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Have natural disasters become deadlier?

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Abstract

The present study seeks to build on earlier work by identifying the factors associated with the frequency of natural disasters and the resulting mortality. Drawing together the main findings, some observations are made from a policy perspective to focus on *key* elements of a disaster reduction strategy. Countries that were prone to natural disasters in the decade1970-79 continued to be so in the next two decades. Geophysical factors (e.g. whether landlocked, size of a country) had an important role in explaining inter-country variation in the occurrence of natural disasters. However, income did not have any effect. Deaths varied with the number of disasters; they also varied with (lagged) deaths in the previous decade; poor countries suffered more deaths; and, controlling for these and other effects, larger countries suffered more deaths. The pay-off from learning from experience is high. Even moderate learning can save a large number of deaths (e.g. through early warning systems, better coordination between governments and communities likely to be affected). Growth acceleration would also help avert deaths through more resources for disaster prevention and mitigation capabilities. A combination of the two – learning from past experience and more resources for disaster prevention and mitigation – would result in a massive reduction in deaths from disasters. Attention is drawn to segmented and shallow disaster insurance markets; the Samaritan's dilemma in providing emergency assistance to poor countries that neglect investment in protective measures; the need for mainstreaming of disaster prevention and mitigation among multilateral development agencies and governments, as also growth acceleration; why short-term relief must be combined with rebuilding of livelihoods and reconstruction, and the potential for public-private partnerships; and, above all, the need for building ownership of local communities and preservation of social networks. A challenge for development assistance is to combine growth acceleration with speedy relief and a durable reduction in vulnerability to natural disasters.

Keywords: disasters, deaths, vulnerability, insurance, reconstruction**.**

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Introduction

A consensus is beginning to emerge that local institutions, governments and development agencies have to pay greater attention to building resilience against natural disasters. This culminated in the World Conference on Disaster Reduction (WCDR) in Kobe in January, 2005. Some recent analyses (e.g. World Bank, 2006, 2010, Birkmann, 2006, Kahn, 2005, Gaiha and Thapa, 2006, *The Economist*, 'Natural disasters', 31 March 2012) point to greater vulnerability to such disasters, reflected in a marked increase in the frequency of their occurrence, and in their costliness in recent years.

The present study seeks to build on earlier work by identifying the factors associated with the frequency of natural disasters and the resulting mortality. Drawing together the main findings, some observations will be made from a policy perspective to focus on *key* elements of a disaster and mortality reduction strategy.

Natural disasters affect household welfare in three *distinct* ways: loss of physical integrity, loss of assets and loss of income. Injuries, fatalities and health epidemics compromise quality of life.[1] Loss of assets is equally common. Houses, for example, are highly vulnerable to the damaging impact of earthquakes, high winds, volcanic eruptions, landslides and floods. Loss of income from flooded arable land, damaged food crops and reduced agricultural production may be temporary or of a long-term nature.[2]

Few would question the rising cost of natural disasters – especially in developing countries. The Indian Ocean tsunami in December 2004 killed over 250,000 people, followed by the earthquake centred on Kashmir that killed tens of thousands and left over three million homeless.[3] Meanwhile, poor harvests and pests threaten famine in the Sahel and Southern Africa. The overall picture of disaster impacts is one of large-scale human suffering, loss of lives and a precipitous rise in financial costs. The global costs of natural disasters have risen fifteen-fold since the 1950s, and more sharply in recent years.[4]

[1] Renaud (2006) throws light on the persistent dangers and health risks of the 2004 tsunami in Sri Lanka, through deterioration of water quality. Communities, for example, reported 'salinity, nauseating odours and coloured water…more than a year after the event' (p.121).

[3] According to a report in *The New York Times*, of the 30, 000 people killed by the 2004 tsunami in Sri Lanka, at least 10,000 were children. Calculating on the same proportion, as many as 50,000 children died in South Asia on 26 December, 2004 (Rohde, 3 April, 2005).

[4] (a) Disaster costs in material losses rose from $38 billion (at 1998 values) in 1950-59 to $652 billion in 1990-99 (World Bank, 2006). More recent evidence points to falling death rates but sharply rising economic losses in recent years. '….multi-billion dollar natural disasters are becoming common. Five of the ten costliest, in money rather than lives, were in the past four years …..Munich Re, a reinsurer, reckons their economic costs were $378 billion last year, breaking the previous record of $262 billion in 2005 (in constant 2011 dollars)' (*The Economist*, 2012).(b) Hallegate and Przyluski (2010) point out the difficulties in defining, measuring and predicting the total cost of disasters. The emphasis is on indirect (output) losses as a major component of the total loss of welfare. But there are insufficient data and inadequate

Another way of looking at damages is that they dilute hard-won development gains. In Mozambique, for example, the floods of 2000 damaged or destroyed about 500 primary schools and seven secondary schools. The Kashmir earthquake of 2005 was also massive in its impact, as the damages totalled $5billion – roughly equivalent to the total official development assistance (ODA) for the preceding three years (World Bank, 2006). What adds to the longer-term impact is the effect on investment – especially in agriculture – through a dampening of 'the animal spirits'.[5]

In an imaginary world of *full* and *complete markets*, poor households could protect themselves by insuring themselves against asset and income losses and by borrowing. In the real world, however, natural shocks decapitalise and impoverish them. A recent investigation of the impact of 1998 Hurricane Mitch in Honduras, and of a drought in Ethiopia (1998-2000) illustrates partial recovery of the poor in terms of asset and income smoothing (Carter et al. 2007).

While we are wary of making generalisations, often women bear the brunt of such disasters.[6] Only one woman for every three men survived the December 2004 tsunami in a district in Aceh (Indonesia). In two other districts, women accounted for 77 and 80 percent of deaths (Oxfam, 2005). Women's deaths outnumbered men's also in the 1991 Bangladesh cyclone and the 1993 Maharashtra (India) earthquakes (World Bank, 2006).

A recent study by Jacobsen (2012) analyses the impact of Hurricane Mitch on assets in Nicaragua. Using three rounds of panel data covering the period 1998-2001, it treats the shock as a natural experiment. The analysis reveals that Hurricane Mitch did not significantly diminish the productive assets of those affected compared with those who lived outside the areas affected. On the other hand, a significant effect was found on the non-productive assets using a difference-in-difference approach. However, a more detailed analysis that allows for heterogeneity among the affected leads to more interesting results. (i) Households at the lower end of wealth distribution experienced larger losses. (ii) The inequality of productive asset distribution was also affected,

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methodologies. Specific network-shaped economic sectors (e.g. electric system, water distribution, transportation) are especially important, but other sectors also involve networks through supply chains. So failure in one system may rupture production in another (fewer supply chains in one may enhance vulnerability of another).

[5] For details, see Gaiha and Thapa (2006). There is, however, some macro-economic evidence favouring speedy recovery (Andersen, 2005).

[6] Wisner (2006) rejects the widely used taxonomy of the vulnerable (comprising women, children and elderly people), as it produces far too many 'false positives'. An important point to bear in mind, however, is that age and sex patterns of deaths resulting from rapid onset extreme events (e.g. earthquakes, floods) may differ from others (e.g. droughts, famines). Dyson's (1991) analysis of deaths in the Bengal famine of 1943 and Bangladesh famine of 1974-75, for example, shows that the mortality of males was higher than that of females. Differences between male and female mortality rates were large in the prime adult age groups. The reasons included differences in migration propensities, higher levels of women's body fat, and, more importantly, lower levels of pregnancy and lactation among women arising from anticipatory fertility decline.

implying that the poorer households were worse off. (iii) It is likely that poorer households in affected areas were caught in a ’poverty trap‘ that did not allow them to generate enough income to accumulate assets. So, altogether, Hurricane Mitch pushed more households towards a lower asset equilibrium and enhanced their vulnerability to a poverty trap.

What is perhaps more serious in the context of developing countries is their vulnerability to a multitude of disasters in short spells. A report in *Time* (2009), for example, points to a *few* countries in the Asia-Pacific region that suffered disasters in the same week and consequent damage and loss of human lives:

> In late September, tropical storm Ketsana killed more than 160 people in Vietnam and nearly 300 in the Philippines, submerging 80% of Manila. Just hours before Sumatra was jolted, another earthquake triggered a tsunami that inundated the Samoan islands and Tonga, extinguishing some 180 lives. In the latest catastrophe, southern India was ravaged by some of the worst torrential rains in decades, killing around 300 people and leaving some 2 million others homeless.

As a broad classification, two types of hazards are distinguished: hydro-meteorological (e.g. floods, droughts, storms) and geophysical (e.g. earthquakes, volcanic eruptions and related tsunamis), as their impacts differ.[7] This is in part due to differences in their frequencies of occurrence and predictability. Some of these differences are discussed in Annex 2.

Issues

The present study is motivated by a broader concern for human wellbeing, in which resilience against natural disasters is a key element. A specific concern is that often natural disasters are far deadlier in low-income countries. For example, between 1980 and 2002, India experienced 14 major earthquakes that killed 32,117 people, while the United States experienced 18 major earthquakes that killed barely 143 people (Kahn, 2005). Our study is designed to throw light on the underlying geographic, institutional and development variables. Specifically, the following issues are addressed:

- Have natural disasters become more frequent?
- Does their occurrence vary across different regions?
- Have the death tolls of these disasters increased in more recent years?
- Do death tolls vary across different regions?

[7] For definitions of natural hazards, see Table A.1.1 in Annex 1.

- How important is the role of geophysical and climate-related factors in the causation of different types of natural disasters?
- Do relatively affluent countries suffer fewer deaths?
- Do institutions matter? Specifically, are there fewer deaths in a democracy?
- Does ethnic/linguistic/religious fragmentation make it harder to avert deaths?
- Does higher frequency of disasters in a previous period induce better disaster preparedness?
- Is the pay-off to disaster prevention high? Specifically, does learning from past experience help to save lives? Also, is the pay-off from a combination of learning and accelerated growth in the poorest countries substantially greater?

Some of these issues are addressed in Kahn (2005). The specifications and sample used, however, differ, as do the findings. Briefly, countries which did not report natural disasters for three years in a row, or with a large number of zeros in the disaster death counts, were excluded. Also, some of the specifications used are contentious.[8]

Data

These issues are addressed with the help of a database compiled from EM-DAT, WDI, FAOSTAT, and from the website of the Kennedy School at Harvard.[9] The main component is EM-DAT, which covers all countries over the entire 20th century. Along with a description of the types of disasters, their dates and locations, the numbers killed, injured, made homeless and otherwise affected are reported. An event qualifies for inclusion in EM-DAT if it is associated with: (i) 10 or more people reported killed; or (ii) 100 or more people affected, injured or homeless; or (iii) a declaration of a state of emergency and/or an appeal for international assistance made.[10]

As the EM-DAT quality has improved in the 1970s, and to focus better on changes in recent years, the present analysis uses the data for the period 1980-2004, with different sub-periods for specific exercises.

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8 When the number of disasters in a country is known, it is intriguing why a probit is used that allows for a dichotomous classification of whether a country experienced a natural disaster or not. More seriously, while occurrence of natural disasters is endogenous, in mortality equations number of natural shocks/disasters is treated as exogenously determined. So changes in some of the important results (e.g. role of higher incomes, institutions and geography), and the conclusions linked to them, cannot be ruled out.

9 Other specialised sources include Alesina et al. (2003). They have constructed by far the most comprehensive indicators of ethnic, linguistic and religious fractionalisation. Another important source on geographical and political regime characteristics is Gallup et al. (1999).

10 As argued later, while hazards may be natural (e.g. tsunamis, cyclones, earthquakes), disasters are often man made. Death tolls in a famine or an earthquake vary with the speed of relief provided by governments, communities and donors.

A recent review draws attention to the following problems/gaps in the EM-DAT:[11]

- Data coverage is incomplete for several categories. The numerical data categories (e.g. numbers killed, total affected) are unsatisfactorily represented before 1970, with many recorded events having no entries for numbers killed or total affected. Even after this year, data are patchy for some countries and event types.
- According to a report by Working Group 3 of the Inter-Agency Task Force of the International Strategy for Disaster Reduction (ISDR), a comparison between EM-DAT and the DesInventar disaster database[12] for Chile, Jamaica, Panama and Colombia shows that differences in numbers of people 'affected' are substantial. Differences in numbers 'killed' are, however, much smaller and 'generally of the same order of magnitude' (Brooks and Adger, 2005, cited on p.15). Larger discrepancies in the numbers affected are due to underreporting in DesInventar, suggesting that EM-DAT are more reliable. In any case, a general consensus is that mortality data are more robust across different data sets.[13]
- The economic losses consist of direct and indirect components (Andersen, 2005). The direct losses refer to the physical destruction of assets, comprising private dwellings, small business properties, industrial facilities, and government assets, including infrastructure (e.g. roads, bridges, ports, telecommunications) and public facilities (e.g. hospitals, schools). The indirect losses, on the other hand, refer to disruption of economic activities, and loss of employment and livelihoods. In addition, business pessimism could dampen investment and consequently growth. So the relationship between destruction of capital and loss of income may vary a great deal.[14] Although there has been a sharp rise in economic losses – especially in recent years – the available estimates are incomplete and unreliable. These are compiled from a variety of sources, including insurance companies, multilateral institutions and the news media. It is thus plausible that insured losses are better covered and, consequently, there is significantly lower coverage of losses in developing countries (Andersen, 2005). Accordingly, the economic losses are not analysed.

An issue of considerable importance is whether natural disasters in rich countries are distinguishable from those in less affluent countries. A recent World Bank study (2006) points out that there is no private insurance against natural hazard risk in most developing countries. Specifically, while about half of the costs of natural disasters are

[11] For details, see Brooks and Adger (2005).
[12] http://www.desinventar.org
[13] For further validation, see Annex 3, and, from different perspectives, Thomas et al. (2012), Jennings (2011) and Munich RE (2011).
[14] A difficulty is that conversion of changes in capital stock to income flows should take into account pre-disaster capacity utilisation, depreciation of capital stock and efficiency of replacement assets (Andersen, 2005).

covered by insurance in the United States, less than two percent of them are covered in the developing world. Besides, the costs of hedging against natural hazard risks in developing countries often exceed the cost of simply paying for the damages when they occur. Finally, both awareness of and preparedness for such risks are much greater in rich countries. We have accordingly restricted our analysis to the sample of countries other than the rich (including OECD and non-OECD groups).

Frequency and deadliness of natural disasters

Let us first consider the frequency distributions of natural disasters and their deadliness.[15] These are given in Table 1. Note that the averages are not meant to illustrate trends.

- In the aggregate sample, floods were the most frequent disaster, accounting for well over one-third of the total disasters during 1985-94. The next most frequent were windstorms, which accounted for over a quarter of the disasters.
- With the exception of insect infestations, all natural disasters became more frequent in the next period (i.e. 1995-2004). While the share of floods rose, that of windstorms declined. Number of droughts and famines rose, while that of insect infestations declined. As the share of droughts also rose, those of famines and insect infestations – already low – declined.
- Ratios of disasters to populations (or, disasters per million of population) also rose – from 0.35 to 0.47– over the period in question. Corresponding ratios of floods and droughts rose, while the values for other disasters changed little.
- Total deaths due to disasters rose sharply in the second sub-period, faster than the increase in the number of disasters.
- Consequently, deaths per disaster rose from 263 to 306 – an increase of over 16 percent. Also, deaths per million of population rose from 92 to 144 – an increase of about 57 percent.
- Among the deadliest were volcanoes and earthquakes (per disaster) during 1985-1994. Both became less deadly in the next decade. Using a different criterion (deaths per million of population), the deadliest were windstorms and earthquakes during 1985-94. Both became less deadly during the next decade. By contrast, there was a sharp rise in the deadliness of wave surges and famines. So, while the aggregate of disasters became deadlier on different criteria, some disasters did so on a specific criterion.

[15] For a disaggregated analysis by type of disaster (i.e. whether hydro-meteorological or geophysical), see Annex 2 and for an update, see Thomas et al. (2012), and Jennings (2011).

Summing up, and subject to the caveat that the averages reported cannot be the basis of trends, frequencies of natural disasters rose and they became deadlier.[16]

In Table 2, frequency distributions of natural disasters by region for two sub-periods, 1985-94 and 1995-2004, are given.

- The largest number of disasters occurred in East Asia and the Pacific, accounting for just under one-third of the total during 1985-94. Latin America and the Caribbean was a close second, accounting for over 22 percent of the natural disasters. The lowest numbers were recorded in Middle East and North Africa, and Europe and Central Asia, with relative frequencies between six and eight percent.
- There was a large increase in the number of disasters during the next decade, from 1,463 to 2,268. This is not surprising, since each region recorded large increases.
- However, the relative frequencies changed slightly, with lower concentrations in South Asia, East Asia and the Pacific, and Latin America and the Caribbean. By contrast, the shares of Europe and Central Asia, and Sub-Saharan Africa rose.

To better understand the vulnerability of different regions to natural disasters, these are expressed per country and per million of population in each region. As may be noted from Table 3, *ex post* vulnerability of regions to disasters differs depending on the ratio used.

- South Asia had the highest number of disasters per country during 1985-94, while Europe and Central Asia, and Sub-Saharan Africa had the lowest.
- All regions recorded large increases in the number of disasters in the next decade, with South Asia continuing to be the most vulnerable, followed by East Asia and the Pacific. Sub- Saharan Africa remained the least vulnerable, followed by Middle East and North Africa.

In the aggregate sample, there was a large increase in the number of disasters over the period in question, implying greater vulnerability.

When disasters are expressed per million of population, there are some striking changes. This is not surprising, as populations of countries *within* a region vary.

Specifically, the most vulnerable was Latin America and the Caribbean during 1985-94, followed by Sub-Saharan Africa, and Middle East and North Africa. Latin America and

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[16] For confirmation of rising trends in the frequency of natural disasters – especially, hydro-meterological – see Thomas et al. (2012) and Jennings (2011).

the Caribbean remained the most vulnerable, followed by Sub-Saharan Africa, and Europe and Central Asia in 1995-04. On the other hand, South Asia, and East Asia and the Pacific remained the least vulnerable (see Figure 1).

- All regions witnessed a rising frequency of disasters – using either ratio – but the increase in disasters per million was relatively small in South Asia. However, the aggregate sample also recorded an increase.

Figure 1: Deaths per Million by Region

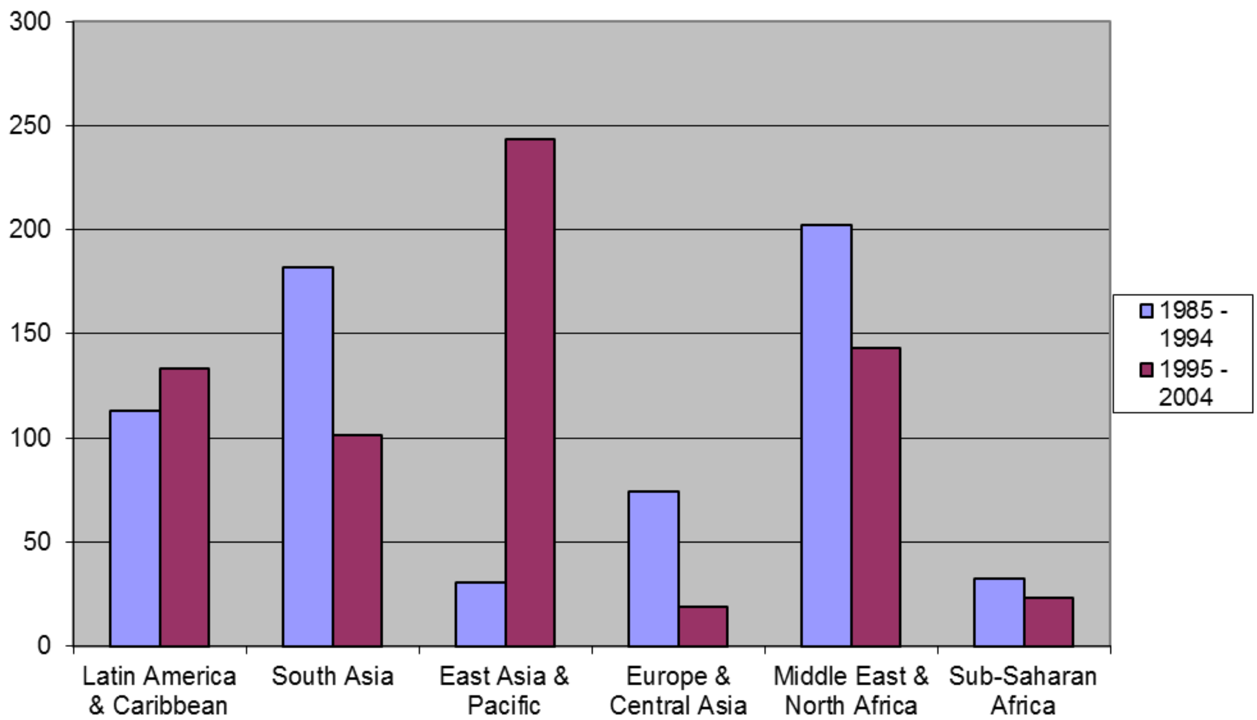


Table 1. Different types of natural disasters and their death tolls

Disaster type	Frequency 1985-94 (%)	Frequency 1995-04 (%)	Deaths 1985-94 (%)	Deaths 1995-04 (%)	Deaths per million 1985-94	Deaths per million 1995-04	Deaths per disaster 1985-94	Deaths per disaster 1995-04	Disasters per million 1985-94	Disasters per million 1995-04
Flood	506 (34.59)	904 (39.86)	51,383 (13.35)	89,975 (12.97)	12	19	102	100	0.12	0.19
Earthquake	200 (13.67)	238 (10.49)	104,124 (27.06)	69,434 (10.01)	25	14	521	292	0.05	0.05
Drought	96 (6.56)	188 (8.29)	2,911 (0.76)	1,798 (0.26)	1	0.4	30	10	0.02	0.04
Famine	25 (1.71)	32 (1.41)	8,640 (2.25)	223,644 (32.24)	2	46	346	6,989	0.01	0.01
Extreme temperature	42 (2.87)	112 (4.94)	3,897 (1.01)	13,721 (1.98)	1	3	93	123	0.01	0.02
Insect infestation	44 (3.01)	17 (0.75)	0 0.00	0 0.00	0.0	0.0	0.0	0.0	0.01	0.004
Landslide	117 (8.00)	169 (7.45)	7,695 (2.00)	8,236 (1.19)	2	2	66	49	0.03	0.04
Wave surge	4 (0.27)	21 (0.93)	111 (0.03)	228,943 (33.00)	0.03	48	28	10,902	0.00	0.00
Volcano	35 (2.39)	38 (1.68)	24,425 (6.35)	227 (0.03)	6	0.05	698	6	0.01	0.01
Wildfire	26 (1.78)	73 (3.22)	438 (0.11)	332 (0.05)	0	0	17	5	0.01	0.02
Wind storm	368 (25.15)	476 (20.99)	181,222 (47.09)	57,379 (8.27)	44	12	492	121	0.09	0.10
Total	1,463 (100.00)	2,268 (100.00)	384,846 (100.00)	693,689 (100.00)	92	144	263	306	0.35	0.47

Table 2. Frequency distributions of natural disasters by region

Region	Number of disasters. 1985-94	Number of disasters, 1995-2004	Relative frequency of disasters, 1985-94, (%)	Relative frequency of disasters, 1995-2004 (%)
Latin America and the Caribbean	326	499	22.28	22.0
South Asia	249	327	17.02	14.42
East Asia and the Pacific	465	659	31.78	29.06
Europe and Central Asia	116	270	7.93	11.90
Middle East and North Africa	95	145	6.49	6.39
Sub-Saharan Africa	212	368	14.49	16.23
Total	1,463	2,268	100	100

Calculations based on EM-DAT.

Note that rich OECD and non-OECD countries are excluded.

Table 3. Number of natural disasters by region

Region	Number of disasters, 1985-94 (per country)	Number of disasters, 1995-2004 (per country)	Number of disasters, 1985-94 (per million)	Number of disasters, 1995-2004 (per million)
Latin America and the Caribbean	13.58	20.79	0.77	1.0
South Asia	35.57	46.71	0.23	0.25
East Asia and the Pacific	24.47	34.68	0.29	0.37
Europe and Central Asia	7.25	16.88	0.28	0.65
Middle East and North Africa	8.64	13.18	0.44	0.56
Sub-Saharan Africa	7.57	13.14	0.49	0.66
Total	13.93	21.60	0.35	0.47

Calculations based on EM-DAT.

Note that rich OECD and non-OECD countries are excluded.

Another classification based on per capita income (based on the World Bank classification) yields somewhat surprising results.[17]

- As may be seen from Table 4, the highest frequency of disasters occurred in lower middle income countries during 1985-94, followed by low income countries. These two groups accounted for 90 percent of the disasters recorded in the sample. Although (absolute) frequencies rose sharply in both groups in the following decade, their (combined) share decreased slightly.

Table 4. Number of natural disasters by income groups

Grouping by income	Number of disasters in 1985-94	Number of disasters in 1995-2004	Relative frequency of disasters (1985-94) in %	Relative frequency of disasters (1995-2004) in %
Low income	544	871	37.18	38.40
Lower middle income	774	1,141	52.90	50.31
Upper middle income	145	256	9.91	11.29
Total	1463	2,268	100	100

Calculations based on EM-DAT. Note that rich OECD and non-OECD countries are excluded.

In Table 5, disasters are divided by number of countries in an income group and by population.

Table 5. Ratios of natural disasters by income groups

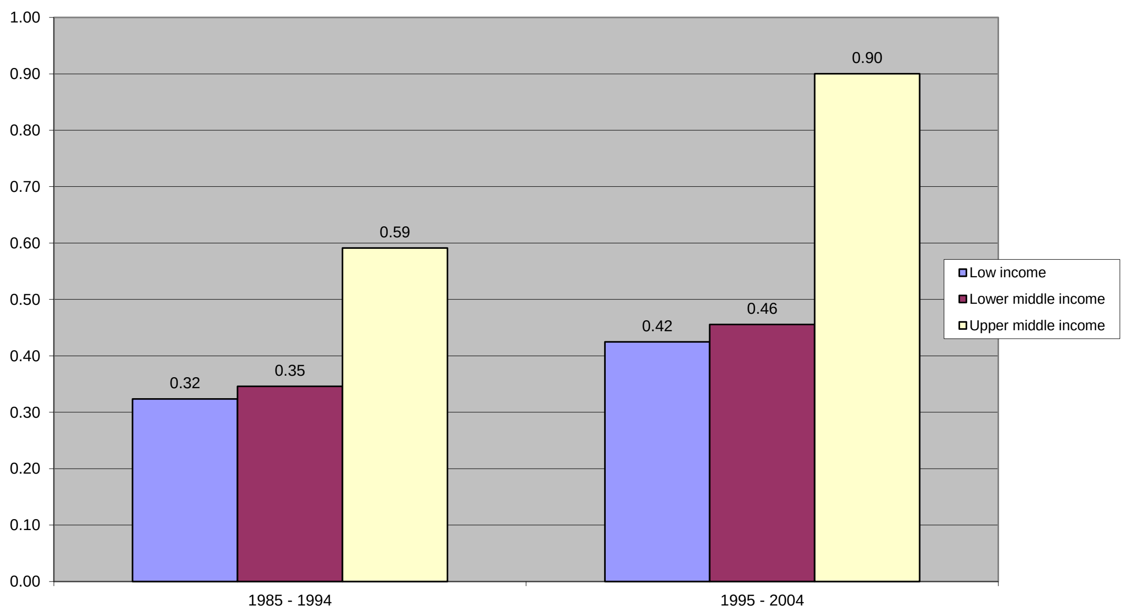
Grouping by income	Number of disasters in 1985-94 (per country)	Number of disasters in 1995-2004 (per country)	Number of disasters in 1985-94 (per million)	Number of disasters in 1995-2004 (per million)
Low income	11.83	18.93	0.32	0.42
Lower middle income	19.85	29.26	0.35	0.46
Upper middle income	7.25	12.80	0.59	0.90
Total	13.93	21.60	0.35	0.47

Calculations based on EM-DAT. Note that rich OECD and non-OECD countries are excluded.

[17] For details of the World Bank classification, see Table A.1.2 in Annex 1.

Using the ratio of disasters per country, Lower middle income countries had the highest frequency during 1985-94, followed by low income countries. In each group, the frequency rose sharply, and, as a result, also in the aggregate sample during the following decade. When the ratio of disasters to population is used, upper middle income countries recorded the largest number of disasters per million during 1985-94, followed by lower middle income countries. In all groups – especially in the upper middle income countries, as also in the aggregate sample – the vulnerability to natural disasters rose (see Figure 2).

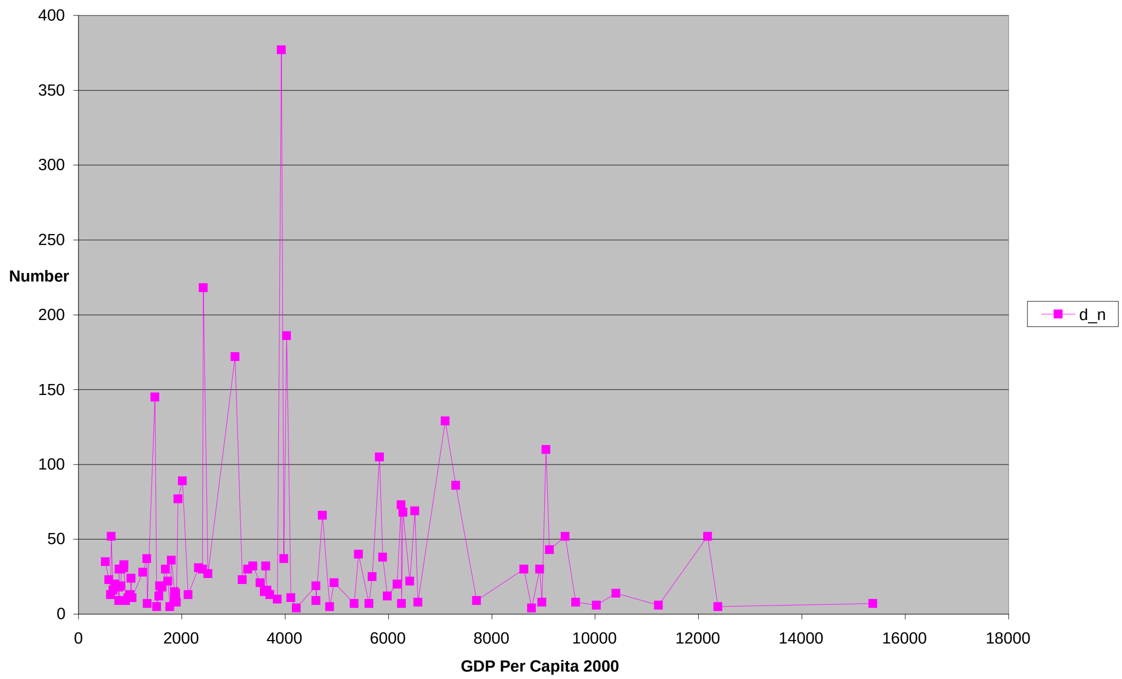
Figure 2: Natural Disasters Per Million by Income Group



A graphical illustration of number of disasters by GDP per capita (PPP) in Figure 3 points to sharp spikes over the period 1985-2004, implying that the relationship between them varies greatly, *despite* the heavy concentration of disasters in low income ranges. As reported later on the basis of regression analysis, income does not have a significant effect on frequency of natural disasters, controlling for the effects of other exogenous factors.

In brief, the frequency of disasters rose over the period 1995-2004, relative to 1985-94. However, there was no clear correspondence (i) either between the frequency of disasters and level of income, or (ii) between the relative frequency of disasters and level of income. Changes in the (absolute and relative frequencies of) disasters also followed a somewhat complex pattern.

Figure 3: Frequency of natural disasters by GDP per capita during 1985-2004



Let us now examine the distribution of deaths associated with natural disasters over the period 1985-94, and changes in it in 1995-2004, using the regional and income classifications.

As shown in Table 6, more than half the deaths in 1985-94 occurred in South Asia, with nearly equal but considerably lower shares in Latin America and the Caribbean, East Asia and the Pacific, and Middle East and North Africa. In 1995-2004, a dramatic change occurred, as the share of East Asia and the Pacific climbed to about 63 percent, while that of South Asia dropped to less than one-fifth. The shares of Middle East and North Africa, Latin America and the Caribbean, Europe and Central Asia, and Sub-Saharan Africa also registered reductions.

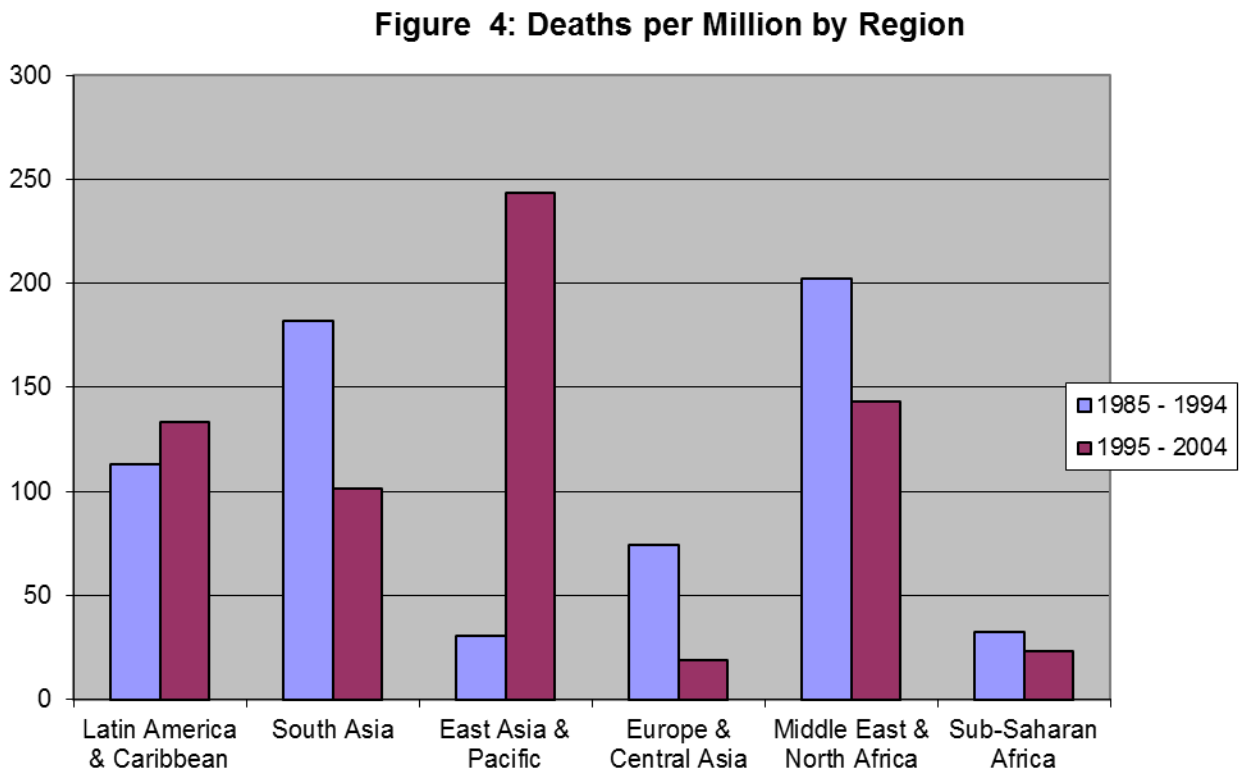
If the ratio of deaths to disasters is used as an indicator of their deadliness, South Asia was ranked highest, followed by Middle East and North Africa, and Europe and Central Asia in 1985-94. In the following decade, East Asia was ranked highest, followed by South Asia, and Middle East and North Africa. East Asia and the Pacific also registered a large increase in the ratio in question, while South Asia recorded a huge reduction.

Table 6. Regional distribution of deaths due to natural disasters

Region	Deaths in 1985-94 (%)	Deaths in 1995-04 (%)	Number of deaths per disaster (1985-94)	Number of deaths per disaster (1995-04)	Number of deaths in 1985-94 (per million)	Number of deaths in 1995-04 (per million)
Latin America and the Caribbean	48,016 (12.48)	66,826 (9.63)	147	134	114	136
South Asia	200,357 (52.06)	132,838 (19.15)	805	406	181	102
East Asia and the Pacific	48,210 (12.53)	436,517 (62.93)	104	662	30	245
Europe and Central Asia	30,231 (7.86)	7,804 (1.12)	261	29	74	19
Middle East and North Africa	44,002 (11.43)	36,789 (5.30)	463	254	205	140
Sub-Saharan Africa	14,030 (3.65)	12,915 (1.86)	66	35	32	23
Total	384,846 (100)	693,689 (100)	263	306	92	144

Calculations based on EM-DAT. Note that rich OECD and non-OECD countries are excluded.

Alternatively, deadliness of disasters could be expressed as deaths per million of population. The ranking changes, with Middle East and North Africa at the top, followed closely by South Asia in 1985-94. In the following decade, the deadliness of disasters was highest in East Asia and the Pacific, with Middle East and North Africa, and Latin America and the Caribbean tied closely for the second rank. But there was a more than moderate reduction in the deadliness of disasters in South Asia and Middle East and North Africa, among others. Figure 4 illustrates graphically these changes. Yet in the aggregate sample the disasters became deadlier.



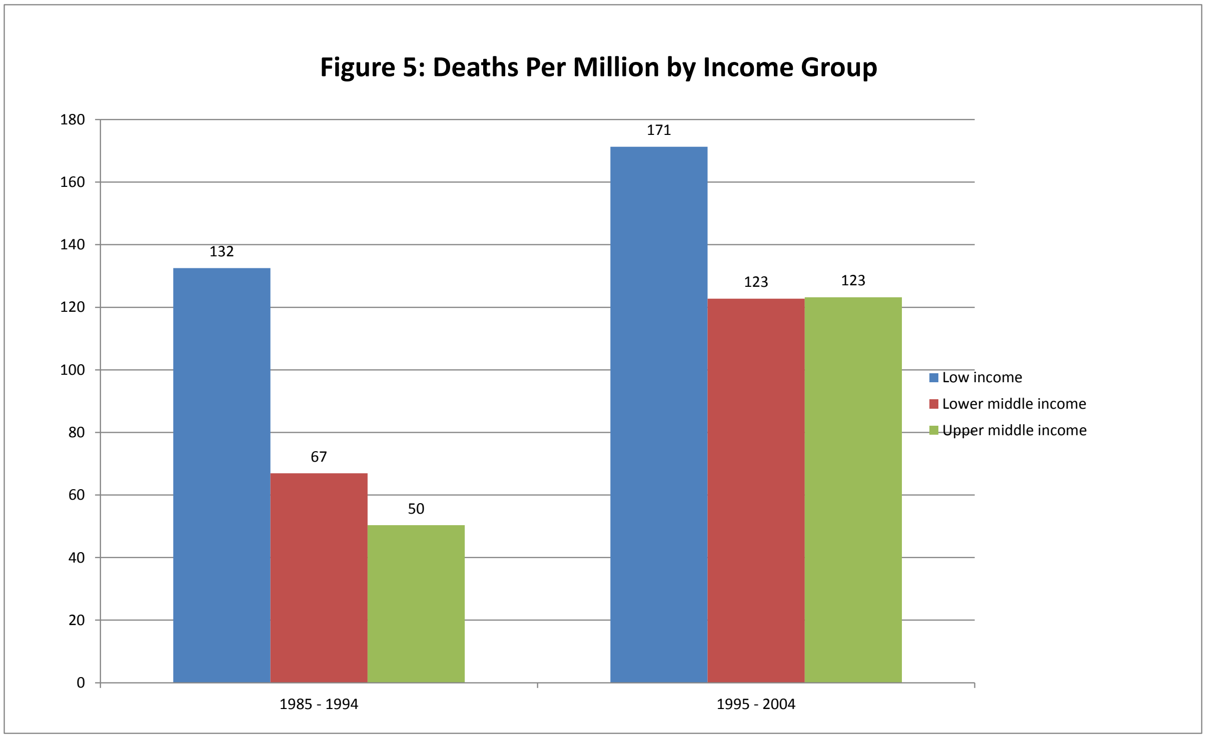
The preceding analysis is repeated for income groups of countries. The main findings are:

- A vast majority of disaster-related deaths occurred in low income and lower middle income countries (about 97 percent of total deaths in 1985-94).
- Although there were large increases in deaths in the following decade, the combined share of these two income groups recorded a slight reduction (it fell to about 95 percent).
- Ratio of deaths to disasters was highest in low income countries, followed by lower middle income countries. Disasters, however, were about half as deadly in the latter. While the deadliness of disasters in low income countries reduced slightly in the next decade, it remained substantially higher than in other income groups.
- In the remaining two groups, there was a marked increase in the deadliness of disasters – especially in lower middle income countries.
- Deaths per million reveal a similar pattern, except that deadliness of disasters rose in all income groups in 1995-04. It is noteworthy that deadliness of disasters in upper middle income countries rose two-and-a-half times (see Figure 5).

Table 7. Deadliness of disasters by income group

Grouping by income	Deaths in 1985-94 (%)	Deaths in 1995-04 (%)	Number of deaths per disaster (1985-94)	Number of deaths per disaster (1995-04)	Number of deaths in 1985-94 (per million)	Number of deaths in 1995-04 (per million)
Low income	222863 (57.91)	351214 (50.63)	410	403	132	173
Lower middle income	149639 (38.88)	307439 (44.32)	193	269	67	123
Upper middle income	12344 (3.21)	35036 (5.05)	85	137	50	124
Total	384846 (100)	693689 (100)	263	306	92	144

Calculations based on EM-DAT.
Note that rich OECD and non-OECD countries are excluded.



The preceding analysis points to an increase in the frequency of natural disasters, as well as higher deaths. There were, however, some regional and income group contrasts that require more detailed investigation. *But these averages are subject to the caveat that they cannot be interpreted as trends.*

Recent patterns in natural disasters

Three studies (Thomas et al. 2012, Jennings, 2011, and Munich RE, 2011) offer updated and insightful accounts of frequency of different types of natural disasters (broadly distinguished into geophysical and hydro-meterological) up to 2010.

An interesting point made by Thomas et al. (2012) in the context of reporting biases in frequency of and losses from disasters is to concentrate on intense disasters (i.e. those which killed 100 or more people or affected 1,000 or more persons), which are likely to be better recorded and thus less likely to be subject to reporting biases. So one important aspect of their analysis is to shed new light on the frequency of such disasters over the period 1971-2010. A second important aspect is the disaggregation of natural disasters into geophysical and hydro-meterological. The related issue of whether the latter are causally linked to climate change, given the available evidence, is examined first globally and in greater detail for Asia and the Pacific and then for the Philippines. Their principal findings are reviewed below.

Intense natural disasters rose over the period 1971-2010. Between 1971 and 1980, 539 intense natural disasters occurred. Their frequency continued to increase across decades, with the total number four times larger between 2001 and 2010.

Such global trends are largely a result of the rise in hydro-meteorological disasters.[18] About two-thirds of these during 1971-2010 were hydro-meteorological. Their number rose from 1210 in 1991-2000 to 2004 in 2001-2010 – an increase of 66 percent.

An econometric analysis of the risks of intense hydro-meteorological disasters in Asia and the Pacific region suggests that these risks are greater in more populous countries.[19] This is understandable, as disasters are defined in terms of number of people killed or affected. But population also serves as a useful proxy for exposure. The higher the vulnerability of a country (defined in terms of high population density and low income), the greater is the disaster risk. Southeast Asia is thus highly prone to such disaster risks. In addition, controlling for the effects of population and vulnerability, climate factors (e.g. annual average temperature anomalies, precipitation deviations from normal) have significant roles in explaining risks from hydro-meteorological disasters. Specifically, precipitation anomalies explain risks from hydro-meteorological disasters across South Asia and Southeast Asia, while temperature anomalies explain such risks in East Asia.

But whether climate change will lead to greater risks is conditional upon robust evidence on trends in climate change-related variables/indicators – specifically, whether the means and

[18] A similar conclusion is obtained by Jennings (2011), based on a linear trend.
[19] A random effect logistic regression model is used. For details, see Technical Notes in Thomas et al. (2012).

variability exhibit long-term tendencies.[20] Thomas et al. (2012) report that in the Asia-Pacific region, monthly temperature anomalies (averaged per year) from baseline temperatures in 1960-1990 are rising across various sub-regions, with some areas exhibiting more temperature variability. Precipitation deviations have not changed, but precipitation appears more variable in recent periods across the sub-regions.

There is growing consensus that many climate changes are attributable to anthropogenic greenhouse gas (GHG) emissions. Further analysis of (i) monthly average temperature analysis in Asia and the Pacific from 1951 to 2010, (ii) monthly average precipitation deviations and (iii) monthly atmospheric carbon dioxide (CO_2) stock data reveal Granger causality between (i) and (iii), and between (ii) and (iii). The changing climate that is affected by GHG emissions is, in turn, affecting extreme events.

As regards hydro-meteorological disasters in Asia and the Pacific, concomitant average temperatures are rising and total precipitation appears to be slightly variable.

Jennings (2011), however, takes a more nuanced view, arguing that: 'there is insufficient evidence to exclude the possibility that climate change is increasing hazards and hence trends in reported disasters' (p.19). He elaborates that: 'the effect is unlikely to be very large, because the magnitude of climate change over the past 20-30 years is relatively small when compared with, for example, the growth in world's population over that time' (p.19).

Catastrophic mortalities

Frequently, a power law probability function is used to characterise the distribution of catastrophic events, as familiar well-behaved distributions, such as the normal distribution, are poor approximations. Catastrophes have too many extreme outliers. The distributions for such catastrophic risks are called 'fat-tailed', reflecting the fact that extreme outliers are much more likely than indicated by the normal (or log normal) distribution(s). Such extreme outliers cause enormous harm and account for a substantial share of expected losses from catastrophes (Viscusi and Zeckhauser, 2011).

A variable x has a power law probability distribution if it can be characterised as $p(x) = cx^d$, where c is a constant and d is the scaling exponent, so that log p(x) = log (c) + d lox (x). In the present context, x denotes fatalities per disaster over a period of time. With finite-size effects, however, it holds in a certain region of scaling $x_0<x<x_c$. The minimum and maximum cut-off points are given by x_0 and x_c, respectively, and they define the scaling region. The idea is to see whether a substantial fraction of events lies in the universal scaling region. This may also be a good way to compare different regions. We see in Figure 6 that the probability of very large events/disasters is non-vanishing. We also see a much faster decay in the last region marked by $x>x_c$. We know in general that probability density of x with finite

[20] [20] On this, refer to IPCC (2007).

size scaling effects is given as $p(x)=cx^a\ \psi(x)$ for $x>x_0$. Here a is the true scaling exponent of the power law and ψ is the scaling function which decays much faster than power law for $x>x_c$. While this function can take several forms, we assume here an exponential form, i.e. $\psi(x) \sim e^{-x}$.

The exponent d obtained from OLS fitting in Figure 6 is the 'apparent' exponent and is related to the true exponent through the scaling function. It is well established that if ψ(x=0)>0 then a~d (almost equal). Thus assuming an exponential scaling function, we have the power law exponents. In some cases, we may have multiple scaling due to more than one region exhibiting power law decay. In such cases, it is evident that the prediction of very large size disasters is not ruled out or to be ignored[21].

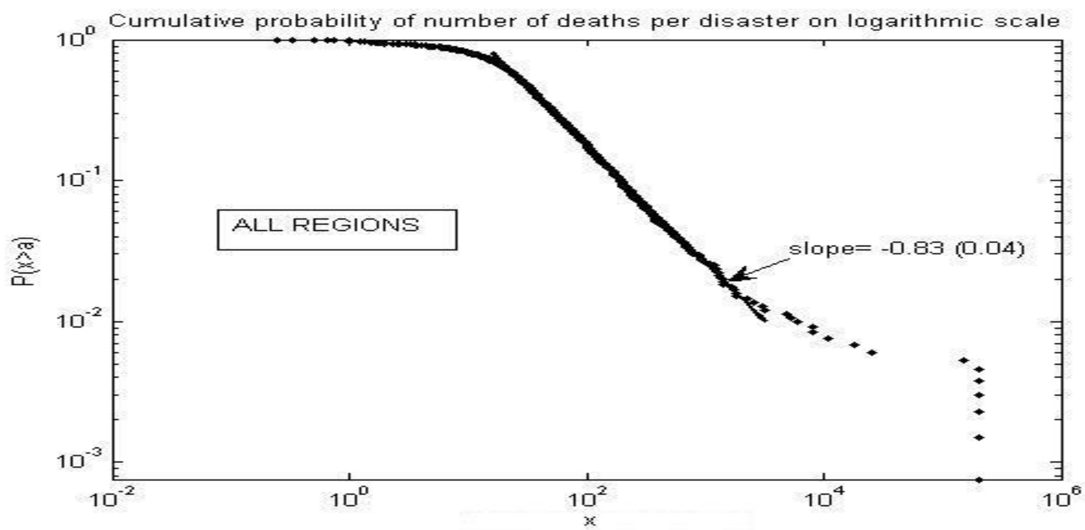


Figure 6: Log of fatality of disasters – cumulative probabilty of deaths per disaster

In some regions and country groups, the power law applies to a narrower range of values before the curve drops sharply. This indicates the certainty of dominance of power law relationship in governing the nature of deadliness. Power law over a broader range implies that the nature of deadliness or its occurrence replicates itself at multiple scales and hence the nature is complex. It describes the occurrence of large deviations from the median of the probability distribution; one of the examples where this is evident is natural disasters.

[21] As pointed out by Barton and Nishenko (1997), loss of life and property due to natural disasters exhibit self-similar scaling behaviour. This self-similar scaling property allows use of frequent small events to estimate the rate of occurrence of less frequent, larger events.

Determinants of disasters and their deadliness

(a) Disasters

Frequency of disasters is specified as a function of geophysical features of a country (e.g. degree of elevation, share of coastal land, size in area [km^2], whether landlocked), its population density, level of income, and how democratic the regime/polity is, log of lagged deaths (in 1970-79) and lagged number of disasters (i.e. in 1970-79). The lagged number of disasters is an instrument for disasters in 1980-2004. It is justified on the ground that it directly influences the frequency of disasters, but without affecting deaths in the sample period 1980-2004. Lagged deaths are a measure of severity of disasters initially. As IV estimation is used, (log of) deaths in the second equation is hypothesised to depend on all exogenous variables in the first equation (except natural disasters in 1970-79) and predicted frequency of disasters from the first equation.[22]

The structural equation of deaths is specified as:

Log of D_i = $\beta_0 + \beta_1 ND_i + \beta_2 Z_{1i} + u_i$..........(1)

where D_i denotes deaths due to natural disasters in country i in 1980-2004, ND_i refers to natural disasters during the same period, and Z_{1i} denotes a vector of exogenous variables (which vary by country). Exogenous variables include geo-physical characteristics of a country (whether landlocked, area, elevation, share of coastal land), socio-economic characteristics (ethnic fractionalisation, per capita income level) and how democratic the political regime is (an aspect of institutional quality). Number of disasters, ND_i, is supposed to be endogenous. So we need another equation – a reduced form – with number of disasters as the dependent variable.

$ND_i = \pi_0 + \pi_1 Z_{1i} + \pi_2 Z_{2i} + v_i$ …………….(2)

where, in addition to Z_{1i}, the exogenous variables from the structural equation, we have an instrument variable, Z_2. The instrument chosen is lagged natural disasters (in 1970-79). There is a caveat, however. If natural disasters are serially correlated, using lagged natural disasters as an identifying instrument for natural disasters (in 80-94) does not fully control for unobserved heterogeneity across countries. A key identification condition is π_2=0, among others.[23] Accordingly, IV estimation is used.

[22] For convenience of exposition, log of deaths and deaths are used synonymously.
[23] For a clear and comprehensive exposition of identification conditions, see Baum (2006).

Since hardly any country escaped a natural disaster during 1980-2004, use of IV procedure is not problematic, with adjustment of standard errors for heteroscedasticity. Several specifications were experimented with to avoid omitted variable bias. A selection of the results is given below.[24] The main findings from Table 9 are as follows.

Number of natural disasters varied positively with the size of a country – especially when the threshold of the largest size was exceeded. Also, higher elevation was associated with greater frequency of disasters, but not so robustly. Disaster frequency was higher in more populous countries. Frequency of disasters varied with the (lagged) frequency during 1970-80. Or, countries that were more prone to disasters in 1970-79 remained so during 1980-2004. If (lagged) deaths in 1970-79 are treated as a measure of severity of disasters, our result implies that countries that were prone to severe disasters were also more prone to disasters in subsequent years in general.

Somewhat surprising are three findings: (i) occurrence of disasters was unrelated to the level of economic development of a country, judged on the basis of GDP per capita (in PPP); (ii) the share of coastal land was also unrelated to the frequency of disasters; and, finally, (iii) how democratic the political regime (measured as Polity mean) was had no effect on the frequency of disasters.

The fact that lagged natural disasters influenced significantly occurrence of disasters in 1980-2004 suggests that the former is a relevant instrument. This is also corroborated by the F-test of excluded instrument(s). The Cragg-Donald Wald F statistic and Kleibergen – Paap Wald rk F statistic reject the null of weak identification.

Analysis of residuals of total disasters during 1980-2004 suggests that these did not bear any relationship to exposure to media – in particular, availability of newspapers per 1,000 people during 1997-2000. It is surmised, therefore, that disaster reporting was not more accurate in countries better exposed to mass media.[25]

[24] Supplementary results based on other specifications are available on request.

[25] Details are given in Annex 3. Note that this variable could not be incorporated in the regressions because of the smallness of the sample. Jennings (2011), however, observes that more disasters are reported in countries in which the media are independent and not subject to pressure from the government.

Table 9. Occurrence of natural disasters 1980-2004

No. of observations = 86			
F (11, 74) = 21.77			
Prob. > F = 0.0000			
Number of natural disasters during 1980-2004	**Coefficient**	**t-value**	**significance**
Landlocked	-5.673	(-0.57)	-
Medium[1]	8.207	(0.92)	-
Large	34.079	(2.11)	**
Mean elevation (meters above sea level)	0.016	(1.56)	-
Ethnic	-42.326	(-1.35)	-
Log of persons/km^2	5.657	(1.78)	*
Log of GDP 1995	2.181	(0.47)	-
Log of deaths from disasters during 1970-79	3.995	(1.73)	*
Polity mean for years 1985-94 (range -10 to 10)	-1.048	(-1.03)	-
Percentage of land within 100km of coast or river	0.010	(0.07)	-
Number of natural disasters during 1970-1979	2.812	(5.32)	***
Constant	-39.276	(-1.04)	-
F test of excluded instruments: F(1, 74) Prob > F = 0.0000	28.29		
Cragg-Donald Wald F statistic	31.95		
Kleibergen-Paap Wald rk F statistic	28.29		

1. The area dummies are as follows: Small = 0-200,000 km^2 (omitted); Medium = 200,000-750,000 km^2; Large = >750,000 km$^{2.}$
2. *** Denotes significance at the 1 percent level; ** at the 5 percent level; and * at the 10 percent level, respectively.

(b) Mortalities

A selection of results on the determinants of deaths from disasters is given in Table 10. The main findings are the following. Deaths varied with the size of a country – highest among the largest relative to the smallest. Somewhat surprisingly, deaths were unrelated to population density. Higher income levels were associated with lower deaths. Deaths were unrelated to ethnic diversity that could impede collective action.[26](Predicted) frequency of disaster had a positive effect on deaths. As (lagged) deaths, a measure of severity of disasters in 1970-79, were related to disasters, there was an *indirect* effect of (lagged) deaths through this channel on deaths in 1980-2004. In addition, there was a *direct* effect of (lagged) deaths during this period. Degree of democracy (defined as the difference between democracy and autocracy) did not have a significant coefficient.[27] As discussed later, this flies in the face of findings from other studies that democracy makes a difference.[28] Nor did the share of coastal land in a country have a significant coefficient.

Table 10. Determinants of mortality

No. of observations = 86			
F (11, 74) = 11.33			
Prob. > F = 0.0000			
Number of natural disasters during 1980-2004	**Coefficient**	**t-value**	**significance**
Predicted natural disasters during 1980-2004	0.010	(1.73)	*
Landlocked	-0.583	(-0.94)	-
Medium[1]	0.880	(1.88)	*
Large	2.129	(2.62)	***
Mean elevation (meters above sea level)	0.000	(1.02)	-
Ethnic	-1.415	(-1.16)	-
Log of persons/ km^2	0.002	(0.01)	-
Log of GDP 1995	-0.931	(-2.9)	***
Log of deaths from disasters during 1970-79	0.262	(3.02)	***
Polity Mean for years 1985-94 (range -10 to 10)	0.040	(0.93)	-
Percentage of land within 100 km coast or river	0.006	(0.69)	-
Constant	12.058	(4.28)	***

1 The area dummies are as follows:
Small = 0-200,000 km^2 (omitted); Medium= 200,000-750,000 km^2 and Large >750,000 km^2.

[26] For a detailed exposition of why ethnic fractionalisation matters a great deal for growth and quality of government, see Alesina et al. (2003).

[27] (a) For details of measurement of polity, see Polity IV project, administered by the Centre for International Development and Conflict Management, University of Maryland. (b) That freedom of the press is an important factor in averting famines in India is persuasively argued by Dreze and Sen (1989).

[28] We also considered a variable designated as New State, but it did not yield a significant result. This is a measure of colonisation. The more recent is the timing of independence, the longer is the spell of colonisation. But, more generally, the more recent the timing of independence, the more daunting is the challenge of nation-building. For details, see Gallup et al. (1999).

2. *** Denotes significance at the 1 percent level; ** at the 5 percent level; and * at the 10 percent level, respectively.

As in the case of occurrence of disasters, the residuals do not indicate more accurate reporting of deaths in countries better exposed to mass media.[29]

Discussion

As detailed simulations of disaster risk prevention and mitigation are not feasible, a broad-brush treatment based on key elasticities is given below. We consider two basic scenarios: the first entails different assumptions about learning from past disasters and fatalities; and the second assumes an increase in levels of income with greater capacity for mitigating distress and loss of human lives.[30] One aspect of learning is whether there is reduction in number of disasters relative to lagged disasters in 1970-79, with an elasticity of 0.39. As our results show, countries with more disasters in 1970-79 were vulnerable to higher frequency of disasters in 1980-2004. This implies that, whatever the prevention measures, their effectiveness was far from adequate. If we interpret lagged fatalities as an indicator of severity of disasters, the positive elasticity of disasters to this variable (0.09) suggests that more severe disasters were associated with higher frequencies of disasters in the subsequent sample period, but only slightly higher frequencies. So it may be inferred that countries experiencing more severe disasters learnt to prevent many more occurring.[31] More populous countries were also more prone to disasters, with a positive elasticity of 0.12. Although the elasticity of disasters with respect to the size of a country (0.24) is largely of

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[29] Details are given in Annex 3.

[30] Cole et al.'s (2012) analysis confirms that government responsiveness is greater when the severity of the crisis is greater. Also, voters punish incumbent politicians for crises beyond their control (a severe drought caused by monsoon failure). While voters also reward politicians for responding well to climatic events, they do not compensate them sufficiently for their 'bad luck'. There is thus a robust confirmation of Sen's (1998, 1999) conjecture that democracies are better at responding to more salient catastrophes. However, what undermines the plausibility of Cole et al. (2012) is its failure to account for the fact that drought relief seldom reaches the victims or a fraction reaches them because of huge leakages. Besides, an analysis grounded in inter-temporal rationality of voters that allows for learning over time – whether, for example, mandates and programmes announced were implemented satisfactorily – would have been more plausible. Nevertheless, a link between democracy and fewer deaths through electoral incentives is established. For another recent analysis, see Jennings (2011). The regression results, however, are far from robust, as significant relationships vary with the specification.

[31] A report in *Time* (2009) further corroborates that learning from past experience saves lives. As reported, 'Early in the morning on Sept. 29, an earthquake deep under the Pacific caused a massive tsunami that devastated the islands of Samoa and American Samoa, killing 111 people, ravaging villages and flattening homes. The earthquake struck at 6:48 a.m. and measured 8.3 on the Richter scale. By 7:04 a.m., an emergency alert went out from the Tsunami Warning System, a global network of sensors monitored by scientists. Less than 10 minutes later, the tsunami, with waves measuring nearly 15ft. high, hit land. Bad as the damage was, it could have been much worse. Laura Kong, head of the International Tsunami Information Centre in Hawaii, says Independent Samoa had run a tsunami drill with planned evacuation routes in October 2007 and again last year. The preparation saved countless lives during this week's disaster'.

descriptive value, it points to the greater vulnerability of such countries stemming from variation in geo-physical and hydro-meteorological characteristics.

Turning to the deaths, their elasticity to (predicted) disasters was high (0.48). Or, a five percent higher frequency of disasters was associated with 2.40 per cent higher mortality. So the death toll of disasters was high. Countries that recorded higher deaths in 1970-79 also recorded higher deaths in 1980-2004 (the elasticity being 0.26). So countries with five percent higher (lagged) deaths recorded 1.3 percent higher deaths. In addition, there is an indirect effect of lagged deaths through higher frequency of natural disasters leading to still higher deaths. However, the indirect elasticity is (relatively) small (0.04). (Absolute) elasticity of deaths to income is high (0.93). So a five percent higher GDP per capita is associated with a 4.65 percent reduction in deaths. Here the emphasis *shifts* to resources for enhancing disaster prevention and mitigation of fatalities, as well as a stronger preference for safety. While these results point to the important role of income in preventing deaths, it is plausible that the effect of income reduces at higher levels.[32]

Somewhat surprising is the absence of a significant relationship between democracy and mortality. This is intriguing, as good institutions (parliaments, media and communities) are frequently associated with lower damages and deaths, since they permit public oversight. But these institutions function differently across countries, even if they have similar legal authority and responsibility. Storm damage, for example, is more severe in Haiti than in adjoining Dominican Republic. Haiti's institutions and communities have suffered from long decades of misrule. Often, institutions are linked to democracy, but what matters more is political competition (World Bank, 2010).

In sum, income (and by implication its growth) matter a great deal in averting disaster-related deaths. While learning from past experience takes diverse forms and magnitudes, our assessment suggests that it has been far from adequate. Lagged disasters are associated with higher frequency of disasters, which in turn cause higher fatalities. Also, the direct effect of lagged deaths on subsequent deaths is high, further pointing to limited learning from past experience of severe disasters. While institutions matter, our analysis was not detailed enough to validate their role.

[32] See, for example, Toya and Skidmore (2007), which confirms an inverse relationship between numbers killed and income.

Table 11. Reduction in disasters and mortality

First stage regression	Elasticity
Number of natural disasters during 1980-2004	
Deaths from disasters during 1970-79	0.085
Persons/ km^2	0.120
Number of natural disasters during 1970-1979	0.391
Large area	0.244
Second stage regression	
Log of deaths from disasters during 1980-2004	
(Predicted) natural disasters during 1980-2004	0.483
Medium area	0.246
Large area	0.718
GDP 1995	-0.931
Deaths from disasters during 1970-79	0.262 Indirect effect: 0.04 [1]

1. The indirect effect of lagged deaths is traced through its effect on frequency of disasters and then on deaths in 1980-2004.

Catastrophic risks, insurance and reconstruction

An important point is that, while natural hazards cannot be controlled, they become disasters because of failures of communities, governments and donors. In that sense, disasters are man-made. A case in point is droughts turning into famines. So a general observation on greater vulnerability to natural disasters in the last three decades is that, whatever the roles of climate change in the greater frequency and severity of natural hazards (e.g. droughts, floods), and growth of physical assets and human settlements in areas more exposed to such hazards, their effects are compounded by government and community failures.[33] In this context, it may be emphasised that growing urbanisation has compounded the problem, as even a minor event can cause enormous damage in a heavily populated area. The proportion of people in developing countries who live in cities has doubled since 1960. More than 40 percent now live in urban areas, and it is projected to rise

[33] (a) There are numerous examples of government policies that prevented famines, but also many others of policies that exacerbated shortages and caused famines and large-scale misery. The British, for example, believed in non-intervention in food markets during famines in India in the 19th century. So food was exported while masses died of starvation. Other examples are worse, as they point to a causal role of government policies (e.g. food procurement policies that caused severe famines in Soviet Russia (i.e. the famine in Ukraine) in the 1930s and in Ethiopia in the mid-1980s). For an elaboration, see Dreze (1999). (b) As World Bank (2010) puts it, earthquakes, droughts and floods are natural hazards, but the unnatural disasters are deaths and damages resulting from human acts of omission and commission.

to 55 percent by 2030. Nearly half of these cities are subject to extreme weather events[34] (Freeman et al. 2003; World Bank, 2010; *The Economist*, 2012, 'The rising cost of catastrophes: how to limit the damage that natural disasters do?', 14 January).

Let us now turn to strategic considerations and priorities in disaster risk prevention and mitigation.

While developing countries bear the brunt of disasters, ironically these are also the countries which have made fewer efforts to adapt their physical environments to mitigate the impact of such disasters and to insure themselves against disaster risks, partly because of the disincentive known as the 'Samaritan's dilemma' (i.e. nations may underinvest in protective measures since they expect foreign donors to help when such disasters strike).[35]

Within developing countries, the poor often bear the brunt of disasters for the following reasons: (i) they are located in areas that are more vulnerable to floods, hurricanes and earthquakes; (ii) disasters often disrupt food production, resulting in loss of livelihoods and higher food prices; (iii) and, finally, not only do the poor lose assets, but they also lack access to risk-sharing mechanisms, such as insurance.[36] It is, therefore, not surprising that disasters substantially increase measured poverty (e.g. 50 percent of the increase in the head-count ratio in the Philippines during the 1998 crisis was due to El Nino).

From a macro-economic perspective, the tax base shrinks while spending is greater. Trade balance may deteriorate, as exports decline and post-disaster reconstruction boosts demand for imports. Additionally, concurrent flight of foreign capital may put a downward pressure on the exchange rate and fuel inflation. Public sector debt ratios may worsen and domestic savings decline, forcing public and private sectors to borrow more from foreign sources.[37]

Catastrophic risks tend to be rare events, but when they do occur there may be extreme outliers. These two factors imply that the occurrence and consequences of catastrophes are difficult to predict. Appropriate policy instruments for different catastrophes differ substantially in both objectives and modes of operation. Some policy instruments are designed to prevent catastrophes, others to reduce their likelihood, others to minimise their consequences, and still others to spread and thus mitigate the impact of their costs (Viscusi and Zeckhauser, 2011).

[34] In fact, 14 of the world's 19 mega cities (with 10 million or more inhabitants) are in coastal zones, and over 70 of the world's 100 largest cities can expect a strong earthquake at least once every 50 years (Freeman et al. 2003).

[35] For an elaboration of these concerns, see Freeman et al. (2003) and World Bank (2010).

[36] For an insightful exposition of the link between poverty and risks, see Dasgupta (2007).

[37] For a review of macro-economic impacts of natural disasters in selected Latin American countries – in particular, the process of recovery – see Mechler (2003) and Andersen (2005). For more recent evidence, see Noy, 2009).

Catastrophes could be classified according to whether there are a few causal agents (e.g. the BP Deepwater Horizon oil spill) or many (e.g. depletion of the ozone layer). If there are a few causal agents, it is easier to fix responsibility (Viscusi and Zeckhauser, 2011).

Prevention is often possible and cost-effective. Government expenditure on prevention is usually lower than on relief. While expenditure matters, what is also important is how it is spent. Bangladesh, for example, reduced deaths from cyclones by spending modest sums on shelters, accurate weather forecasts, warnings and evacuation. These cost less than building large-scale embankments (World Bank, 2010)

Risk mitigation through adaptation of physical environment includes land use planning (e.g. avoiding construction on seismic faultlines, vulnerable coastal regions, and ensuring that buildings are resistant to hurricanes and earthquakes); prevention of soil erosion; and building of dams for flood control, and seawalls to break storm surges. Governments could also promote farming practices so that farmers can cope better with climatic variations – drought-resistant crops – and adapt to longer-term changes.

While disaster insurance is extensive in many developed countries – in USA, for example, 50 percent of direct catastrophic losses are insured – in developing countries (with per capita incomes <\$10,000 per annum) insurance coverage is less than 10 percent (and in countries with per capita incomes below \$760 the coverage is about one percent). This lack of protection is further corroborated by the fact that Asia, which suffered half of all damages caused by natural disasters and two-thirds of the casualties from them, accounted for eight percent of global purchase of catastrophic insurance, while Japan, USA and UK accounted for 55 percent of the total (Freeman et al. 2003).

Adverse selection is a problem in disaster insurance but less than in other insurance markets, as many disasters can be predicted more accurately, as also the value of property at stake. In developing countries, however, specific problems arise from the thinness of insurance markets and ill-defined property rights (Freeman et al. 2003).

Two other problems are arguably more serious. One is the difficulty of risk spreading and the second is linked to the Samaritan's dilemma. While risk-spreading in developing countries in general should not be difficult – since the losses they face are a small fraction of global resources – it often is difficult because of the segmented and shallow insurance markets.[38] The Samaritan's dilemma, on the other hand, may arise from: (i) households and firms underinvesting in insurance and undertaking adaptive measures on the presumption that governments would come to their rescue; (ii) governments also underinvesting in the

[38] In the 1990s, the Caribbean countries, for example, faced insurance rate increases of between 200-300 percent, due to indemnity payments for large hurricane and earthquake losses worldwide (Freeman et al. 2003).

hope that foreign donors would bail them out; and (iii) rich countries finding it difficult to scale down their *ex post* assistance in the absence of significant *ex ante* protective measures by governments in developing countries. The humanitarian urge to help when a disaster strikes is often overwhelmingly strong (Freeman et al. 2003). New financial instruments (e.g. catastrophic bonds, swaps, and weather derivatives) have been devised to deal with disaster risk, but with little impact.[39]

While there is potential for governments to correct market failures in the provision of disaster insurance, they are unable to act as insurers of last resort. Governments are often involved in compensating for losses that could be more efficiently handled by commercial insurance arrangements if the insurance market was sufficiently well developed. Distribution of claims among electoral constituencies creates moral hazard issues and bureaucratic corruption (Andersen, 2005).[40]

Governments could help correct insurance market failures through: (i) tax deductions; (ii) subsidies; (iii) guarantees to insurers and reinsurers; (iv) hedging of such guarantees on world reinsurance and capital markets; and (v) mandatory levels of insurance.[41] A general response to the Samaritan's dilemma is to require those at risk to undertake *ex ante* measures to reduce the harm that they will suffer if the hazard occurs.[42] Donors, for example, may credibly commit emergency assistance to countries deemed to have taken disaster mitigation measures (e.g. provision for self-insurance, sea wall protection, enforcement of building guidelines in coastal and other hazard prone- areas). This would help in overcoming a basic inefficiency in disaster insurance and free resources for other development purposes (Freeman et al. 2003).[43] Some observations to address donor

[39] Froot (2001) makes an important observation that catastrophic bonds cause a reduction in the barriers to entry into reinsurance. Indeed, it is the barriers to entry and not the amount of capacity in current use that explains deviations from fair pricing.

[40] For insightful treatments of the market for catastrophic risks, see Kunreuther (1997), Froot (2001) and Froot and O'Connell (1997), among others.

[41] Lave and Apt (2006) emphasise government's important role in providing information to people regarding the risks they face, as they do not have well-formulated risk-beliefs concerning low probability but high loss natural catastrophes. Government information provision could remedy this inadequacy and foster more rational risk taking. There is one important caveat, however. Even when there is substantial scientific basis for making risk judgements, as with hurricane warning systems, the risk is not known until the emergency has passed (Viscusi and Zeckhauser, 2011).

[42] Mitigation also encourages reinsurers to reduce their rates: encouraging policy holders to adopt risk-mitigation measures provides an additional option for small insurers to meet insolvency constraints and puts pressure on reinsurers not too charge too high a premium (Kunreuther, 1997). For a sample of studies of why reinsurance is expensive, see Froot (2001) and Froot and O'Connell (1997).

[43] In this context, the findings from a US survey are illuminating: (i) over 90 percent of the respondents believed that they faced average or below average fatality risks from natural disasters; (ii) experiencing a hurricane or a tornado decreases the percentage of those who rate their risks below average by about 10 percent, but a similar experience with floods and earthquakes has a minimal effect on the victims' perceptions. For each risk, having experience with it shifts perceived risks upwards. However, this updating (anchoring) is insufficient. (iii) Over 82 percent of the respondents favoured subsidised insurance and relief for disaster victims; the percentage favouring

concerns and a more coordinated disaster prevention and mitigation strategy are made below.

A major strategic concern is mainstreaming of disaster prevention and mitigation among multilateral development agencies and governments. This rests on the presumption that the response to disasters has been *reactive* and *tactical*, and not strategic, in the sense that the emergencies caused by natural hazards (e.g. floods, earthquakes) are not periodic but on-going in the context of highly vulnerable countries (World Bank, 2006, 2010). Pacific Rim states, for example, will continue to be hit by earthquakes and floods, while low-lying coastal areas on the Bay of Bengal will continue to get flooded.

Recovery from a disaster and poverty reduction go hand in hand. Choices made during the initial phase could influence the outcomes in terms of poverty favourably or unfavourably over time. If interventions do not go beyond short-term relief and shy away from rebuilding of livelihoods and reconstruction from a longer-term perspective, communities/regions highly vulnerable to natural hazards (e.g. low-lying coastal areas are highly vulnerable to floods) are likely to fare worse with recurrent catastrophes.

Why should multilaterals/developing countries be concerned? As noted earlier, a striking piece of evidence is that the damage from the Kashmir earthquake of December 2005, exceeded total development assistance in the preceding three years (World Bank, 2006). A related question is why the longer-term implications of building resilience against such disasters do not get the priority they deserve. Typically, disaster responses are like a military operation, with a heavy reliance on command-and-control systems designed to make a chaotic situation manageable (World Bank, 2006). In such a process, people and institutions that might help to rebuild affected communities are left out.[44] What makes matters worse is that little attention is paid to how the next disaster could be averted. Neither donor funding, nor funding from developing country governments is geared to that goal. As soon as the emergency is over, other development priorities take over. So the key interrelationships between recovery, disaster prevention and an abrupt worsening of poverty reduction over a period of time must be addressed in a coherent strategy through development assistance. Even small, incremental efforts can go a long way towards disaster prevention (IFRC, 2001).

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these measures for the victims who chose to live in disaster prone-areas was, however, much smaller (about 37 percent). This is referred to as ’efficient compassion‘. Individuals who perceive themselves to be at greater personal risk are more supportive of government assistance. So there are elements of both compassion and self-interest in support of government assistance (Viscusi and Zeckhauser, 2006). From a larger perspective of the developing countries, see World Bank (2010).

[44] A best practice example of how vulnerability to flooding could be reduced by preventing environmental degradation comes from a highly eroded region of China. Small check dams, planting of trees, bushes, and shrubs on sloping lands, and building of terraces, using contour ditches and stone barriers, helped eliminate flash floods, and sediment inflows to the Yellow River. In due course, incomes of poor farmers rose. The design of this project and its implementation were in consultation with various stakeholders – especially local communities. Much of its success also depended on the initial results demonstrating the potential of improved practices in reducing poverty (World Bank, 2006).

Building of ownership through borrower financing and involvement of local communities, preservation of social networks in rehabilitation programmes, support for complementary activities (e.g. rehabilitation centres ensuring provision of safe water and sanitation) and maintenance of infrastructure, are all imperative.[45]

Evidence has accumulated pointing to coordination failure turning natural catastrophes into disasters. Marris (2005), for example, documents that much of the destruction and deaths in the wake of the 2004 tsunami could have been averted. In fact, there was a chain of coordination failures.[46] Another case in point is the Orissa cyclone of 1999. But a cyclone three years later (in 2002) resulted in far fewer deaths, as both official agencies and affected communities responded more quickly and in a coordinated manner (Thomalla and Schmuck, 2004). The mortalities in the wake of the Kashmir earthquake in 2005 were staggering for a variety of reasons, including slow and uncoordinated response, inaccessible terrain, tight-fistedness of donors, mistrust between neighbours and failure to enforce building codes (*The Economist*, 15 October, 2005).

Donors typically respond to disasters after they strike: about a fifth of total humanitarian aid between 2000-2008 was spent on disaster relief. Donors concerned with prevention could earmark official development aid (rather than humanitarian aid) to prevention- related activities. And such aid, used effectively, could reduce issues arising from the Samaritan's dilemma (World Bank, 2010). .

Concluding observations

Let us first summarise the main findings, followed by observations from a broad policy perspective.

Our analysis has drawn attention to the higher frequency of natural disasters and deaths associated with them. There are regional variations as well as across countries ranked by income levels. A somewhat surprising finding is that, while the frequency of disasters was not the highest in low income countries, disasters in these countries were far deadlier

[45] It is crucial to avoid unnecessary processes and the establishment of new bureaucracies, and to build instead on existing public, private and local self-help organisations. Capacity-building may include support for public and private sector providers of services to rural communities, but the major thrust must be on community organisations.

[46] Prediction of a tsunami with any useful time advantage requires data on small changes in sea level and pressure collected directly from the floor and surface of the sea. Instruments that could provide such data are already in the Indian Ocean. However, a coordinated and continuous monitoring is needed, under the auspices of UNESCO's Intergovernmental Oceanographic Commission (IOC). But collection of information and its dissemination are often difficult. Data exchange, hazard analysis, and hazard mapping thus become difficult. Sharing of data is often resisted for security, commercial and defence reasons (World Bank, 2010).

relative to those in higher income countries. *But as these are essentially averages, they cannot be interpreted as trends*.

Floods were the most frequent disaster, accounting for well over one-third of the total disasters during 1985-1994. The next most frequent were windstorms, which accounted for a quarter of the disasters. Most disasters became more frequent in the next decade (1995-2004). While the share of floods rose, that of windstorms declined. Both droughts and famine also became more frequent but the share of the former rose and that of the latter – already low – declined.

Windstorms accounted for a little under one-half of the deaths in 1985-94, followed by earthquakes accounting for over a quarter of deaths. The next decade, however, witnessed wave surges claiming one-third of deaths, followed closely by famines that claimed about the same share. While famines and wave surges became far deadlier (per disaster) during 1995-2004, floods became the deadliest (per million of population). So, while the aggregate of disasters became deadlier on various criteria, deadliness of some disasters varied with the criterion used.

A selection of the regression results on occurrence of disasters and deaths due to them was given. Much of this analysis, however, was robust to changes in specification and in sample periods. In particular, countries that were prone to natural disasters in 1970-79 continued to be so in the next decade or two. Also, their frequency was higher in countries that experienced more severe disasters initially. Geophysical factors (e.g. elevation and size of a country) had an important role in explaining inter-country variation in the occurrence of natural disasters. They were also more frequent in more populous countries. Disasters, however, were unrelated to income and polity.

Income (and by implication its growth) matter a great deal in averting disaster-related deaths. While learning from past experience takes diverse forms and magnitudes, our assessment suggests that it has been far from adequate. (Lagged) disasters are associated with higher frequency of disasters, which in turn cause higher fatalities. Also, the direct effect of lagged deaths on subsequent deaths is high, further pointing to limited learning from past experience of severe disasters. While institutions matter, our analysis was not detailed enough to validate their role.

Even moderate learning can save a large number of deaths (e.g. through early warning systems, and better coordination between governments and communities likely to be affected). Growth acceleration would also help avert deaths through more resources for disaster prevention and mitigation capabilities. A combination of the two – learning from past experience and more resources for disaster prevention and mitigation – would of course result in a massive reduction in deaths from disasters.

Attention is drawn to segmented and shallow disaster insurance markets and governments' role in developing them; the Samaritan's dilemma in providing emergency assistance to poor countries that neglect investment in protective measures; the need for mainstreaming of disaster prevention and mitigation among multilateral development agencies and governments, and the imperative of better coordination among them; why short-term relief must be combined with rebuilding of livelihoods and reconstruction, and the potential for public-private partnerships; and, above all, the need for building ownership of local communities and preservation of social networks.

In conclusion, while our evidence points to a growing vulnerability to natural disasters and their grave implications for human security, a challenge for governments and development assistance is to combine growth acceleration with speedy relief and durable reduction in vulnerability. If our analysis has any validity, there are indeed grounds for optimism.

Annex 1

Table A.1.1. Definitions of natural hazards

Type	Hazard	Definition
(a) Hydro-meteorological	(i) Hurricanes and tropical storms	Large-scale, closed circulation system in the atmosphere with low barometric pressure and clockwise in the southern hemisphere
	(ii) Floods	Temporary inundation of normally dry land by overflowing lakes or rivers, precipitation, storm surges, tsunami, waves, mudflow and lahar. Also caused by the failure of water-retaining structures, groundwater seepage and water back-up in sewer system.
	(iii) Drought	Lack or insufficiency of rain for an extended period that causes hydrological imbalance and, consequently, water shortage, crop damage, stream flow reduction and depletion of groundwater and soil moisture. It occurs when, for a considerable period, evaporation and transpiration (the release of underground water into the atmosphere through vegetation) exceeds precipitation.
	(iv) Forest fires	Uncontrolled fires whose flames can consume trees and other vegetation of more than 6 feet (1.8 m) in height. These often reach the proportions of a major conflagration and are sometimes begun by combustion and heat from surface and ground fires.
(b) Geophysical	(i) Earthquake	Sudden tremor of the earth's strata caused by movements of tectonic plates along fault lines in mountain ranges or mid- oceanic ranges
	(ii) Tsunami	Wave train or series of waves generated in water by an impulsive disturbance (such as earthquakes) that vertically displace gigantic water columns. Tsunamis may reach a maximum run-up or above sea-level height of 10, 20 or even 30 metres.
	(iii) Slides	Downward slope movement of soil, rock, mud or snow because of gravity. A common source of slides is prolonged torrential downpours of rain or the accumulation of heavy snow. Mass displacement of large mud, snow or rocks can also be triggered by seismic waves.
	(iv) Lahars	Mudflows that are caused by the melting of the ice cap by lava from a volcano or the downhill run-off of volcanic ash because of heavy rainfall.
	(v) Volcanic eruption	Process whereby molten lava, fragmented rocks or gases are released to the earth's surface through a deep crater, vent or fissure.

Source: Adapted from Auffret (2003).

Table A.1.2. Classification by income

For operational and analytical purposes, the World Bank's main criterion for classifying economies is gross national income (GNI) per capita. Based on its GNI per capita, every economy is classified as low income, middle income (subdivided into lower middle and upper middle), or high income. Other analytical groups, based on geographic regions and levels of external debt, are also used.

Definitions of groups

Geographic region: Classifications and data reported for geographic regions are for low-income and middle-income economies only. Low-income and middle-income economies are sometimes referred to as developing economies. Classification by income does not necessarily reflect development status.

Income group: Economies are divided according to 2004 GNI per capita, calculated using the World Bank Atlas method. The groups are: low income, $825 or less; lower middle income, $826 - $3,255; upper middle income, $3,256 - $10,065; and high income, $10,066 or more.[47]

Source: Adapted from *World Development Indicators* (WDI, 2006).

[47] http://data.worldbank.org/about/country-classifications/country-and-lending-groups#lincome

Annex 2

(a) Hydro-meteorological and geophysical disasters

Here a disaggregated analysis of natural disasters into hydro-meteorological and geophysical disasters is carried out. The empirical evidence confirms that *both* their frequencies and impacts differ.

Table A.2.1. Different types of natural disasters and their death tolls

Disaster type	Frequency	Frequency	Deaths	Deaths	Deaths per million	Deaths per million	Deaths per disaster	Deaths per disaster	Disasters per million	Disasters per million
	1985-94	1995-04	1985-94	1995-04	1985-94	1995-04	1985-94	1995-04	1985-94	1995-04
	(%)	(%)	(%)	(%)						
Hydro-meteorological	1111	1823	248602	615792	60	128	224	338	0.27	0.38
	(75.94)	(80.38)	(64.60)	(88.77)						
Geophysical	352	445	136244	77897	33	16	387	175	0.08	0.09
	(24.06)	(19.62)	(35.40)	(11.23)						
Total	1463	2268	384846	693689	92	144	263	306	0.35	0.47
	(100.00)	(100.00)	(100.00)	(100.00)						

1. Based on the classification in Auffret (2003). Calculations based on EM-DAT. Note that rich OECD and non-OECD countries are excluded.

- As may be noted from Table A.2.1, the frequencies of both hydro-meteorological and geophysical disasters were considerably higher in 1995-04, relative to 1985-94. If these frequencies are expressed as a ratio of population, there was an increase in the frequency of the former, while that of the latter remained unchanged.
- However, a vast majority of the disasters were hydro-meteorological during 1985-94, and their share rose during the next decade.
- So also was the case with their share of deaths – this rose from about 65 percent during 1985-94 to about 88 percent in 1995-04, while there was a sharp reduction in that of geophysical disasters.
- Hydro-meteorological disasters became deadlier during 1995-04 on the criterion of deaths per disaster, while geophysical ones recorded a decline in their deadliness.
- A similar pattern is revealed by our preferred criterion of deaths per million of population, confirming a more than doubling of the deadliness of hydro-meteorological ones and a halving of that of geophysical.

In sum, while both types of disasters became more frequent, only hydro-meteorological disasters became far deadlier.

Let us now turn to their frequencies and measures of their deadliness by region.

- East Asia and the Pacific accounted for just under one-third of hydro-meteorological disasters, followed by Latin America and the Caribbean, South Asia and Sub-Saharan Africa during 1985-94. The (relative) frequencies changed during 1995-04. While both East Asia and the Pacific, and South Asia recorded moderate reductions, Europe and Central Asia, and Sub-Saharan Africa, among others, recorded higher shares.
- Hydro-meteorological disasters per million of population were, however, most frequent in Latin America and the Caribbean, followed closely by Sub-Saharan Africa in 1985-94. Both also recorded higher frequencies in 1995-04.
- Over 90 percent of the deaths were concentrated in South Asia, and East Asia and the Pacific during 1985-94, with the majority in the former. The shares of the remaining regions were relatively small.

Going by the criterion of deaths per disaster, hydro-meteorological ones were the deadliest in South Asia, followed by East Asia and the Pacific, and Sub-Saharan Africa. There was a sharp reversal in the next decade, with these disasters becoming the deadliest in East Asia and the Pacific, followed by South Asia. Also, while Sub-Saharan Africa experienced more deadly disasters, Latin America and the Caribbean experienced a reduction.

Table A.2.2. Hydro-meteorological disasters and their death toll

Region	Number of disasters (85-94)	Number of disasters (95-04)	Deaths (85-94)	Deaths (95-04)	Deaths per million (85-94)	Deaths per million (95-04)	Deaths per disaster (85-94)	Deaths per disaster (95-04)	Disasters per million (85-94)	Disasters per million (95-04)
Latin America & Caribbean	232	394	6,902	62,105	16	126	30	158	0.55	0.8
	(20.88)	(21.61)	(2.78)	(10.09)						
South Asia	207	268	185,847	101,339	168	78	898	378	0.19	0.21
	(18.63)	(14.70)	(74.76)	(16.46)						
East Asia & Pacific	353	489	38,437	432,093	24	242	109	884	0.22	0.27
	(31.77)	(26.82)	(15.46)	(70.17)						
Europe & Central Asia	62	213	2,327	4,076	6	10	38	19	0.15	0.51
	(5.58)	(11.68)	(0.94)	(0.66)						
Middle East & North Africa	62	110	2,926	3,768	14	14	47	34	0.29	0.42
	(5.58)	(6.03)	(1.18)	(0.61)						
Sub-Saharan Africa	195	349	12,163	12,411	28	23	62	36	0.45	0.63
	(17.55)	(19.14)	(4.89)	(2.02)						
Total	1,111	1,823	248,602	615,792	60	128	224	338	0.27	0.38
	(100.00)	(100.00)	(100.00)	(100.00)						

Calculations based on EM-DAT. Note that rich OECD and non-OECD countries are excluded.

- This pattern is largely reproduced when deaths are expressed as a ratio of the population. These disasters were the deadliest in South Asia during 1985-94, followed by Sub-Saharan Africa, and East Asia and the Pacific. However, but consistent with the previous normalisation, deadliness of these disasters shot up in East Asia and the Pacific (by a multiple of 10) and in Latin America and the Caribbean (by a multiple of eight) in the next decade. While there was a reduction in the deadliness of these disasters in South Asia, the fatalities were markedly higher than in all other regions (excluding the previous two).

Let us now turn to geophysical disasters by region.

- They were the most frequent in East Asia and the Pacific, followed by Latin America and the Caribbean during 1985-94.
- While the share of East Asia and the Pacific rose more than moderately, that of Latin America and the Caribbean fell slightly. South Asia recorded a slight increase during the next decade.
- When these are normalised by population, Latin America and the Caribbean recorded the highest frequency, followed by Middle East and North Africa, and Europe and Central Asia during 1985-94.
- The distribution of deaths is strikingly different from that of hydro-meteorological ones. Latin America and the Caribbean, Middle East and North Africa, and Europe and Central Asia accounted for over 80 percent of the deaths, with the two sub-regions of Asia accounting for less than one-fifth of the share during 1985-94.
- During the next decade, significant reversals occurred. While geophysical disasters in Middle East and North Africa accounted for over 42 percent of the deaths, the share of South Asia rose by a multiple of four. The combined share of these two regions was about 83 percent. There were sharp reductions in the shares of Latin America and the Caribbean, and Europe and Central Asia.
- Deaths per disaster were highest in Middle East and North Africa, followed by Europe and Central Asia, and Latin America and the Caribbean during 1985-94.
- While these disasters remained the deadliest in Middle East and North Africa, but with lower fatalities, there was a marked spurt in South Asia, and substantial reductions in Latin America and the Caribbean, and Sub-Saharan Africa during the next decade.
- With deaths normalised by population, there are a few changes. While these disasters were the deadliest in Middle East and North Africa, the next in rank was Latin America and the Caribbean, followed by Europe and Central Asia. While Middle East and North Africa remained the deadliest with a marked reduction in fatalities, the only region that witnessed higher fatalities was South Asia.

An alternative classification of these types of natural disasters by level of income is revealing.

Table A.2.3

Table A.2.3. Geophysical disasters and their death toll

Region	Number of disasters (85-94)	Number of disasters (95-04)	Deaths (85-94)	Deaths (95-04)	Deaths per million (85-94)	Deaths per million (95-04)	Deaths per disaster (85-94)	Deaths per disaster (95-04)	Disasters per million (85-94)	Disasters per million (95-04)
	%	%	%	%						
Latin America & Caribbean	94	105	41,114	4,721	97	10	437	45	0.22	0.21
	(26.70)	(23.60)	(30.18)	(6.06)						
South Asia	42	59	14,510	31,499	13	24	345	534	0.04	0.05
	(11.93)	(13.26)	(10.65)	(40.44)						
East Asia & Pacific	112	170	9,773	4,424	6	2	87	26	0.07	0.1
	(31.82)	(38.20)	(7.17)	(5.68)						
Europe & Central Asia	54	57	27,904	3,728	69	9	517	65	0.13	0.14
	(15.34)	(12.81)	(20.48)	(4.79)						
Middle East & North Africa	33	35	41,076	33,021	192	126	1,245	943	0.15	0.13
	(9.38)	(7.87)	(30.15)	(42.39)						
Sub-Saharan Africa	17	19	1,867	504	4	1	110	27	0.04	0.03
	(4.83)	(4.27)	(1.37)	(0.65)						
Total	352	445	136244	77897	33	16	387	175	0.08	0.09
	(100.00)	(100.00)	(100.00)	(100.00)						

Calculations based on EM-DAT. Note that rich OECD and non-OECD countries are excluded.

Table A.2.4. Hydro-meteorological disasters and their death tolls by income

Sum

Income	Number of disasters (85-94)	Number of disasters (95-04)	Deaths (85-94)	Deaths (95-04)	Deaths per million (85-94)	Deaths per million (95-04)	Deaths per disaster (85-94)	Deaths per disaster (95-04)	Disasters per million (85-94)	Disasters per million (95-04)
Low income	463	757	205,347	318,864	122	157	444	421	0.27	0.37
	(41.67)	(41.52)	(82.60)	(51.78)						
Lower middle income	534	845	41,048	262,278	18	105	77	310	0.24	0.34
	(48.06)	(46.35)	(16.51)	(42.59)						
Upper middle income	114.00	221.00	2,207.00	34,650.00	9	123	19	157	0.47	0.78
	(10.26)	(12.12)	(0.89)	(5.63)						
Total	1,111	1,823	248,602	615,792	60	128	224	338	0.27	0.38
	(100.00)	(100.00)	(100.00)	(100.00)						

Calculations based on EM-DAT. Note that rich OECD and non-OECD countries are excluded.

Table A.2.5. Geophysical disasters and their death tolls by income

Income	Number of disasters (85-94)	Number of disasters (95-04)	Deaths (85-94)	Deaths (95-04)	Deaths per million (85-94)	Deaths per million (95-04)	Deaths per disaster (85-94)	Deaths per disaster (95-04)	Disasters per million (85-94)	Disasters per million (95-04)
	%	%	%	%						
Low income	81	114	17,516	32,350	10	16	216	284	0.05	0.06
	(23.01)	(25.62)	(12.86)	(41.53)						
Lower middle income	240	296	108,591	45,161	49	18	452	153	0.11	0.12
	(68.18)	(66.52)	(79.70)	(57.98)						
Upper middle income	31	35	10,137	386	41	1	327	11	0.13	0.12

Calculations based on EM-DAT. Note that rich OECD and non-OECD countries are excluded.

- Low income and lower middle income countries accounted for the vast majority of hydro-meteorological disasters (about 90 percent) during 1985-94. There was a slight reduction in their share over the next decade.
- While each income group recorded higher frequencies per million of population, the largest increase occurred in upper middle income countries.
- Deaths, however, were more concentrated, with low income and lower middle income countries accounting for nearly all fatalities during 1985-94. During the next decade, their combined share declined. While that of low income countries dropped sharply from about 83 percent to about 52 percent, that of lower middle income countries climbed from about 17 percent to about 43 percent.
- Deaths per disaster were the highest in low income countries, followed by lower middle income countries, but with considerably fewer fatalities in 1985-94. While the deadliness of hydro-meteorological disasters remained highest in low income countries, but with fewer fatalities, it shot up in lower middle income countries as well as in upper middle income countries.
- Deaths per million of population reveal a different pattern across these income groups. They were highest in low income countries during 1985-94 and remained so during the next decade with higher fatalities. The fatalities shot up in the remaining two groups as well – especially among upper middle income countries.

The frequencies and deadliness of hydro-meteorological and geophysical disasters differ across these income groups as well.

- The majority of geophysical disasters occurred in low income and lower middle income groups, with the latter accounting for more than two-thirds of such disasters. The (relative) frequencies changed little during the next decade, with a slightly higher share of low income countries.
- Frequencies of such disasters per million of population were highest in lower middle income countries and remained so in the next decade, with a slight increase.
- Deaths, however, were mostly concentrated in the two lowest income groups, accounting for nearly 93 percent of the total during 1985-94. The bulk of the deaths occurred in lower middle income countries. While this group recorded a sharp reduction during 1995-04, the share of low income countries shot up.
- Deaths per disaster were highest in lower middle income countries during 1985-94, but they experienced a marked reduction in fatalities in the next decade. Upper middle income countries also recorded a substantial reduction. By contrast, the fatalities rose in low income countries, surpassing those in other income groups.
- A slightly different pattern of deadliness is revealed by deaths per million of population. Geophysical disasters were the deadliest in lower middle income countries, followed closely by upper middle income countries during 1985-94.

While the deadliness declined in both lower middle income and upper middle income groups – especially the latter – there was a more than moderate rise in low income countries.

To sum up, both the frequency and deadliness of hydro-meteorological and geophysical disasters differ over time, across regions and income groups. The main findings are that a vast majority of natural disasters were hydro-meteorological and their (relative) frequency rose during more recent years; not only was the deadliness of the former greater in the aggregate sample, it also doubled, while that of the latter halved during more recent years; and, while hydro-meteorological disasters also became deadlier in both low income and lower middle income groups – especially in the latter – geophysical ones did so only in the former.[48]

(b) Power Law applications to disaster mortalities

Here plots of logarithms of deaths per disaster–cumulative frequency (or probability) of deaths per disaster are given first for regional sub-samples and then for groups of countries by level of income over the period 1980-2004.

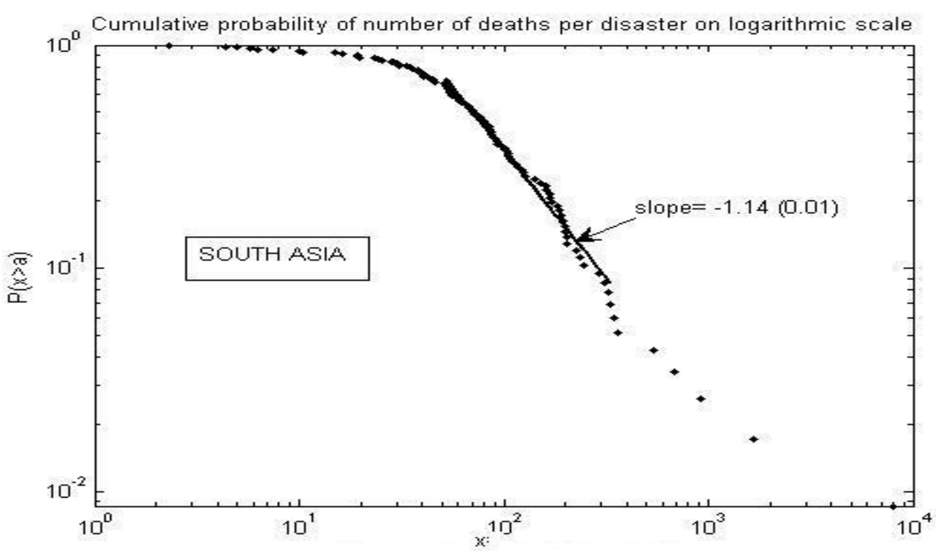

Figure A.2.1: Logarithm of deaths per disaster–cumulative frequency (probability) of deaths per disaster in South Asia

[48] For an update, see Thomas et al. (2012) and Jennings (2011). Both confirm a rising trend of hydro-meteorological disasters on different criteria across decades up to 2010.

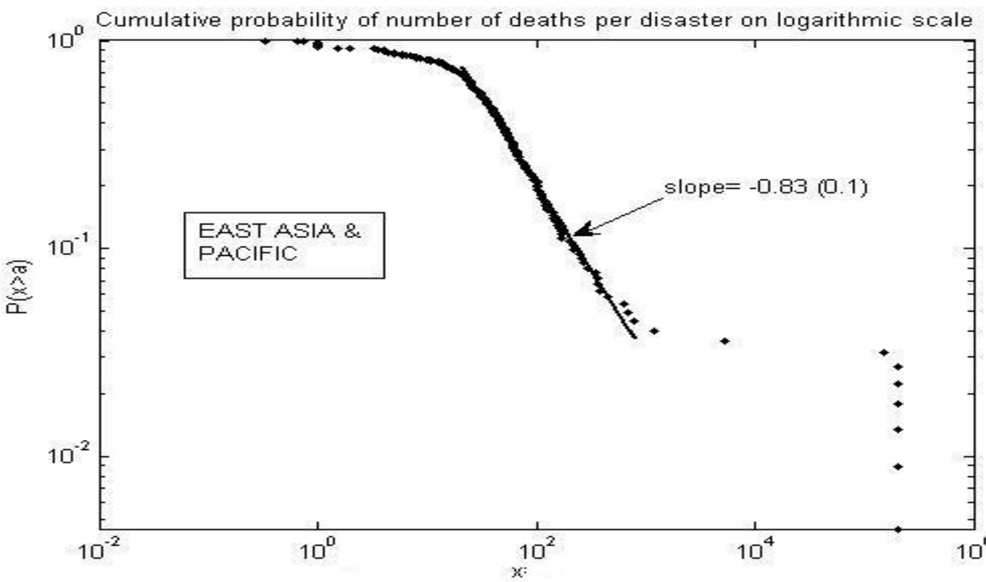

Figure A.2.2: Logarithm of deaths per disaster–cumulative frequency (probability) of deaths per disaster in East Asia and the Pacific

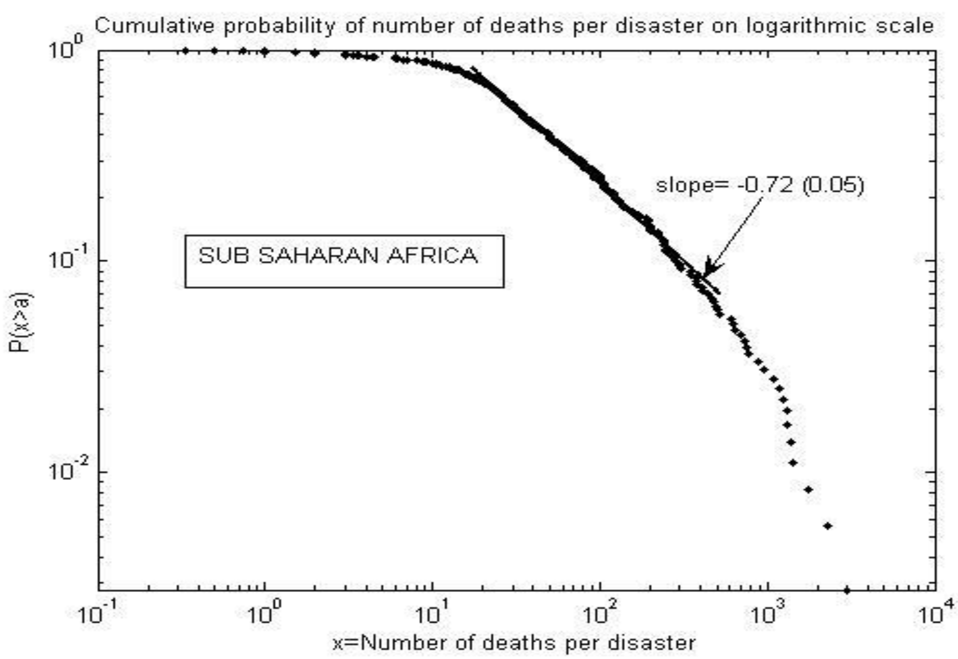

Figure A.2.3: Logarithm of deaths per disaster –cumulative frequency (probability) of deaths per disaster in Sub-Saharan Africa

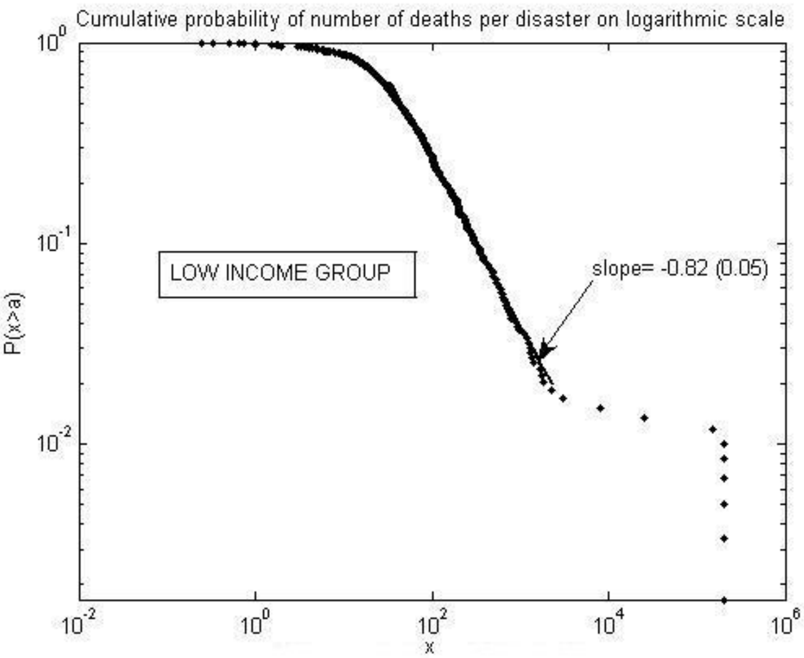

Figure A.2.4: Logarithm of deaths per disaster–cumulative frequency (probability) of deaths per disaster in low income countries

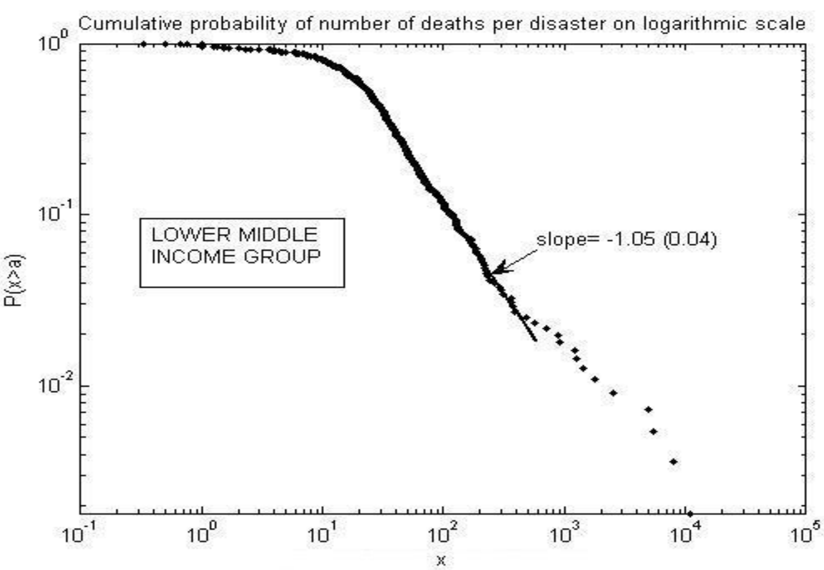

Figure A.2.5: Logarithm of deaths per disaster–cumulative frequency (probability) of deaths per disaster in lower middle income countries

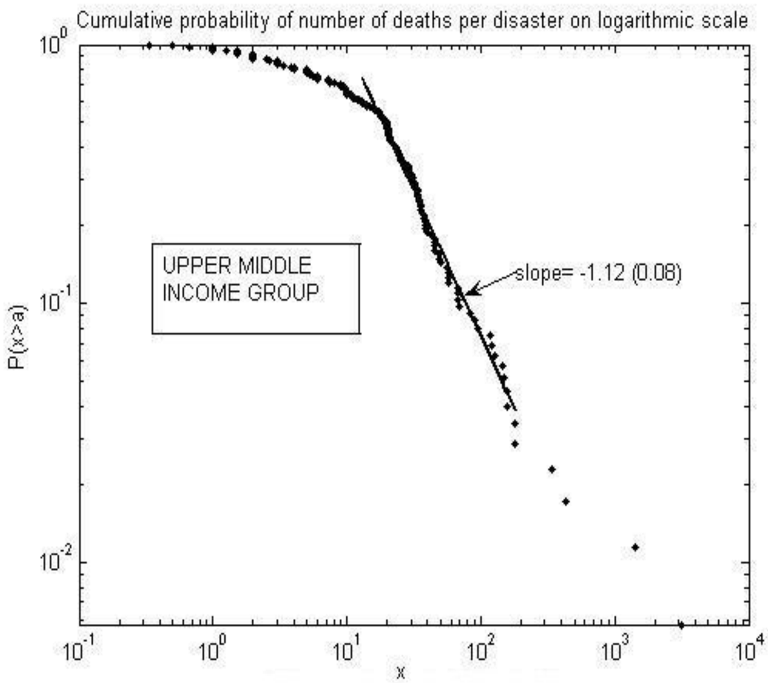

Figure A.2.6: Logarithm of deaths per disaster–cumulative frequency (probability) of deaths per disaster in upper middle income countries

Annex 3

Reliability of data on natural disasters

As discussed earlier, doubts have been raised about the reliability of numbers of natural disasters and deaths associated with them. A careful scrutiny of EM-DAT and its cross-validation from other independent sources confirms that: (i) in general, the quality of the data since the 1970s has been uniformly good; and (ii) the mortality estimates are more reliable than those of people affected and economic losses.

While some doubts will persist, we report below the results of two regressions and corresponding graphs that confirm that neither the frequency of natural disasters nor the deaths associated with them vary systematically with exposure to mass media – in particular, availability of newspapers per 1,000 people during 1997-2000.

In Table A. 3.1, we regress the residuals from our preferred specification for occurrence of natural disasters during 1980-2004 on log of newspaper circulation. As may be noted from the results, the coefficient of newspaper circulation is not significant, implying the absence of a relationship between the two variables.

Table A.3.1: Residuals of disasters and log exposure to newspapers

No. of observations = 55			
F (1, 53) = 0.85			
Prob. > F = 0.362			
Residual natural disasters during 1980-2004	**Coefficient**		**t-value**
Log newspaper circulation 1997	1.790	0.92	-
Constant	-6.191	-1.00	-

A similar finding is obtained when residuals of (log) deaths are regressed on log of newspaper circulation, as shown below in Table A.3.2. The robust regression results do not show any relationship between the two variables.

Figure A.3.1: Residual natural disasters and log newspaper circulation

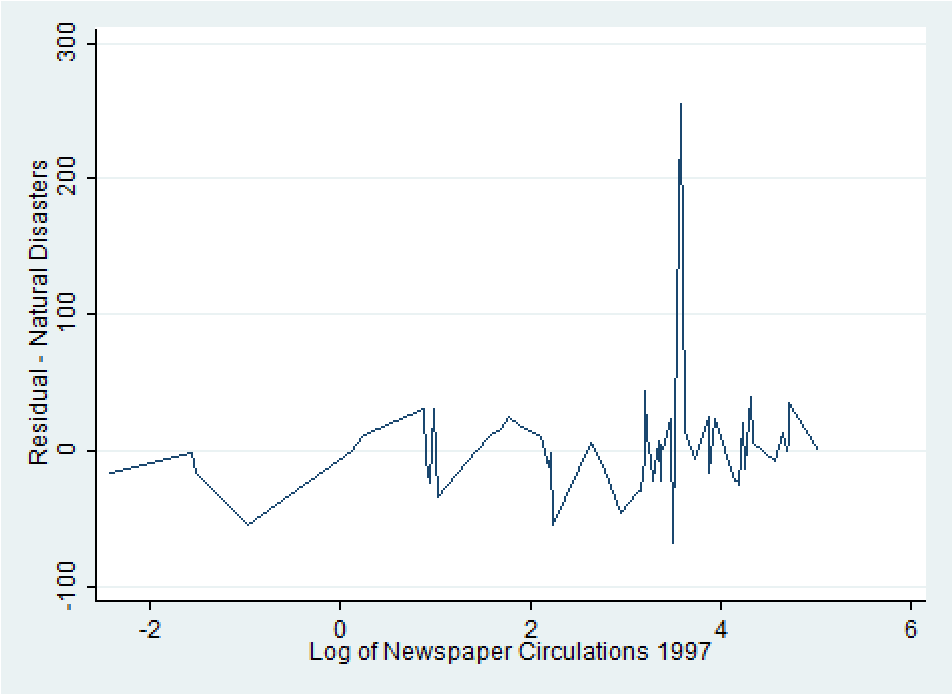

Table A.3.2. Residuals of (log) deaths and log newspaper circulation

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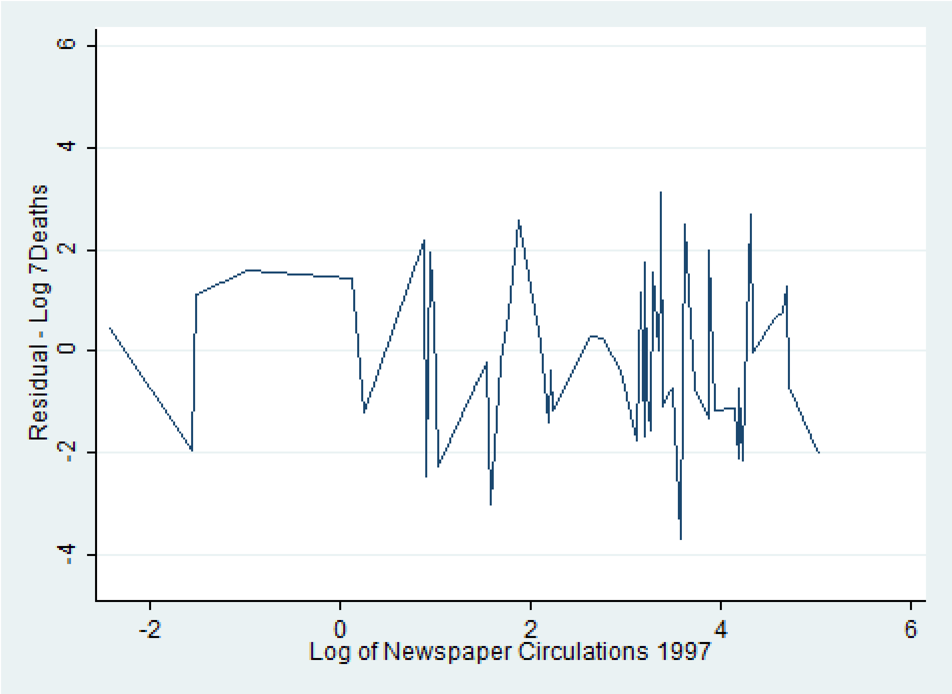
No. of observations = 55			
F (1, 53) = 0.63			
Prob. > F = 0.4298			
Residual log of deaths from disasters during 1980-2004	**Coefficient**	**t-value**	
Log newspaper circulation 1997	-0.105	-0.80	-
Constant	0.128	0.30	-

Figure A.3.2: Residuals of log deaths and log exposure to newspapers



These results are further confirmed by the two graphs. The residuals do not vary systematically with newspaper circulation.

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