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# Natural Disasters in South Asia

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# Abstract

Various types of natural disasters (e.g. extreme temperatures and floods) became more frequent in 1998-09, relative to 1985-97. However, the deadliness of earthquakes rose sharply and of extreme temperatures more than moderately while that of most others (droughts, floods, storms and wildfires) declined. 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. 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. While our evidence points to growing vulnerability to natural disasters and their grave implications for human security, a challenge for development assistance is to combine speedy relief with durable reduction in vulnerability. If our analysis has any validity, there are indeed some grounds for optimism.



Key words: Disasters, Deaths, Geography, Institutions, Reconstruction, South Asia.

JEL codes: Q54, Q57, I 12

# Natural Disasters in South Asia[1]

## 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. Climate change reinforces this concern, as its impacts are already evident, with more droughts, floods, storms and heat waves, drawing resources away from development (World Bank, 2009).

The present study seeks to build on earlier work (notably World Bank, 2006, Birkmann, 2006, Kahn, 2005, Gaiha et al. 2007, 2009, among others) by identifying the factors associated with their frequency and the resulting mortality in South Asia. Drawing together the main findings, some observations will be made from a policy perspective to focus on key elements of a disaster reduction strategy.

Natural disasters affect household welfare in three distinct ways: loss of physical integrity, assets and income. Injuries, fatalities and health epidemics compromise the quality of life.[2] 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.

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 3 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 15-fold since the 1950s.[4]

Another way of looking at damages is that they dilute hard-won development gains. For example, the Kashmir earthquake of 2005 was massive in its impact, as the damages totalled $5billion-roughly equivalent to the total 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]

[1] Raghbendra Jha, Anil Deolalikar and Cormac O’Grada and an anonymous reviewer offered several constructive suggestions. We are grateful to Raj Bhatia and Manoj Pandey for competent econometric analysis. The views expressed are those of the authors and not necessarily of the institutions to which they are affiliated.

[2] Renaud (2006) throws light on the persistent dangers and health risks of the 2004 *tsunami* in Sri Lanka, for example, through deterioration of water quality. Communities 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, for example, at least 10,000 were children. On the same proportion, as many as 50,000 children died in South Asia on 26 December, 2004 (Rohde, 3 April, 2005).

[4] Disaster costs in material losses rose from $38 billion (at 1998 values) in 1950-59 to $652 billion in 1990-99 (World Bank, 2006).

[5] For details, see Gaiha and Thapa (2006).

While we are wary of making generalizations, 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 per cent of deaths (Oxfam, 2005). Women's deaths outnumbered men's also in the 1991 Bangladesh storm and the 1993 Maharashtra (India) earthquakes (World Bank, 2006).

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.

## Issues

The present study is motivated by a broader concern for human well-being in which resilience against natural disasters is a key element. An attempt is therefore made to address the following issues:

- Have natural disasters become more frequent?
- Have the death tolls of these disasters increased in more recent years?
- How important is the role of geophysical and climate related factors in the causation of natural disasters?
- Do institutions matter? Specifically, whether there are fewer deaths in a democracy?
- Is the pay-off to disaster prevention high?

Some of these issues are addressed in Kahn (2005). The specifications and sample used, however, differ. Besides, the focus of the present analysis is on South Asia which in recent years has suffered some of the worst disasters.

## Data

These issues are addressed with the help of a data base compiled from EM-DAT, WDI, FAOSTAT, and from the website of the Kennedy School at Harvard.[8] 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

[6] Wisener (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-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.

[7] For definitions of natural hazards, see Annex 1.

[8] Other specialized sources include Alesina et al. (2003). They have constructed by far the most comprehensive indicators of ethnic, linguistic and religious fractionalization.

international assistance made.[9] These criteria ensure greater uniformity in classifying an event as a natural disaster.

As EM-DAT quality has improved in the 1970s, and with a view to focusing better on the changes in recent years, the present analysis uses the data for the period 1985-2009, with different sub-periods for specific exercises.

A recent review draws attention to the following problems/gaps in the EM-DAT:[10]

- 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 (http://www.desinventar.org) 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, p.15). Larger discrepancies in the numbers affected are due to underreporting in DesInventar, suggesting EM-DAT is more reliable. In any case, a general consensus is that mortality data are more robust across different data sets.[11]
- The economic losses comprise direct and indirect losses. Direct losses refer to the physical destruction of assets, including private dwellings, small business properties, industrial facilities, and government assets, such as infrastructure (e.g. roads, bridges, ports, telecommunications) and public facilities (e.g. hospitals, schools). 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.[12] Although there has been a steady increase in economic losses, the available estimates are incomplete and unreliable. These are compiled from a variety of sources, mainly 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 reported in EM-DAT are not analysed.

## Methodology

First, a broad brush treatment of occurrence of natural disasters, and deaths per disaster and per million of population, over 4 year intervals, covering the period 1985-2009, is given. Next, a description of the frequency of different types of natural disasters and their deadliness is given. These cross-tabulations are supplemented by graphical illustrations at the sub-

[9] 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.

[10] For details, see Brooks and Adger (2005).

[11] For further validation, see Gaiha et al. (2007).

[12] A difficulty is that conversion of changes in capital stock to income flows should take into account pre-disaster capacity utilization, depreciation of capital stock and efficiency of replacement assets (Andersen, 2005).

regional (i.e. South Asia) level. A classification of natural disasters into hydro-meteorological and geophysical is carried out, and their frequencies and deadliness are examined. This is followed by an econometric analysis of the occurrence and deadliness of natural disasters over the period 1985-2009. The focus here is on the geography, institutions and affluence of a country.

## Model Specifications

Following Kahn (2005), we will first estimate a logit model of why some countries are more vulnerable to natural disasters given their geographic and institutional characteristics, and level of income. A negative binomial regression will then be carried out to assess the likely count of natural disasters in the sample countries.[13] This is followed by a (robust) regression of deaths due to natural disasters.

A brief exposition of each specification is given below.

### *(a) Logit*

Suppose y refers to a natural disaster (1 if a disaster occurred and 0 otherwise). Our interest is in the probability of a disaster occurring given certain country-specific characteristics and time (year).

Consider a class of binary response models of the form

$$P(y = 1 \mid \mathbf{x}) = G(\beta_0 + \beta_1 x_1 + ...... + \beta_k x_k) = G(\beta_0 + \mathbf{x\beta}) ........(1)$$

where G is a function taking on values strictly between 0 and 1: 0<G(z)<1, for all real numbers z. This ensures that the estimated probabilities are strictly between 0 and 1.In the logit model, G is the logistic function

$$G(z) = \exp(z) / \left[1 + \exp(z)\right] = \Lambda(z) ..........(2)$$

### *(b) Negative Binomial*

Consider disasters as a non-negative count variable that takes integer values (0,1, 2, 3…). Our interest lies in cases where y takes on relatively few values, including zero. A nominal distribution for count data could be the Poisson distribution. As we are interested in the effects of explanatory variables on y, we consider the Poisson distribution conditional on **x**. As this distribution is entirely determined by its mean, we only need to specify E(y|**x**). A compact notation then is

$$E(y|\mathbf{x})=\exp(\mathbf{x\beta}) \quad ……….(3)$$

However, a restrictive assumption of the Poisson distribution is that, in principle, the variance is equal to the mean

$$Var(y|\mathbf{x})= E(y|\mathbf{x})……..(4).$$

In case the Poisson specification is not validated, we use a negative binomial regression. The Poisson is a special case of the negative binomial.

[13] Somewhat surprisingly, in an otherwise meticulous and detailed analysis, Kahn (2005) does not investigate this aspect.

*(c) Robust Regression.*

As there were a large number of cases in which disasters did not result in any deaths, a tobit specification would have been appropriate. However, taking into account missing observations for some of the explanatory variables, the cases without any deaths were 9 in a total sample of 119 observations. So we first transform deaths into log (1+deaths). This dependent variable is then regressed on country-specific variables some of which are time invariant while others vary over the sample period.[14] This follows the procedure used by Toya and Skidmore (2007).[15]

## Cross-Tabulations

Table 1 reveals a striking pattern of occurrence of natural disasters in South Asia during the last 9 years. Altogether there were 84 disasters. These included 69 floods, 8 earthquakes, 4 spells of extreme temperature and 3 storms. In fact, 64 of the 69 floods occurred in India; out of the 10 earthquakes, 3 occurred in India; and all 4 episodes of extreme temperature also occurred in India. Worse, in 2004, India experienced 6 floods, followed by 17 floods each in 2005 and 2006. Bangladesh — one of the poorest countries in this sub-region — fared slightly better, with 2 storms and 2 floods in 2007.

**Table 1**
**Frequency of Natural Disasters in South Asia, 2000-09**

| Year | Type Of Disaster | Country | Frequency |
|---|---|---|---|
| 2000 | Floods | India | 6 |
| 2001 | Earthquake | India | 1 |
| 2002 | Extreme Temperature,<br>Earthquake | India,<br>Afghanistan | 2,<br>3 |
| 2003 | Extreme Temperature | India | 2 |
| 2004 | Earthquake,<br>Earthquake,<br>Floods,<br>Floods | Sri Lanka,<br>India,<br>India,<br>Bangladesh | 1,<br>1,<br>6,<br>3 |
| 2005 | Earthquake,<br>Earthquake,<br>Floods | Pakistan,<br>India,<br>India | 1,<br>1,<br>17 |
| 2006 | Floods | India | 17 |
| 2007 | Storm,<br>Floods,<br>Floods | Bangladesh,<br>Bangladesh,<br>India | 2,<br>2,<br>16 |
| 2008 | Storm | Afghanistan | 1 |
| 2009 | Floods | India | 2 |

Source: EM-DAT

However, greater frequency of natural disasters does not necessarily imply greater severity or fatalities. Table 2 therefore supplements this analysis with a list of the deadliest natural disasters over a longer period, 1990-2009.

[14] For an exposition of regression models for limited dependent variables, see Long (1997). Another useful reference is Wooldridge (2006).

**Table 2**
**Deadliness of Selected Natural Disasters in South Asia, 1990-2009**

| Type | Country | Year | Deaths (Number of Persons) |
|---|---|---|---|
| Storm | Bangladesh | 1991 | 138,987 |
| Earthquake (seismic activity) | Pakistan,<br>Sri Lanka,<br>India,<br>Afghanistan | 2005,<br>2004,<br>2004,<br>1998 | 73,338,<br>35,399,<br>16389,<br>7,023 |
| Extreme Temperature | India | 1998,<br>2002,<br>2003 | 2641,<br>1930,<br>1610 |
| Floods | India | 1998,<br>2005,<br>2007,<br>2008,<br>2009 | 2,131,<br>2129,<br>2051,<br>1590,<br>1,197 |

Source: EM-DAT

Storms were the deadliest, followed by earthquakes, extreme temperature and then floods. Also, their deadliness varies over time (e.g. extreme temperature and floods) in the same country.

Graphical illustrations for aggregate disasters and deaths are given for 4-year intervals in Fig: 1-3, followed by others in which disasters are disaggregated by type and deaths due to them in two longer intervals in Fig. 4–6. So, emphasising that these are averages for 12- and 11-year intervals, a general inference about a (trend) decline in the deadliness of natural disasters is subject to further validation.[16] Annual frequency of different disasters and deaths are, however, suggestive.[17]

To avoid repetition, brief comments on the graphs are made. Let us first consider Fig; 1-3 for (aggregate) disasters and deaths due to them. Fig. 1 illustrates a rise in the frequency of disasters over the period 1985-2009. Except for unusually high deaths in 1990-94, largely due to a devastating storm in Bangladesh in 1991, the number of deaths also rose over the remaining period. A similar pattern is revealed by Fig: 3 in which deaths per disaster are plotted over 4-year intervals. Annual disasters rose from 23 during 1985-97 to over 35 during 1998-2009, while annual deaths rose from 16577 to 17888.

In Table 3, an overview of frequency of disasters by type and by number of deaths is given for two (slightly unequal) intervals: 1985-97 and 1998-2009. Graphical illustrations are given in Fig: 4-6. With the exception of insect infestations whose frequency fell, all other types of disasters became more frequent (e.g. extreme temperatures and floods). Their frequencies also rose in more populous countries, as illustrated by the frequency of disasters per million of population. If we go by total deaths, a mixed pattern is revealed. Total deaths due to droughts, floods, storms and wildfires declined while those due to earthquakes and extreme temperatures rose. Deaths per million of population, however, rose for earthquakes and extreme temperatures, and declined for droughts and storms. However, the deadliness of disasters rose sharply for earthquakes and more than moderately for extreme temperatures but declined for most others (droughts, floods, storms and wildfires).

[16] A positive time trend is, however, corroborated in Tables 6 and 7.
[17] We are grateful to an anonymous reviewer for this suggestion.

**Fig.1: Total Number of Natural Disasters in South Asia**

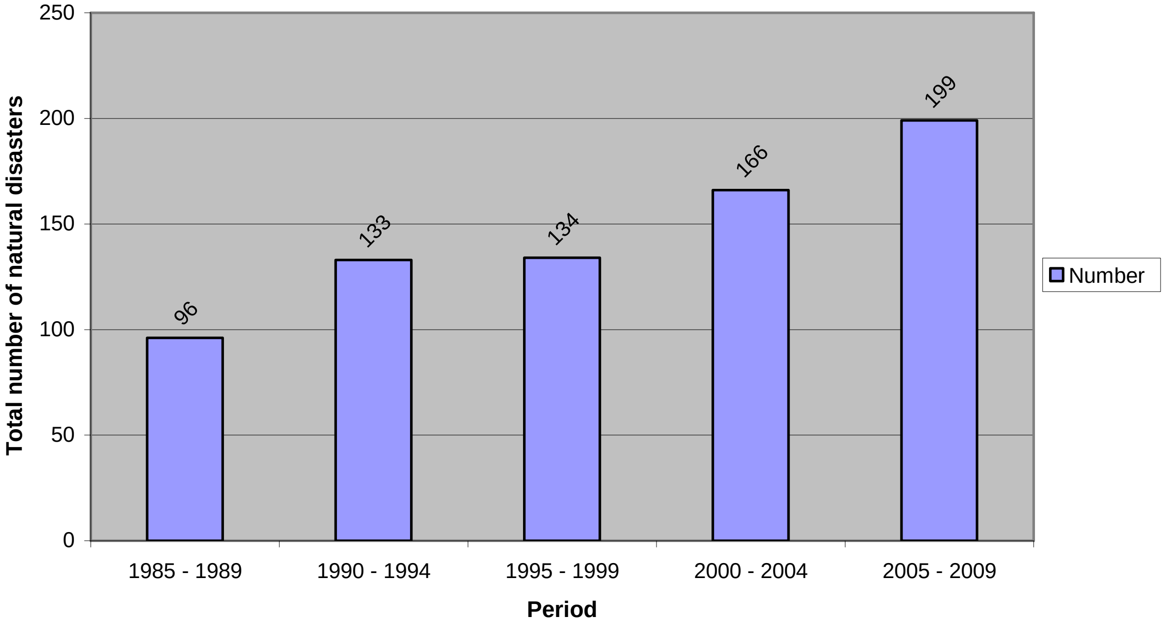



**Fig.2: Total Number of Deaths Due to Natural Disasters in South Asia**

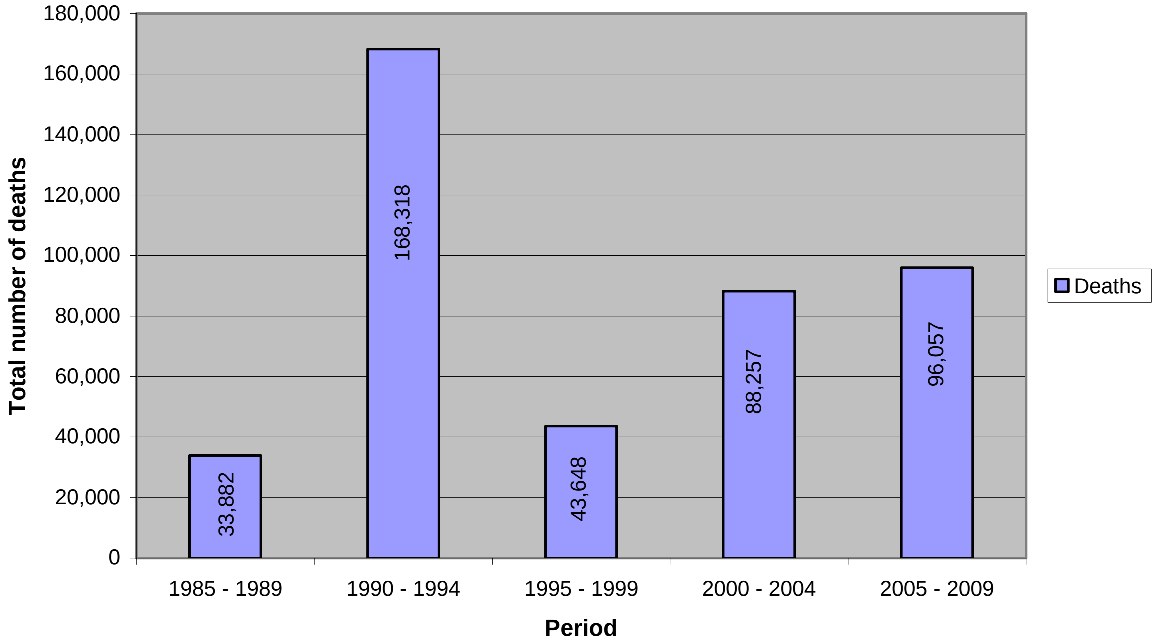
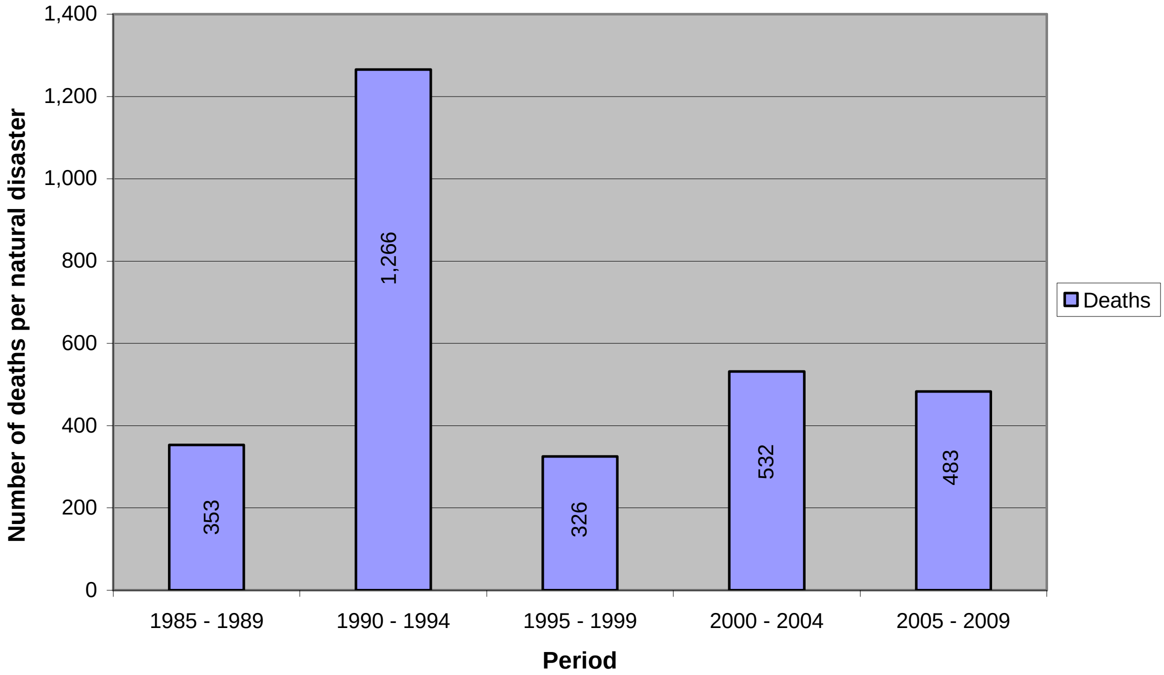


**Fig.3: Deaths Per Natural Disaster in South Asia**




We note from Table 4 that Afghanistan, India and Pakistan recorded significantly higher frequencies of disasters while Nepal recorded a slightly lower frequency in the period 1998-2009 relative to 1985-1997. Deadliness of disasters (deaths per disaster) also reveals a mixed pattern, with greater deadliness in Afghanistan, Bhutan, India, Pakistan and Sri Lanka. The ranges of deaths expanded in Afghanistan, India, Pakistan and Sri Lanka while it contracted in Nepal.

India accounted for a large share of natural disasters (about 38 per cent) in 1985-97, followed by Bangladesh and then Pakistan. In the next period (1998-09), while India maintained its share, that of Bangladesh declined and Pakistan's rose. The distribution of deaths was, however, strikingly different in 1985-97, with a large majority of deaths in Bangladesh (about 78 per cent), followed by India. The change in 1998-09 was striking too. India and Pakistan accounted for a large majority of deaths (about 72 per cent), followed by a moderate share of Sri Lanka's.[18]

[18] Details will be furnished on request

**Table 3**
**Different Type of Natural Disasters and their Death Tolls**

| Disaster Type | Frequency | | Deaths | | Deaths per Million | | Deaths per Disaster | | Disasters per Million | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1985-97(%) | 1998-2009(%) | 1985-97(%) | 1998-2009(%) | 1985-97 | 1998-2009 | 1985-97 | 1998-2009 | 1985-97 | 1998-2009 |
| Complex Disaster | 0 (0.00) | 2 (0.47) | 0 (0.00) | 0 (0.00) | 0.00 | 0.00 | 0 | 0 | 0.000 | 0.001 |
| Drought | 6 (1.98) | 9 (2.12) | 300 (0.14) | 200 (0.09) | 0.22 | 0.15 | 50 | 22 | 0.004 | 0.007 |
| Earthquake | 27 (8.91) | 35 (8.24) | 13166 (6.11) | 155233 (72.32) | 9.77 | 115.21 | 488 | 4435 | 0.020 | 0.026 |
| Extreme temperature | 28 (9.24) | 41 (9.65) | 4011 (1.86) | 10021 (4.67) | 2.98 | 7.44 | 143 | 244 | 0.021 | 0.030 |
| Flood | 141 (46.53) | 235 (55.29) | 32610 (15.13) | 26111 (12.16) | 24.20 | 19.38 | 231 | 111 | 0.105 | 0.174 |
| Insect infestation | 3 (0.99) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0.00 | 0.00 | 0 | 0 | 0.002 | 0.000 |
| Storm | 97 (32.01) | 99 (23.29) | 165360 (76.73) | 23056 (10.74) | 122.73 | 17.11 | 1705 | 233 | 0.072 | 0.073 |
| Wildfire | 1 (0.33) | 4 (0.94) | 56 (0.03) | 38 (0.02) | 0.04 | 0.03 | 56 | 10 | 0.001 | 0.003 |
| Total | 303 (100.00) | 425 (100.00) | 215503 (100.00) | 214659 (100.00) | 159.94 | 159.32 | 711 | 505 | 0.225 | 0.315 |

Note: Figures in parenthesis are percentages along with numbers.

**Table 4**
**Natural Disasters and Deaths Country-Wise, 1985-2009**

| Year and Country | N (Disasters) | Mean (death) | Standard deviation (death) | Minimum (death) | Maximum (death) |
|---|---|---|---|---|---|
| 1985-1997 | | | | | |
| Afghanistan | 21 | 120 | 188 | 0 | 728 |
| Bangladesh | 91 | 1834 | 14612 | 0 | 138866 |
| Bhutan | 2 | 20 | 4 | 17 | 22 |
| India | 114 | 326 | 967 | 0 | 9748 |
| Maldives | 2 | 0 | 0 | 0 | 0 |
| Nepal | 21 | 152 | 298 | 0 | 1048 |
| Pakistan | 34 | 153 | 275 | 0 | 1334 |
| Sri Lanka | 18 | 26 | 76 | 0 | 325 |
| Total | 303 | 711 | 8034 | 0 | 138866 |
| 1998-2009 | | | | | |
| Afghanistan | 69 | 167 | 648 | 0 | 4700 |
| Bangladesh | 91 | 121 | 475 | 0 | 4234 |
| Bhutan | 4 | 53 | 98 | 0 | 200 |
| India | 161 | 474 | 2182 | 0 | 20005 |
| Maldives | 2 | 51 | 72 | 0 | 102 |
| Nepal | 17 | 95 | 87 | 0 | 260 |
| Pakistan | 59 | 1324 | 9538 | 0 | 73338 |
| Sri Lanka | 22 | 1626 | 7544 | 0 | 35399 |
| Total | 425 | 505 | 4171 | 0 | 73338 |

Source: EM-DAT

Following Gaiha et al. (2007), and in response to the concerns raised in the *World Development Report 2010* (World Bank, 2009) about a rise in weather-related disasters, we have classified the natural disasters into hydro-meteorological and geo-physical. An earlier analysis for all developing countries confirmed that their frequencies and impacts differ. We have carried out this disaggregation for South Asian countries and the results are given in Table 5. Details of this classification are given in the Annex.

Not only were hydro-meteorological disasters more frequent than geophysical ones in both intervals but their frequency also rose very sharply. However, total deaths due to hydro-meteorological disasters plummeted, as also their share in total deaths. By contrast, deaths due to geo-physical disasters shot up, as also their share in total deaths.

Deaths per hydro-meteorological disaster also registered a sharp fall while those due to geo-physical ones rose. That most of these deaths occurred in more populous countries is also corroborated while those associated with hydro-meteorological ones were fewer per million of population. So, while the evidence supports more frequent hydro-meteorological disasters, their deadliness declined markedly.

**Table 5**
**Hydro-Meteorological and Geophysical Disasters**

Different Type of Natural Disasters and their Death tolls

| Disaster Type | Frequency | | Deaths | | Deaths per Million | | Deaths per Disaster | | Disasters per Million | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1985-97 (%) | 1998-2009 (%) | 1985-97 (%) | 1998-2009 (%) | 1985-97 | 1998-2009 | 1985-97 | 1998-2009 | 1985-97 | 1998-2009 |
| Hydro-meteorological | 276 (91.09) | 388 (91.29) | 202337 (93.89) | 59426 (27.68) | 150.17 | 44.11 | 733 | 153 | 0.205 | 0.288 |
| Geophysical | 27 (8.91) | 37 (8.71) | 13166 (6.11) | 155233 (72.32) | 9.77 | 115.21 | 488 | 4195 | 0.020 | 0.027 |
| Total | 303 (100.00) | 425 (100.00) | 215503 (100.00) | 214659 (100.00) | 159.94 | 159.32 | 711 | 505 | 0.225 | 0.315 |

Source: EM-DAT

**Fig.4: Total Number of Natural Disasters by Type in South Asia**

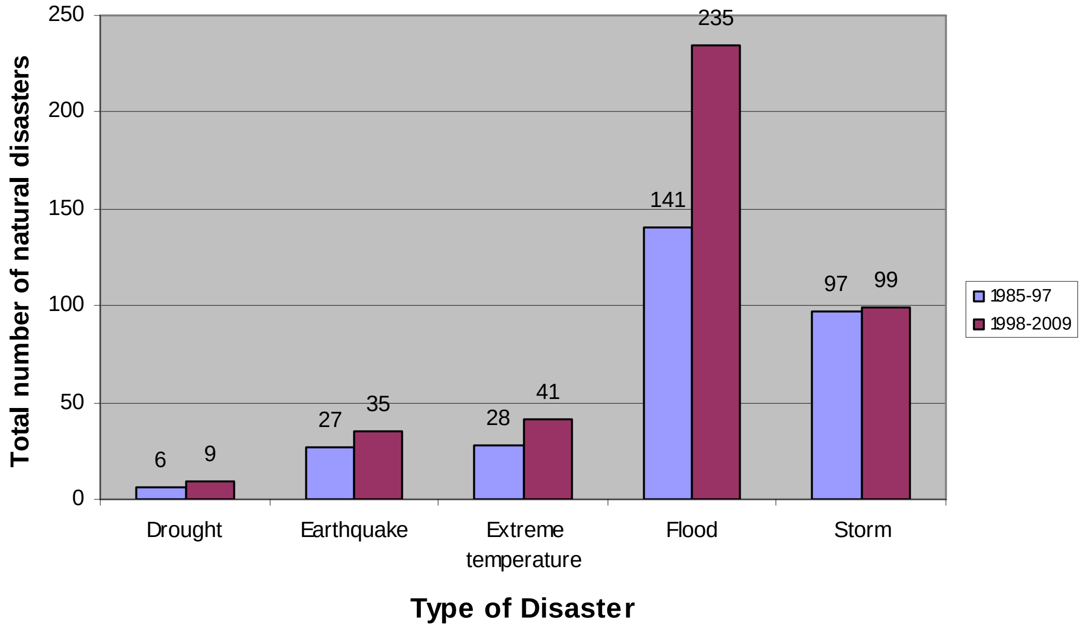



**Fig.5: Total Number of deaths Due to Natural Disasters by Type in South Asia**

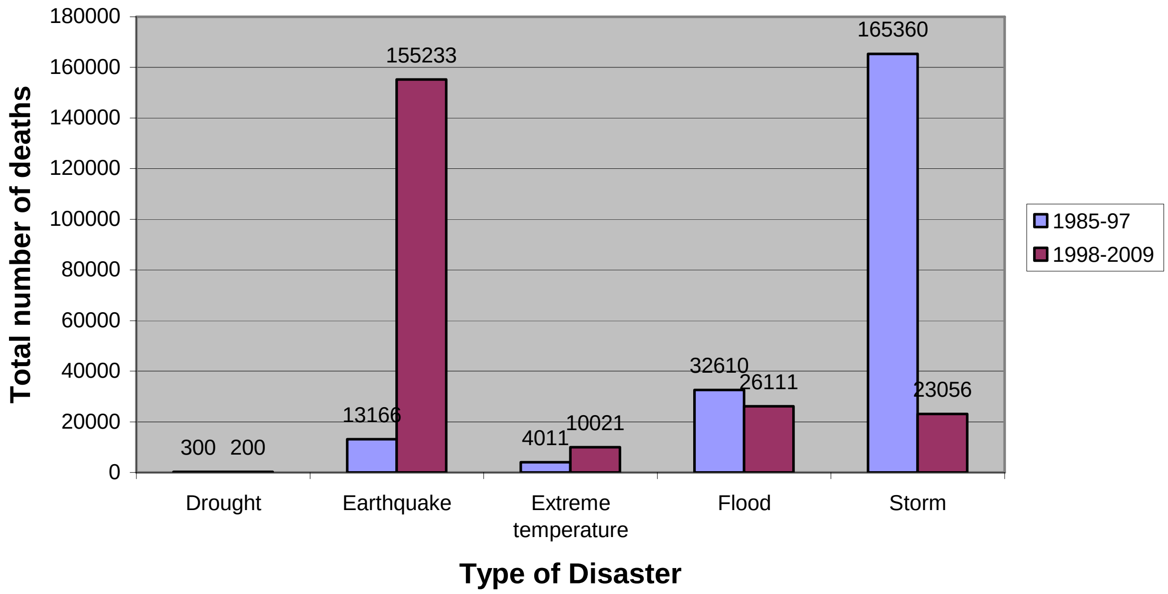
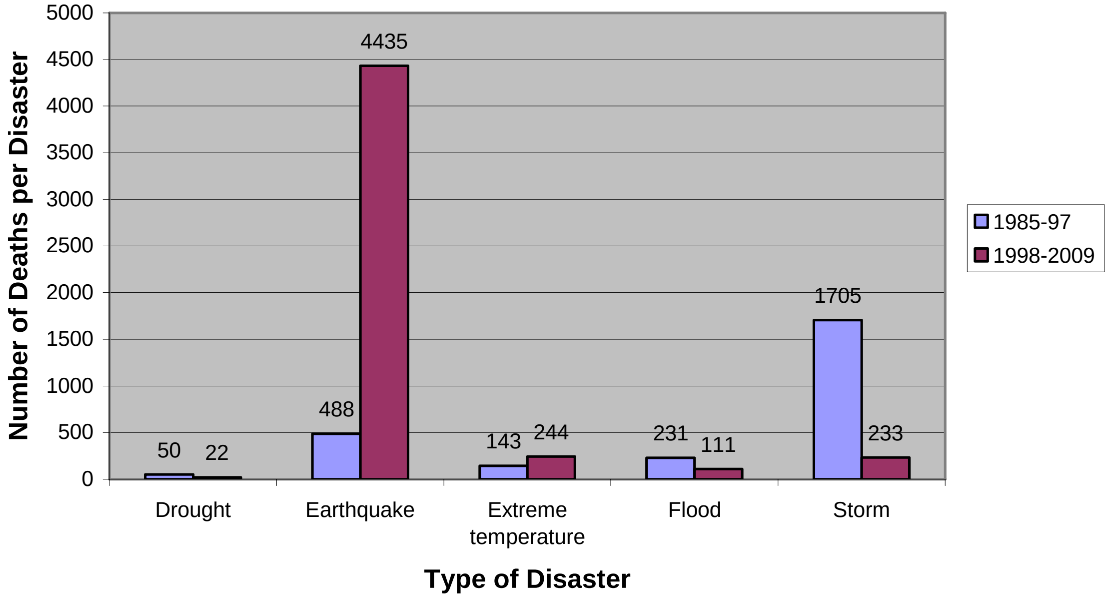


**Fig. 6: Deaths Per Disaster by Type in South Asia**




## Econometric Results

For a focused discussion of our results, we have summarised the main findings under a few themes that have figured prominently in the recent literature.[19]

**Table 6**
**Logit Analysis of Whether Natural Disasters Occurred?**

| | |
|---|---|
| Dependent variable | Disaster Occurrence |
| Estimation method | Logit |
| Explanatory variables | Coeff(z-values) |
| Elevation | -.011***(-3.74) |
| Distance | 0.019**(2.34) |
| GDP Per Capita | 0.012***(2.80) |
| Square of GDP Per Capita | -1.50e-06***(-2.80) |
| Urbanisation | -0.931***(-3.29) |
| Log area | 1.068**(2.05) |
| Year | 0.155**(2.47) |
| Constant | 2.575(0.50) |
| Number of observations | 144 |
| Wald chi2 | 136.37*** |
| Pseudo R2 | 0.6470 |
| Log pseudolikelihood | -23.464 |

*** Significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

[19] Note that, except for the analysis based on country-fixed effects, Afghanistan and Maldives were excluded for lack of data on GDP.

**Table 7**
**Negative Binomial Regression Analysis of Count of Natural Disasters (1)**

| | |
|---|---|
| Dependent variable | Count of Natural Disasters |
| Estimation method | Negative Binomial Regression |
| Explanatory variables | Coeff(z-values) |
| Years | 0.030***(4.55) |
| Afghanistan | 0.845***(3.85) |
| Bangladesh | 1.573***(9.16) |
| Bhutan | -1.851***(-4.13) |
| India | 1.976***(11.79) |
| Maldives | -2.256***(-4.66) |
| Pakistan | 0.886***(4.84) |
| Sri Lanka | 0.047(0.26) |
| Constant | 0.005(0.02) |
| lnalpha | -3.089 |
| alpha | 0.046 |
| Number of observations | 200 |
| Wald chi2 | 452.15*** |
| Log pseudolikelihood | -337.7754 |

*** Significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

## Growth, Disasters and Deaths

Various contributions (e.g. Kahn, 2005, Toya and Skidmore, 2007) have confirmed a robust negative relationship between level of (per capita) income and deaths from natural disasters, supporting the proposition that higher incomes allow countries to mitigate disaster risk. Kellenberg and Mobarak (2008), however, point to a non-linear relationship where the risks increase with income before they decrease. They show that disaster risk associated with flooding, landslides and windstorms increase with income up to certain (specific) levels and decrease thereafter. Such non-linear impacts are absent for other disasters such as extreme temperature events and earthquakes where the links between behavioural choices and exposure to risk are not so strong.[20] A particularly interesting result is that urbanisation has a positive coefficient while its interaction with GDP per capita has a negative coefficient for deaths from some disasters (e.g. earthquakes). This leads to the observation that low income but highly urbanised countries see higher levels of deaths from earthquakes than similarly urbanised high income countries. This is consistent with the view that building codes are more stringent and structures are of better quality in developed countries.

[20] A basic premise is that for risk averse individuals, whose marginal utility of income varies with the level of income, the marginal benefit of rising income is greater than the marginal damage associated with increased natural disaster risk. Thus disaster risk will rise along with income in the lower part of the income distribution. Above a certain threshold, the same individual may value the latter more, and disaster risk may fall with higher income (Kellenberg and Mobarak, 2008).

**Table 8**
**Negative Binomial Regression Analysis of Count of Natural Disasters (2)**

| Dependent variable | Number of Disasters | |
|---|---|---|
| Estimation method | Negative Binomial Regression | |
| Explanatory variables | Coeff(z-values) | Marginal effects(z-values) |
| Elevation | -0.0020***(-12.28) | -0.005***(-12.08) |
| Distance | 0.0046***(7.42) | 0.012***(7.19) |
| Log GDP | -4.9168**(-2.19) | -13.151**(-2.18) |
| Log of GDP ×Log of GDP | 0.3317**(2.1) | 0.887**(2.09) |
| Latitude | 0.0002(0.02) | 0.001(0.02) |
| Constant | 19.2978**(2.43) | |
| lnalpha | -1.5560 | |
| alpha | 0.2110 | |
| Number of observations | 144 | - |
| Wald chi2 | 218.57*** | - |
| Log pseudolikelihood | -296.7736 | - |
| Predicted number of events | - | 2.6748 |

*** Significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

**Table 9**
**Robust Regression Estimation of Deaths from Disasters**

| Dependent variable | Log of number of deaths |
|---|---|
| Estimation method | Robust Regression |
| Explanatory variables | Coeff.(t-values) |
| Log GDP | -17.447***(-2.65) |
| Log GDP x Log GDP | 1.139**(2.48) |
| Elevation | 0.001***(5.80) |
| Urbanisation | 0.239***(6.62) |
| Number Disasters | 0.367***(3.02) |
| Democracy | 0.610***(6.99) |
| Disasters x Democracy | -0.039***(-2.85) |
| Constant | 61.270***(2.67) |
| Number of observations | 119 |
| F( 7, 111) | 30.98*** |

*** Significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

As we have computed three different sets of results comprising (i) the probability of occurrence of a natural disaster (Table 6), (ii) likely number of natural disasters (Tables 7 and 8), and (iii) deaths associated with them (Table 9), these are considered in turn.

Both GDP per capita and its square influence the probability of occurrence of a natural disaster. While higher incomes have a positive effect, its square has a negative effect. Their sizes, however, are negligible. Controlling for these and other effects, the higher the share of urban population, the lower is the probability of a natural disaster. The fact that 'year' has a significant positive coefficient, a trend increase in the occurrence of disasters is confirmed.[21]

The negative binomial regression results in Table 7 focus on the likely number of natural disasters, taking into account country-specific effects as well as the effect of time (measured in years)[22]. The significant positive coefficient of time confirms that the frequency of disasters has risen over the period analysed.[23] As far as the country-specific effects are concerned- these supposedly capture both observable and unobservable differences relative to the omitted case of Nepal- Afghanistan, Bangladesh, India and Maldives are likely to have more disasters while Bhutan and Maldives are likely to have fewer disasters.

In Table 8, using the count of disasters as the dependent variable, we focus on the observable differences, based on a negative binomial regression.[24] While log of GDP lowers the number of disasters, its square partly weakens this effect.[25] So the higher the GDP per capita, the lower is likely number of disasters but this relationship weakens at higher levels of GDP. What is also interesting to note is that the magnitudes are large, as shown by the marginal effects.

In the analysis of deaths (Table 9), we have used the sub-sample of data where disasters occurred. The dependent variable is log (1+deaths) to allow for no deaths during a disaster.

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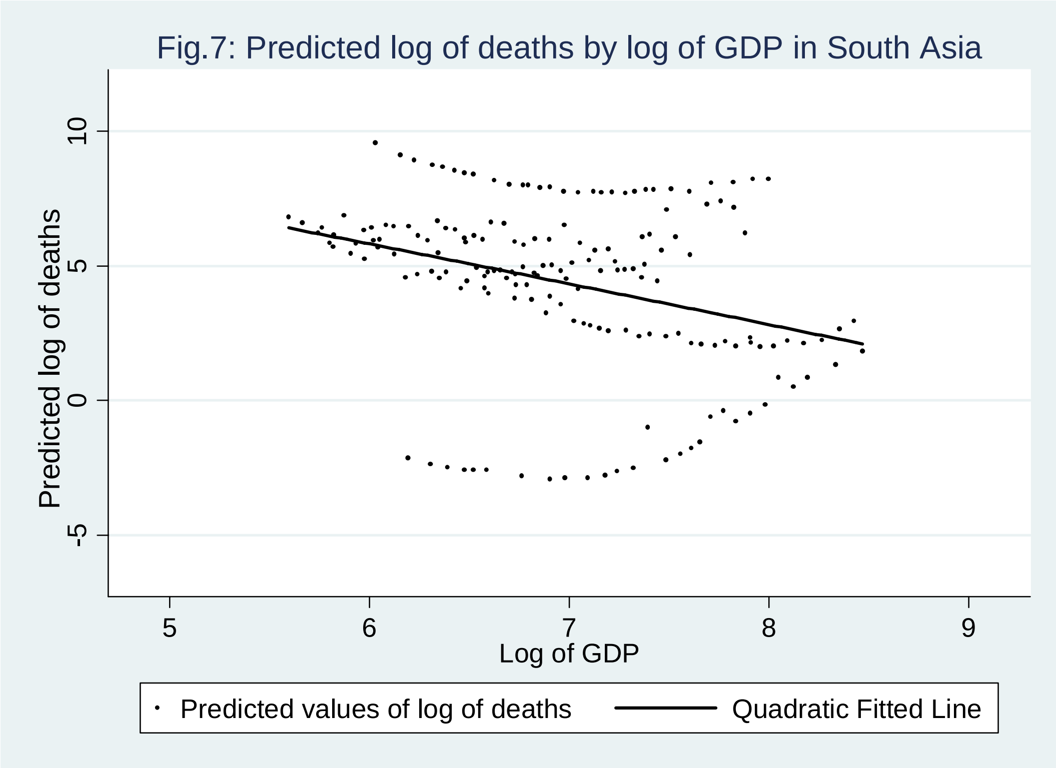
[21] As suggested by the reviewer, year dummies were used in an alternative specification, replacing 'year=1, 2, .26'. However, several dummies were deleted by STATA. So we do not comment on these results. Details will be furnished on request.

[22] We first experimented with a Poisson regression but it was rejected by the goodness-of-fit test.

[23] With year dummies, all country effects (except for Bhutan) were positive and significant. All year dummies for years 1990-93 and 1996-2008 were significant and positive. Details will be furnished on request.

[24] An alternative Poisson regression was tried but it was rejected by the goodness-of-fit test. Also, 'year' as an explanatory variable did not yield significant results.

[25] As log of GDP per capita and GDP per capita are monotonically related, for ease of exposition, the former is sometimes referred to as GDP per capita. A similar remark applies to the square of log GDP per capita.




In line with earlier studies, the excess deaths decrease with higher levels of GDP but with a diminishing rate given the positive coefficient of square of GDP. However, as the effect of GDP is larger than that of its square, it follows that economic growth reduces the severity of the impact of natural disasters. The effects are large-especially of GDP per capita. The elasticity of deaths to GDP is -1.26. This is graphically illustrated in Fig. 7. Urbanisation, on the other hand, is associated with higher fatalities (the elasticity being 5.39). (In fact, a similar result is obtained using population density)[26].

**Do Geography and Institutions Matter?**

Kahn (2005) shows that a nation's geography is a key determinant of its probability of experiencing a disaster. There are large inter-regional differences in the propensity to experience a disaster. In particular, Asia is most disaster-prone. Larger nations, the more elevated ones, and those farther from the equator are more likely to experience shocks.

Controlling for the number of disasters, geography also matters in determining deaths. Asia, for example, experiences more deaths than Africa. The nation's elevation has a negative effect on deaths-specifically from windstorms-whereas distance from the equator raises deaths from earthquakes.

Various institutional measures are considered, including a nation's democracy and the World Bank indicators of governance (e.g. voice and accountability, rule of law). Democracies experience fewer deaths. However, ethnic fragmentation as a barrier to social capital either has no effect on deaths or reduces them.

[26] Details will be furnished on request.

Our analysis further corroborates the role of geography but with some differences. While elevation lowers the risk of a natural disaster, distance from the sea/river coast increases it. Also, the larger the area of a country, the higher is the probability of a natural disaster. The marginal effects, however, are negligible.[27]

Geography also influences the (likely) number of disasters, as shown in Table 8. While elevation lowers the number, distance from the sea/river coast increases it. The values of their marginal effects are non-negligible. Latitude, however, does not have a significant effect.

Excess deaths are higher at higher elevation, and the effect is non-negligible, as shown in Table 9.

Let us now turn to the effects of number of disasters and the Polity index of democracy. The fact that the sample is confined to 6 Asian countries does constrain the analysis somewhat as there are a few extreme cases.[28] Nevertheless, some insights are obtained. While the number of disasters has a significant positive effect, its interaction with the index of democracy has a negative effect. Democracy, on the other hand, has a significant positive effect. These results imply that the greater the frequency of disasters in a democracy, the lower are the deaths.[29] The elasticity of deaths to disasters is still moderately high (0.26). Whether the negative effect of interaction of democracy with number of disasters implies learning on the part of a democratic government to avert severity of disasters when their numbers are higher requires a more detailed investigation.. Presumably, the responsiveness of democracies is contingent on how frequent and severe natural disasters are.

In this context, the Cole et al.(2009) analysis of response to droughts in India is insightful. His results confirm 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). But voters also reward politicians for responding well to climatic events but not sufficiently to compensate them for their ‘bad luck’. There is thus a 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. (2009) 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.

## Concluding Observations

A summary of the main findings is given below from a broad policy perspective.

With the exception of insect infestations whose frequency fell, all other types of disasters became more frequent (e.g. extreme temperatures and floods) in 1998–09, relative to 1985–97. Their frequencies also rose in more populous countries, as illustrated by the frequency of

[27] Details are omitted.
[28] Details will be furnished on request.
[29] Given that the sample does not allow much variation in the index of democracy (Polity 2), and India recorded a large number of fatalities-one of the more democratic countries in the region-the implausible positive effect of democracy on excess deaths (the elasticity being 0.42) is likely to change in a larger sample.

disasters per million of population. If we go by total deaths, a mixed pattern is revealed. Total deaths due to droughts, floods, storms and wildfires declined while those due to earthquakes and extreme temperatures rose. Deaths per million of population, however, rose for earthquakes and extreme temperatures, and declined for droughts and storms. However, the deadliness of disasters rose sharply for earthquakes and more than moderately for extreme temperatures but declined for most others (droughts, floods, storms and wildfires).

Not only were hydro-meteorological disasters more frequent than geophysical ones in both intervals but their frequency also rose very sharply. However, total deaths due to hydro-meteorological disasters plummeted, as also their share in total deaths. By contrast, deaths due to geo-physical disasters shot up, as also their share in total deaths.

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).

Within developing countries, the poor often bear the brunt of disasters as (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) finally, not only do the poor lose assets but they also lack access to risk- sharing mechanisms such as insurance.

Risk mitigation through adaptation of physical environment includes land use planning (e.g. avoiding construction on seismic fault lines, vulnerable coastal regions, and ensuring that buildings are resistant to hurricanes and earthquakes); prevention of soil erosion; 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.

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.

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 because of the segmented and shallow insurance markets. The Samaritan's dilemma, on the other hand, may arise from (i) households and firms under-investing in insurance and undertaking adaptive measures on the presumption that governments would come to their rescue; (ii) governments may also underinvest in the hope that foreign donors would bail them out; and (iii) rich countries may find it difficult to scale down their *ex post* assistance in the absence of significant *ex ante* protective measures by governments in developing countries.

New financial instruments (e.g. catastrophic bonds, swaps, and weather derivatives) have been devised to deal with disaster risk but with little impact.

Some observations to address donor 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). Pacific-rim states, for example, will continue to be hit by earthquakes and floods, while low-lying coastal areas in the Bay of Bengal will continue to get flooded. Given climate change projections, vulnerability to some of these hazards may rise (World Bank, 2009).
- 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 designed to make a chaotic situation manageable. In such a process, people and institutions that might help rebuild affected communities are left out. What makes matters worse is that little attention is paid to how the next disaster could be averted. Neither donor funding is geared to that goal nor developing countries, as soon after the emergency is over other development priorities take over.
- Need for 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 must ensure provision of safe water and sanitation), and maintenance of infrastructure (World Bank, 2009).
- Evidence has accumulated pointing to coordination failure turning natural catastrophes into disasters. 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. 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 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.

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

# Annex

**Table A.1**
**Classification 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, ground water 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 conflagaration 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 icecap 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.2**
**List of Variables Used in Regression Analysis**

| Variables | Description |
|---|---|
| Elevation | Mean Elevation (metres above sea level) |
| Area | ($km^2$) |
| Distance | Mean Distance to Nearest Coastline (km) |
| GDP | GDP Per Capita (PPP dollars) Source: WDI 2009 |
| Square of GDP | Square of GDP |
| Urbanisation | Share of Urban Population, 1995-2000 (WDI, 2009) |
| Latitude | Latitude of Country Centroid |
| Number of Disasters | Number of Natural Disasters |
| Democracy | Polity 2 Scores (Mean 1995-2004), ranging from -10 to 10. |
| Disasters x Democracy | Interaction of Number of Natural Disasters and Polity 2 Scores (Mean 1995-2004), ranging from -10 to 10. |
| Log GDP | Log of GDP |
| Log GDP x Log GDP | Square of Log of GDP |
| Log area | Log of area |
| Year | Year 1985=1, Year 1986=2,…….and year 2009=26 |

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