption (Benson et al. 2001), a situation common for many African countries. The current account is affected by trade imbalance and international help in the form of loans that increase long-term foreign debt (Charveriat 2000; Albala-Bertrand 1993; Downing et al. 1999).

The effect of natural disasters on selected components of GDP ultimately traces back to a fall in GDP per capita and to lower real income levels. When income levels fall, there is an increase in poverty since people have fewer resources available to fulfill their needs. If the relative income level of different groups is affected, income disparity swell. Usually when income level drops, it is also redistributed and disparity increases, because more resources flow toward the rich (the capital assets they hold are now scarcer and the value of these assets is increased) and less to the poor. Thus, natural disasters tend to increase poverty and worsen income disparity.

In addition to a fall in income that has effects on welfare itself, the poor often are more affected because they tend to settle in the most vulnerable areas and have inadequate housing and working facilities (World Bank 2003). They are more vulnerable because they have fewer assets and access to insurance and credit markets to smooth income losses and consumption needs (IMF 2003). Additionally, natural disasters have a negative impact on living standards that may be felt outside the region directly affected. Therefore, there are regional, national and very often international effects of natural disasters, mainly through migration.

The magnitude of these effects is linked to the share of land, population, and economic activity affected by the natural disaster, as well as to the initial conditions and resilience of the population and the economy. Understanding the macroeconomic effects both within and across countries is key to the proper assessments of vulnerabilities and policies to

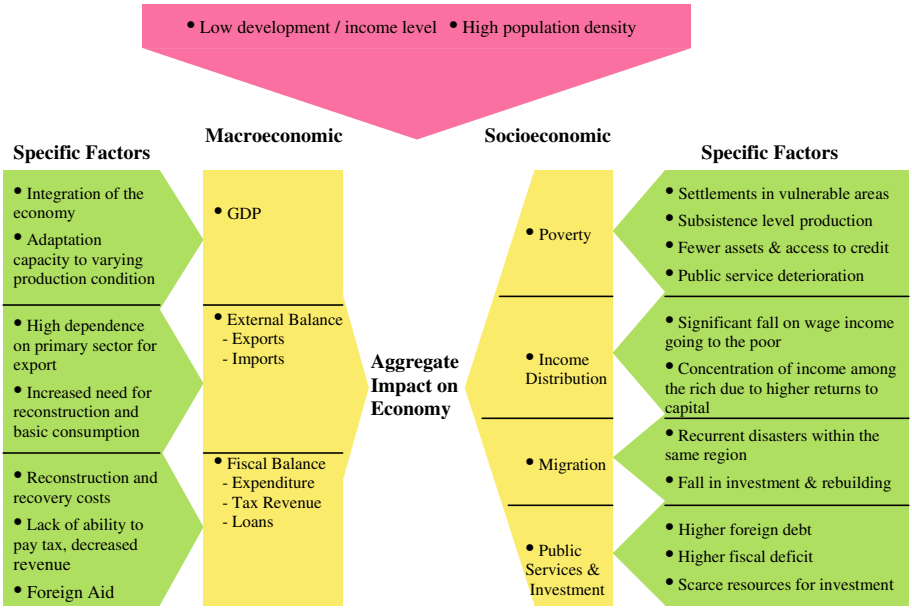

Fig. 2 Factors affecting economic and social vulnerability

reduce them. Figure 2 summarizes the factors affecting economic and social vulnerability from a macro perspective.

3.2 Differential effects across countries

As discussed above, not all countries suffer equally from the effects of natural disasters. Even though the probability of getting hit by a natural disaster is not statistically different for developing and industrialized countries, developing countries are more affected in terms of deaths and injury. According to Kahn (2005) this may be precisely due to their development level, since usually they have not made (or rather they cannot afford to make) the required investments to protect themselves from such natural events, and they are unable to protect their population, i.e., poverty makes the population of certain areas more vulnerable to nature's events.

Benson and Clay (2004) state that short-run macroeconomic effects are more commonly seen in small island economies and in rural/agricultural settings. This is the case of Dominica, for example, where in 1979 Hurricane Allen caused its GDP to drop by 20%.

Countries of larger geographic size tend to suffer less of an economic impact. Longer term impacts can be difficult to determine at a national level even though negative impacts are usually present. This is quite evident for the case of Bangladesh. The change in GDP is rarely negative even under extreme weather-related events. For instance, even though agricultural GDP shows variability, aggregate GDP is quite stable. However, distributional impacts may be quite strong, generating winners and losers (Benson and Clay 2004). This cannot be seen directly from macroeconomic variables such as the change in GDP.

Even though many countries have been able to build up their capacity to buffer natural disasters and therefore reduce their vulnerability through infrastructure, development, and

institutions, this is not always the case. Vulnerability is a changing feature of an economy. It can be affected by a change in the rate of economic growth and due to socio-economic change. Malawi, for example, now more prone to drought due to a deteriorating natural environment, is a case where vulnerability has increased. Vulnerability increased due to unsustainable agricultural practices and weaknesses of the agricultural sector, de-industrialization and the return of competition from other countries into the regional economy, political instability and governance issues, public finance volatility, and the effect of HIV/AIDS on the population (Benson and Clay 2004). Output of maize has been highly variable, sometimes falling up to 60% as a response to drought.

Other empirical evidence suggests that, for example, as GDP per capita grows there are fewer fatalities, controlling for the strength of the natural event Kahn (2005). This raises an equity concern related to the distribution of the negative effects of natural disasters and eventually of climate change, as long as it seems to increase intensity and frequency of natural hazards: they both hit the poorer nations hardest. Thus, natural disasters and climate change have a clear regressive effect on world development since they affect the poorer nations far more than the rich ones. This again poses the question of how much particular nations should mitigate emissions that cause climate change, vis-à-vis their historic responsibility towards the buildup of those emissions in the atmosphere, their ability to pay, and the costs they impose on others (Johnson 1993).

The differential impact of natural disasters on different countries may also be explained in that the higher income level of industrialized nations eventually translates into better institutions with a higher capability of addressing the effects of natural disasters. These stronger institutions were approximated in Kahn (2005) using an index showing the openness of political institutions and some heterogeneity variables such as the Gini coefficient, ethnic fragmentation, and perception of governance. To control for initial conditions and quality of institutions today, Kahn includes the settler mortality risk in colonies and origin of legislation (references for these variables in Kahn). All of these variables may help explain the differences in cross-national economic performance in a broader sense than only related to natural hazards. Overall Kahn's results show that better institutions insulate the population from the effects of disasters, i.e., proxies for institutional quality lower deaths from natural disasters. Additionally, controlling for income, less democratic nations and more unequal nations face higher number of deaths. Finally, corruption indices are negatively correlated with income per capita. Corruption may increase deaths because of a lack of enforcement of building and zoning codes and poor quality of infrastructure.

3.3 Effects of natural disasters on poverty and income distribution

Even though statistical analysis of 57 countries listed in the EM-DAT dataset indicates that rich and poor nations are similarly prone to natural hazards (Kahn 2005), vulnerability clearly varies significantly among and within countries, with poor countries and poor people usually ranking among the most susceptible. Studies continually show that the poor suffer higher mortality rates after natural disasters (Winchester 2000; Pelling 1997; Kahn 2005). This may be due to two factors. First, the poor have fewer resources for preventative and adaptive measures; that is, they lack the endowments that provide resources to cope with the effects of natural disasters. Second, their social networks are less likely to contain connections to influential people, such as moneylenders or government officials.

The first of these factors relates to the fact that assets and income are a critical part of social vulnerability. Among the poor, reliance upon a single source of income is found to

be correlated with lower income (Kelly and Adger 2000). This increases the likelihood that a natural disaster will seriously and adversely affect their livelihood. With lower incomes and reduced assets, the poor then lack the savings to manage unplanned expenses associated with natural disasters, both preventative and recuperative. Items such as quality health care, sturdy housing, adequate food and water supplies, and communication devices, which could mitigate injury and property damage, are not accessible for the poor (Adger and Kelly 1999; O'Brien and Leichenko 2000; Wisner 1997; Pelling 1997; Blaikie et al. 1994; Winchester 2000). Additionally, due to a low income level and a lack of an endowment, the poor do not have the savings to purchase productive, stable land. Thus, marginal populations may be forced to live in marginal areas (Wisner 1997; O'Brien and Leichenko 2000; Vaux and Lund 2003; Lavell 1994; Chan and Parker 1996; Blaikie et al. 1994). Winchester (2003) found that in India, 20 years after the 1977 cyclone, more of the poor South Indian agricultural laborers had migrated to vulnerable coastal regions that are less expensive and more prone to damage from natural disasters (than what? The phrase starts, "more of the poor..." but there's no resolution to the "more." How many more, or More than what). Impacts of disasters may even increase as poor groups may overexploit natural defenses, such as wetlands or forests, for their livelihood (Blaikie et al. 1994).

A second reason for disproportionate impacts of disasters on the poor lies in the limited access to credit markets and government officials. This deprives the poor of the most critical forms of resilience, such as private and public insurance (Chan and Parker 1996; Pelling 1997; Blaikie et al. 1994). Insurance serves to protect against large swings in income. In Bangladesh, a country that is particularly vulnerable to sea level rise from climate change, there is a low ability to insure against catastrophe, both because most people don't qualify or are able to purchase it, and there are few providers of catastrophe insurance. On the other hand, government recovery and assistance plans act as a form of public insurance, though the poor may be left out of these programs as a result of systematic exclusion or oversight (Winser 1997; Blaikie et al. 1994; Adger 1999). Furthermore, the poor may not be part of a government's social insurance program because they are concentrated in economic sectors that cannot afford or choose not to contribute: these include the informal sector, small businesses, or self-employment. Without private or public insurance, the poor often turn to informal insurance agreements. However, these plans may also fail after shocks because providers are often hit by the disaster as well (Lustig 2000) and financial resources may be diverted to rebuild infrastructures rather than compensate for the loss of livelihoods.

Social networks can provide essential information resources prior to the occurrence of a disaster and a source of support in the recovery period (Wisner 1997). The wealthy may be better able to work their way through the government system and receive a larger share of assistance. This can be facilitated through their network; ties to government officials provide early warning or public assistance after an event. Pelling (1997) found that wealthier neighborhoods in Guyana had better infrastructure and maintenance of government provisions such as sewers, sources of drinking water, and municipal waste disposal. Incidence of sickness and reported response to flood was less serious in these areas than in their lower income regions. Finally, ties to local lenders allow the wealthy to obtain scarce loans after a natural disaster (Wisner 1997; Winchester 2000). Therefore, access to all of these resources reduces the social vulnerability of the wealthy, and the lack of access to these resources increases the vulnerability of the impoverished.

Income distribution—or rather income concentration—plays a role in determining the death toll from natural disasters. Controlling for differences in GDP, countries with a

higher Gini coefficient experience a higher death toll from natural disasters. Thus, improving income distribution is crucial because a more equitable income distribution is usually associated with a better distribution of coping abilities.

Population density and land extension also dictate deaths from natural disasters. Japan would experience a much higher death toll than less densely-populated countries. Similarly, Iceland, because of its small land extension, would be hit harder than countries of comparable income but with much larger land areas.

3.4 Poverty and environmental degradation

The standard literature on this topic describes a downward spiral of poverty and environmental degradation (Cleaver and Schreiber 1994; Forsyth et al. 1998). About 80% of the poor in Latin America, 60% in Asia, and 50% Africa live on lands with low productivity and high vulnerability to degradation and natural hazards (Hardoy et al. 2004). Their presence only seems to worsen conditions of those natural resources and their own vulnerability to natural disasters. This, in turn, makes the livelihood of the poor more difficult because of the low quality natural capital they have access to, feeding back into a negative loop of poor micro- and macroeconomic conditions and environmental degradation. As Indira Gandhi said at the first UN World Environmental Conference in 1972, "poverty is the greatest polluter."

Gandhi was one of the first to connect development issues with environmental issues, and we are still struggling with how to address this nexus today. Where there is a lack of infrastructure for fuel, drinking water, sewage and other resources, the poor in developing countries rely on common property natural resources as a source of income to provide for their daily needs. This can create deforestation, erosion, water pollution and other situations that can, in turn, affect the health and well-being of the population. As the population increases, environmental degradation may increase, which further affects the livelihood of the population and leads to greater poverty. Without education on sustainable practices or proper investment in infrastructure, this cycle of poverty and pollution is difficult to break. The empirical evidence for this downward spiral, however, is mixed (Mink 1993; Grepperud 1996). For example, Scherr (2000) has found a wide range of cases where the micromanagement practices of the poor improve environmental quality, often reversing degradation. In these cases local knowledge and technology have controlled degradation by expanding vegetation cover and diversifying crops to maintain income (Forsyth et al. 1998).

Both within and across countries, we know that the poor are the most affected by natural disasters, i.e., they are the most vulnerable. Yet vulnerability is not equally spread across all the poor. A breakdown of vulnerability is discussed in the following section.

4 Group-specific vulnerability to climate change

Here we draw on research from a variety of disciplines to synthesize the effect of natural hazards on the livelihood, health, and general wellbeing of the poor, depending on their age cohorts, gender, and ethnicity and race. Social class, as a separate factor, is not considered here because it is in many ways an expression of the combined influences of income, education, race, ethnicity and age.

Several empirical studies directly examine group-specific differences in vulnerability to the impacts of climate change (e.g., OECD 2003; Bunyavanish et al. 2003; Cutter et al. 2003; Bohle et al. 1994). Most of the studies dealing with group-specific vulnerabilities are

qualitative, owing to the environmental, social, economic, and technological complexities that determine the extent to which a social group experiences risks. Some of this large body of literature isolates the effects of extreme events on marginal populations. Additionally, since risks, vulnerabilities, and resilience are most apparent in periods of natural disasters, and since climate change increases the severity and frequency of extreme events, these studies can help ascertain climate impacts on marginal populations (IPCC 2001; Cubash et al. 2001). We use these studies as a guide to disaggregate the vulnerability for the sub-groups of the poor.

4.1 Defining social vulnerability

Among several options, here we choose to describe two major approaches to vulnerability. Bohle et al. (1994) break down vulnerability into environmental hazards and social inequalities. The poor are often more exposed to harmful environmental perturbation (risk of *exposure*); they are also more vulnerable because they possess limited coping capacity (risk of inadequate *capacities*). They suffer the most from the impact of an extreme event because they are far more constrained in their potential for recovery (risk of *potentiality*). Vulnerability, composed of the latter risk factors, is therefore a product of *human ecology* (the relationship between people and the environment); *expanded entitlements* (property rights, endowments, social entitlements, and empowerments) and *political economy* (class and other macro-structures in which resource endowments and patterns of entitlements are embedded).

Cutter et al. (2003) create a model that combines the geographic distribution of hazards with the social characteristics of people. They define social vulnerability as the product of social inequalities that eventually shape the susceptibility of various subgroups to harm and govern their ability to respond. These inequalities are often expressed in the lack of or limited access to resources or political power and representation. Social vulnerability also incorporates place inequalities, defined as the characteristics of communities and the built environment. These could include level of urbanization, growth rates and economic vitality. Furthermore, vulnerable groups will have limited social capital, including social networks and connections, and may hold beliefs and customs that increase their susceptibility. As mentioned in previous sections, groups with high social vulnerability may have increased biophysical/environmental vulnerability as well. Since it is often difficult to quantify many of these concepts, social vulnerability is usually described using the specific characteristics of a subgroup. The variables commonly used to represent these groups are age, gender, socioeconomic status, and special-needs, such as the needs of physically/mentally challenged, immigrants, homeless, transients, and seasonal tourists.

4.2 Empirical evidence

With this brief overview of how social vulnerability is perceived, we move on to describe specific ways in which particular groups among the poor are vulnerable in the face of natural disasters and climate change. The literature clearly suggests that, generally, ethnic or racial minorities, females, and the elderly, and/or very young tend to suffer most.

4.2.1 Gender

In studies of heat waves in the United States, no significant difference was found between women's and men's mortality rates (Semenza et al. 1996). Yet, this fact masks the higher

vulnerability of women during natural disasters. While women may not be biophysically more vulnerable to natural disasters, and thus do not suffer higher mortality rates because of that, the difference lies in their social vulnerability (Rashid 2000; Cannon 1994; Enarson 2000). All else equal, women are more likely to be poor than men (Gordon et al. 2003). This gender-poverty gap is the result of lower empowerment. Indeed, wealthy, developed nations occupy the top rankings in indices of gender empowerment that aggregate a woman's right to make economic and political decisions (UNDP 1995). Empowerment reduces their vulnerability.

Restrictions on women's livelihoods have effects on gendered-vulnerability in both developing and developed nations. Schroeder (1987) cites four broad categories that affect women's vulnerability in developing nations: lack of access to means of production, lack of access to alternative sources of food, lack of assets, and restricted access to the labor market. Within these categories, he mentions specific examples for women, such as lower wages, restrictions on education, and virilocal marriage practices which displace them from their social networks. These factors inhibit women from fully contributing to their own or their family's welfare, reducing the resources available to them to cope with disaster. Across developed nations, gender differences in employment opportunities and pay are also one of the greatest contributors to the increased poverty rates among women.

As we discussed above, the poor often lack multiple sources of income. For women, this is of greater importance, because their labor tends to be in particularly disaster-prone sectors (Denton 2002). As the opportunities for women's paid labor are reduced because of natural disasters, the amount of unpaid work in the home increases, exacerbating this problem (Enarson 2000). Household chores become more difficult and numerous (Rashid 2000). In the developing world, tasks such as cooking, cleaning, fetching water, care giving, and balancing work and family require more effort when tools are washed away and sources of water become contaminated (Rashid 2000; Enarson 2000). Women of developed nations face an increase in these tasks because of tragedy, lack of child-care, and the loss of conveniences like electricity and permanent housing. Furthermore, the death of family members (loss of social network) and breakdown of law and order after a natural disaster might lead to violence against women, making them more vulnerable.

Poor women are especially dependent upon aid for recovery after disasters because they lack the endowments available to wealthier counterparts. However, institutional discrimination may reduce the aid that reaches them. Aid is sometimes distributed to male heads of household (Enarson 2000). Cases of this have been documented in both developed and developing countries; Enarson (2000) reports occurrences in California and Malawi. When men leave their families, as is not infrequent after a natural disaster, women receive no public assistance. A report found that the United States Small Business Administration disproportionately favored male-headed businesses in granting recovery loans (Enarson 2000).

Thus, the greatest source of gendered-vulnerability is through the other half of the feedback loop; women in both developed and developing countries are disproportionately poor, adding to the risk factors that accompany low socioeconomic status (Chan and Parker 1996; Enarson 2000).

4.2.2 Race and ethnicity

In most regions, racial and ethnic minorities tend to have a lower socioeconomic status (Fothergill et al. 1999; Chan and Parker 1996). Studies consistently show these minorities have higher death rates from natural disasters (McGeehin and Mirabelli 2001; Fothergill

et al. 1999). Jones et al. (1982) found that non-white residents had heatstroke mortality rates three to six times higher than white residents after a U.S. heat wave. Higher vulnerability for racial and ethnic subgroups is usually the result of discrimination, both intentional and through negligence. Deliberately discriminatory practices like insurance red-lining and neighborhood segregation place minorities in precarious housing situations with few resources for disaster mitigation (Fothergill et al. 1999). As with females, racial and ethnic minorities tend to depend upon the government for aid. Government workers may participate in discrimination because of a lack of knowledge about cultural norms, i.e., warning signs may be in the wrong language, or aid may be structured around a nuclear household unit. As an example of the latter, FEMA could not sufficiently assist Haitians living in Florida after a natural catastrophe because several families often live in one household (Fothergill et al. 1999). Examples of discrimination in emergency response have also been documented (Beady and Bolin 1986). Knowing about previous discrimination may also affect minorities' current view of government services, discouraging them from seeking available help (Langer 2004).

Meadows and Hoffman (2003) provide a clear example of the interaction of poverty and race-based vulnerability. Historic inertia also plays a role. In South Africa black farming communes were relegated to sloped, marginal land during apartheid. Today this land is more degraded from a lack of investment due to discriminatory lending practices, and more intensive farming because of poverty. Conversely, land given to whites had higher commercial value and continues to be productive because they are able to afford inputs. Consequently, Meadows and Hoffman predict that black farming communities will be hit harder given climate change induced drought.

4.2.3 Age

While the elderly and very young are physiologically more vulnerable to natural disasters, they are more socially vulnerable as well (McGeehin and Mirabelli 2001; Blaikie et al. 1994; Scheraga and Grambsch 1998; Ngo 2001). This physical vulnerability is channeled into overall vulnerability depending on the resources they have to mitigate risk.

There is empirical evidence that in general the elderly display disproportionately higher injury rates after natural disasters (Ngo 2001). Studies on heat wave mortality also show that persons over the age of 65 have higher rates of heatstroke and are more likely to exhibit characteristics of risk (Kilbourne et al. 1982; Jones et al. 1982). Older persons are more vulnerable because they have diminished coping skills. Their bodies adapt to temperature changes slower and are less able to perceive excess heat, preventing them from taking adaptive measures (Scheraga and Grambsch 1998; McGeehin and Mirabelli 2001). Reduced mobility may also inhibit them from leaving a dangerous situation. Finally, they are also more susceptible to disease because of preexisting health conditions (Ngo 2001).

This physical vulnerability can be overcome with adaptive measures; but frequently these measures are only accessible to the wealthy. For example, the elderly are more likely to lack private transportation that could be used to leave a dangerous area. The wealthy may be able to hire a taxicab. The poor, though, must rely upon neighbors or relatives, for whom the ride may constitute a considerable burden, discouraging the elderly from requesting assistance. Thus, the elderly's vulnerability is highly dependent upon their economic status (Langer 2004). Controlling for other variables, the elderly show disproportionate rates of poverty, because they do not generate income anymore and often have low endowments, if any. Poor older persons in developed nations are more likely to live

isolated and alone. Lack of personal contact and distrust of strangers decreases their access to assistance (Scheraga and Grambsch 1998; Langer 2004). The elderly are also less likely to take advantage of public recovery and prevention programs that they might perceive as welfare (Langer 2004; Ngo 2001). In developing countries, they are marginalized because of their lower income capability and the extra work they impose on others; more often than not the government may ignore their needs.

Children, in contrast, are not typically thought to be a marginalized population, but they lack the power to make critical decisions that affect their wellbeing. Children suffer from many of the same physiological effects as the elderly. The young are more susceptible to disease because their respiratory and immune systems are not yet fully developed (Bunyavanich et al. 2003). Children also have diminished abilities to care for themselves (Blaikie et al. 1994). Adults are responsible for adjusting physical conditions for the very young. Barriers to communication, lack of mobility, and reduced ability to employ coping mechanisms like ingesting fluid or changing attire increase youth vulnerability (Blaikie et al. 1994; Blum et al. 1998). Children also have greater sustentative needs. If food or water sources become scarce during a drought, poor children may be more seriously impacted, especially in cultures where children eat last (Bunyavanish et al. 2003). If a disproportionate number of children are poor, like the elderly, this vulnerability is more likely to go unmitigated (Gordon et al. 2003).

4.3 Poverty and vulnerability feedbacks

Climate change has been linked to an increase in frequency and intensity of extreme events and natural disasters. There is empirical evidence that the macroeconomic effects will fall largely upon the poor (Deininger and Squire 1996). Given that the poor are more vulnerable, climate change has the potential to create a vicious cycle of poverty and vulnerability.

While growth tends to increase the incomes of the poorest groups, thereby reducing poverty, economic declines have an opposite impact. Additionally, shocks tend to increase income inequality (Deininger and Squire 1996). Reardon and Taylor (1996) find empirical evidence for this phenomenon in Burkina Faso. The poor use livestock sales to augment their income from agriculture. Droughts lead to further sales, making them more vulnerable to the next drought. After the 1984 drought, the richest third of the population suffered a 58% drop in income, while the poor suffered a 69% drop accompanied by larger livestock sales. Lustig (2000) estimates that for every percent decrease in gross domestic product in Latin American countries, there is a corresponding 2% increase in poverty, but this is mainly due to the downward mobility of the middle class. Incomes of the top 10% rose during this period. Other studies find that the wealthy may also fall into poverty as a result of natural disasters. In South India, Gaiha and Imai (2004) show that all segments of the population, landless and land-holders, upper and lower castes, are vulnerable to poverty after crop shocks. Regardless of the distribution of a shock's impact, the gross increase in poverty increases social vulnerability within a population. Social vulnerability can magnify over time, especially with increased frequency of natural disasters, forcing groups into a permanent state of poverty and exposure.

5 Policy implications

Several lessons can be drawn from this research. First, given that the poor are more vulnerable to natural disasters and that climate change tends to increase the frequency

and intensity of many of these disasters, climate change has the potential to create a vicious cycle of poverty and vulnerability. Second, investment in disaster prevention, awareness, and mitigation will be progressive in terms of inequality and poverty reduction. Empirical evidence presented here shows that the macroeconomic impact of these disasters fall largely upon the poor; however, the review of the literature also indicates that through physical, economic, and institutional development a country—or a group of people—may somewhat insulate itself from the negative effects of natural disasters.

Additionally, even though catastrophes can be unexpected and uncertain in their occurrence and effects, they need to be considered as events that are likely to happen and therefore require advanced planning. Past experiences highlight the need to prepare for disasters, giving special attention to their effects on poverty and distributional impacts. This implies that the monetary and physical resources to face such catastrophes should be available beforehand and, when feasible, reflected within the national budgets. Moreover, subgroup vulnerability should be addressed and built into natural disaster prevention programs to avoid further gaps among the poor, thus increasing overall social and economic resilience to disasters. This could be done by granting relief to women when appropriate, rather than men, for example. Well planned evacuation programs could help mobilize the elderly and the very young, and particular policies could address minorities, making sure particularly not to discriminate against the non-minority poor.

Finally, adaptation has to be implemented on two levels. Household and community level strategies may be put in place to reduce risk. Such strategies may include moving out of hazard-prone zones, investing in hazard-resistant technology, and diversifying income sources.

At the public level, a short-run policy is to design a contingency fund within the budget to provide aid when a disaster takes place. A tricky balance may need to be struck between providing insurance (or government assistance) in case a disaster hits, and not encouraging through the supply of such provisions moral hazard and adverse behaviors, such as settlements in flood-prone regions, or farming on steeply sloped lands. Other public level policies that could be accomplished in the medium term may be relocating settlements and building physical infrastructure to mitigate the effects of natural disasters and contain their magnitude. In the long run, policies such as diversification and relocation of economic activity and the generation of resources to face future disasters may be vital. In this sense, physical and institutional awareness, as well as financial preparedness, are crucial in order to respond to emergencies and to allow for rehabilitation and reconstruction in a timely fashion.

Ultimately, natural disasters and climate change have a clear regressive effect on world development because they impact poorer nations far more than rich ones and have a clear effect on the distribution of income, wealth, and costs worldwide. This again poses the question of how much particular nations should contribute to mitigating emissions that cause climate change, in terms of their role in the buildup of those emissions in the atmosphere, their ability to pay, and the costs they impose on others.

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Appendix 1 Natural disaster statistics for selected nations

Country	Annual average total count of disasters	Annual average total deaths per million people	Average deaths per earthquake	Average deaths per extreme temperature extent	Average deaths per flood	Average deaths per landslide	Average deaths per windstorm
Algeria	1.3478	7.1542	320.1111		66.8421	15.0000	2.0000
Argentina	2.0000	0.4238	3.0000	7.2500	7.9667	–	4.7000
Australia	4.0000	0.6741	7.6667	5.7500	3.5926	14.0000	1.6964
Austria	1.0435	0.7453	–	0.0000	3.7143	23.2500	1.2500
Bangladesh	6.2609	65.9391	6.0000	139.6667	211.4565	–	1,940.4940
Belgium	1.0000	0.0521	1.0000	0.0000	0.9000	–	0.1000
Bolivia	1.0556	4.3244	46.0000	7.5000	28.3158	37.2500	4.0000
Brazil	3.3913	0.8721	1.0000	28.0000	42.7400	42.8000	14.2222
Cambodia	0.5714	7.4703	–	–	143.0000	–	–
Canada	1.1304	0.1839	–	0.0000	2.6667	–	7.1687
Chile	1.5217	3.6315	40.0000	0.6667	34.5882	86.5000	18.6250
China	13.9130	1.7657	36.9039	29.1429	328.4300	63.9091	71.7268
Columbia	2.9130	5.4748	162.5455	–	34.5484	76.5714	9.0000
Costa Rica	1.0000	2.7530	7.5714	–	4.0909	7.0000	22.5000
Cuba	1.6667	0.7885	0.0000	–	7.3333	–	1.8571
Denmark	0.3913	0.1591	–	0.0000	–	–	2.3750
Dominican Republic	0.6957	2.8905	–	–	9.3750	–	50.3750
Ecuador	1.1739	7.7614	43.1250	–	60.2500	114.8571	–
Egypt	0.6087	1.0882	190.3333	19.0000	125.2000	34.0000	24.0000
El Salvador	0.8696	27.4940	569.7500	–	62.4444	22.0000	98.4000
Ethiopia	1.7692	0.7672	–	–	27.1500	13.0000	–
Fiji	0.8333	9.3557	0.0000	–	14.5000	–	9.4211
France	3.4348	0.3699	–	8.0000	4.4839	9.1429	6.9714
Germany	0.7391	0.0674	1.0000	30.0000	6.0000	–	6.3750
Ghana	0.4615	0.9618	–	–	36.3333	–	–
Greece	1.5217	6.0054	14.0588	216.0000	3.6000	–	16.6667
Guatemala	1.0870	6.6072	5.8750	0.0000	80.3000	47.3333	130.6667
Haiti	1.1053	15.8560	–	–	15.7857	0.0000	284.3333
Honduras	1.0000	132.7648	1.0000	–	43.6000	10.0000	2,953.8000
Hong Kong	1.4783	1.5246	–	10.0000	3.6000	1.0000	7.2727
Hungary	0.4348	0.5624	–	81.0000	1.2857	–	22.0000
India	10.0870	4.7195	2294.0720	328.7692	291.7245	91.1429	332.0606
Indonesia	5.7826	1.9380	92.5455	–	46.3939	47.5000	0.6667
Iran	4.3043	41.2894	1105.3260	–	69.0625	26.5000	39.0000
Ireland	0.5217	0.4608	–	–	1.0000	–	3.8889
Italy	2.0870	3.9857	299.3750	3.3333	17.5294	15.2500	8.2500
Jamaica	0.6087	2.6586	–	–	12.8333	–	8.8750
Japan	4.0000	2.7159	311.0000	–	46.1429	26.6364	17.7500
Kenya	0.5217	0.7109	0.0000	–	36.3333	16.0000	50.0000

Appendix 1 continued

Country	Annual average total count of disasters	Annual average total deaths per million people	Average deaths per earthquake	Average deaths per extreme temperature extent	Average deaths per flood	Average deaths per landslide	Average deaths per windstorm
Korea, Republic	2.0435	2.9153	–	33.5000	65.6111	22.0000	64.3600
Madagascar	0.8696	3.7580	–	–	0.0000	–	58.2222
Malawi	0.9286	4.2386	9.0000	–	46.4167	–	–
Malaysia	0.8696	1.2154	–	–	7.5385	38.0000	90.6667
Mexico	4.2609	6.9996	528.1765	90.1667	62.4231	24.6667	42.6000
Morocco	0.8462	2.7069	–	0.0000	103.0000	–	14.0000
Mozambique	0.8261	4.3834	–	–	94.7000	87.0000	58.3750
Nepal	1.6522	14.0229	404.5000	30.0000	220.3684	113.3333	16.16667
New Zealand	1.3913	0.2120	1.0000	0.0000	0.2500	–	1.6667
Nicaragua	0.7826	41.8757	62.0000	–	8.8333	–	403.3333
Nigeria	1.5333	0.4064	–	39.0000	27.4118	10.6667	100.0000
Pakistan	3.2609	3.1358	46.9333	91.2222	187.4074	33.3333	76.6667
Panama	0.5652	1.6756	30.0000	–	2.4444	–	14.0000
Papua New Guinea	0.8000	6.2280	10.6667	–	11.6000	104.6667	23.5000
Peru	2.9130	7.4365	23.6111	21.0000	74.0714	63.5000	59.0000
Philippines	8.4348	16.4698	253.2000	–	38.2000	63.1111	153.8512
Poland	1.0000	2.1226	–	134.1667	29.6667	–	3.5000
Portugal	0.3913	0.3544	–	0.0000	12.8333	–	2.0000
Romania	2.2727	1.0186	–	15.2500	8.5000	0.0000	7.2500
Russia	6.0000	2.8809	400.2000	107.4667	14.4815	56.7500	18.6364
South Africa	1.5652	1.7289	11.3333	30.0000	68.8235	34.0000	11.2857
Spain	1.3043	0.4931	0.0000	17.5000	16.0000	84.0000	8.5385
Sri Lanka	1.4348	1.6455	–	–	19.3667	65.0000	2.5000
Switzerland	1.2174	0.3064	–	0.0000	1.0000	9.3333	0.8333
Taiwan	1.1053	1.2368	13.0000	–	20.5000	14.0000	23.5294
Tajikistan	2.2857	3.9778	1.0000	–	12.8889	25.5000	0.0000
Tanzania	1.4615	1.2361	1.0000	–	33.2857	13.0000	4.0000
Thailand	2.4348	2.1485	–	–	55.7838	39.0000	35.2778
Turkey	2.4348	16.1699	908.8636	19.2500	27.1667	77.0000	8.3600
United Kingdom	1.8696	0.2013	0.0000	16.0000	0.7857	–	8.3600
United States	17.9565	1.3337	7.9444	115.8333	6.3820	–	17.2361
Venezuela	1.0435	66.6421	16.3333	–	2,015.7330	96.0000	54.0000
Vietnam	4.0000	11.6504	–	–	98.8333	110.5000	270.9091
Yemen	1.1667	2.9587	11.0000	–	47.2727	–	15.0000

A period indicates that the nation did not experience this type of natural disorder

Source: Kahn (2005)

Appendix 2 Frequency and impact of natural disasters, 1972–2001

	1970s	1980s	1990s	1970–2002	Ratio 1990s–1970s
In ECCU countries[a] (six Fund members)					
Number of natural disasters	6	18	18	44	3.0
Number of persons affected (in thousands)	94	200	96	390	1.0
In percent of population[b]	2.08	3.93	2.53	2.59	1.2
Number of observations	3	1	16	31	5.3
Damage (in millions of 2002 US$)	107	424	277	808	2.6
In percent of GDP[c]	1.90	2.98	1.70	2.00	0.9
Number of observations	2	11	5	18	2.5
In developing countries[a] (excluding ECCU, 120 countries)					
Number of natural disasters	643	1,296	1,924	4,952	3.0
Number of persons affected (in millions)	723	1,429	1,886	5,063	2.6
In percent of population[b]	1.50	2.61	2.31	2.22	1.5
Number of observations	447	890	1531	3,738	3.4
Damage (in billions of 2002 US$)	72	106	257	479	3.6
In percent of GDP[c]	0.46	0.65	0.93	0.69	2.0
Number of observations	225	347	502	1,276	2.2
In advanced economies[a] (24 countries)					
Number of natural disasters	204	433	583	1,484	2.9
Number of persons affected (in millions)	6.2	6.7	34.2	49.5	5.5
In percent of population[b]	0.08	0.05	0.52	0.20	6.3
Number of observations	73	158	316	742	4.3
Damage (in billions of 2002 US$)	60	149	406	650	6.8
In percent of GDP[c]	0.06	0.10	0.08	0.08	1.4
Number of observations	97	221	351	742	3.6
Worldwide[a] (150 countries)					
Number of natural disasters	853	1,747	2,525	6,480	3.0
Number of persons affected (in millions)	0.73	1.44	1.92	5.11	2.6
In percent of population[b]	1.28	2.24	1.95	1.88	1.5
Number of observations	523	1,059	1,863	4,511	3.6
Damage (in billions of 2002 US$)	132	256	663	1,130	5.0
In percent of GDP[c]	0.45	0.65	0.82	0.64	1.8
Number of observations	324	579	858	2,036	2.6

Sources: EM-DAT: and IMF, World Economic Outlook database

[a] Omits countries without at least one natural disaster associated with a cost estimate and/or missing information on GDP

[b] Average percentage of population affected each year. Figures are unweighted average across countries

[c] Average damage each year in percent of GDP. Figures are unweighted average across countries

Source: Rasmussen 2004

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