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On Devastating Droughts

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Abstract

Droughts often turn into famines. Loss of agricultural output and food shortage are, however, not the only consequences. There are often large second round effects some of which persist over time. By the time these effects play out, the overall economic loss is substantially greater than the first round loss of income. Hardships manifest in malnutrition, poverty, disinvestment in human capital (e.g. withdrawal of children from school), liquidation of assets (e.g. sale of livestock) with impairment of future economic prospects, and, in extreme cases, mortality, given the incompleteness of credit and insurance markets.

Our analysis with cross-country data builds on the extant literature. While the frequency of droughts has risen, their deadliness declined. Our analysis throws light on the underlying geographical, institutional, development indicators in explaining inter-country differences in mortality. Our analysis also confirms the favourable effects of openness in saving human lives.

That much of this devastation is avoidable- through a timely and speedy entitlement protection strategy- is illustrated. Our simulations yield additional insights. Even moderate learning has the potential to avert a large fraction of deaths. But capacity-building-synonymous with availability of more resources for disaster prevention-has considerable potential too in averting deaths. In fact, these findings are broadly consistent with the view that fatalities are greater in countries with weak governments and pervasive poverty.

Attention is drawn to the mechanisms through which democratic regimes help avert mortalities. Government responsiveness is greater when the severity of the crisis is greater. Also, voters punish incumbent politicians for crises beyond their control. But voters also reward politicians for responding well to climatic events but not sufficiently to compensate them for their “bad luck”.

Even within a democratic regime, there are marked differences in the ability to prevent starvation deaths. Competitive local politics and decentralized structures of governance are crucial in preventing deaths. Specifically, local political parties and vigilant village councils act not just as conduits of information on distress but also pressure district administration to take appropriate action.

If the goal of development is *security* of livelihoods and human lives, a broader strategy is called for- a strategy that goes well beyond protection of food entitlements of the vulnerable. Some key elements include higher agricultural research outlays, public-private partnerships in promoting pro-poor technologies, a compatible incentive structure, and more effective extension systems. Specifically, soil and water conservation technologies with effective community participation deserve high priority in arid, semi-arid and sub-humid regions/areas.

As large sections of the rural population in developing countries will continue to be vulnerable to various shocks- droughts, pests, famines, floods, among others -insurance also has a potentially important role in mitigating the hardships.

In conclusion, while building resilience against natural disasters, such as droughts, is a challenge for developing countries, the prospects are far from bleak.

Key words: Drought, agricultural productivity, food, prices, mortality, agricultural research, technology

JEL codes: Q16, Q18, Q 54, I 18

On Devastating Droughts[1]

Introduction

Droughts often turn into famines causing hunger, malnutrition and, in extreme cases, deaths (Dreze, 1990, Kumar, 1990, Ghose, 1982). Following the seminal contribution of Sen (1981), it is now widely believed that famines occur despite adequacy of food availability. It is not so much the *irrelevance* of food availability but its *inadequacy* as an explanation of why famines occur that Sen (1981) and others have emphasized, using an entitlements framework.

Sen (1981) drew attention to the occurrence of famines due to entitlement failures and not so much because of decline in food production or availability. A case central to this analysis is the Bengal famine of 1943. More generally, two sets of causal factors may be distinguished: one includes conflict, devastation and destruction of crops due to natural factors (e.g. floods, droughts), and another set includes distinct but not necessarily unrelated factors associated with a spurt in food prices, loss of employment and/ or a sharp decline in wages of a large subset of the population, resulting in a sudden erosion of food entitlements. Sen's (1981) important contribution was to demonstrate that erosion of food entitlements and consequently famines do not necessarily occur in years of decline in food availability (FAD). In fact, some of the major famines analysed by him occurred *despite* adequate food availability[2].

[1] This study was funded by IFAD. Raghav Gaiha and Vani S. Kulkarni would like to thank Harvard's Centre for Population and Development Studies for excellent support-especially its present Director, Lisa Berkman. Raj Bhatia carried out the econometric analysis with admirable competence and efficiency. Discussions with Raghbendra Jha, K. Imai, M. Walton, Shylashri Shankar, D. Bromley, Sanjay Reddy, Mani Arul Nandh, Alain de Janvry, Anil Deolalikar and Ganesh Thapa helped clarify a number of points. The comments of the participants –especially T. Seckel, G. Libicap and Cormac O'Grada-were particularly useful in revising and extending the analysis. The views expressed are, however, those of the authors and not necessarily of the institutions to which they are affiliated, and any remaining deficiencies are their sole responsibility.

[2] In an instructive but somewhat overstated contrast, Sen (1982) distinguishes between the food availability decline (FAD) and entitlement failure-in particular, food entitlement failure: "Empirical studies of some of the major recent famines confirmed that famines could thrive even without a general decline in food availability. Even in those cases in which a famine is accompanied by a reduction in the amount available per head, the causal mechanism precipitating starvation has to bring in many variables other than the general availability of food……… The FAD approach gives little clue to the causal mechanism of starvation, since it does not go into the relationship of food to people" (p.154). He goes on to elaborate that "A person's ability to command food……..depends on the entitlement relations that govern possession and use in that society. It depends on what he owns, what exchange possibilities are offered to him, what is given to him free, and what is taken away from him"(p.155). For example, a barber's food entitlement "may collapse without any change in food availability if for any reason the demand for hairdressing collapses and if he fails to find another job or any social security benefit" (p.155). For a forceful critique, see O'Grada (2007, 2008, 2009).

That food availability did not often decline when large famines occurred is interesting but far from conclusive in rejecting food-supply based explanations of famines. While the entitlements framework is retained, the focus of the present study is on how supply shocks (e.g. through droughts) trigger changes in entitlements. So much of what Sen (1981) and others have emphasised in the explanation of famines through shifts in food entitlements is indeed valuable but somewhat incomplete in its limited attention to supply shocks. As noted by Ghose (1982) in a review of famines in India during the colonial period: Even when there is a decline in food availability the available food supply may still be adequate to feed the population of the region concerned. Yet, in numerous instances in history, a crop failure in one part of a country has often led to large-scale starvation deaths. " (p.369). He goes on to point out that in a monetised exchange economy a crop failure causes starvation by drastically altering the employment entitlements as also the money price of food. Indeed, a crop failure may reduce the real incomes of the non-food producers more drastically than those of the food producers. A rise in the relative price of food increases the real incomes of the surplus food producers but reduces the real incomes of all those who have to acquire food through exchange. Some of these linkages between supply shocks and food entitlements are illuminated below.

In the analysis of causal role of droughts in excess mortality, while controlling for the effects of climatic differences, geography (e.g. population density, whether landlocked, distance from the coast, elevation), careful attention will be given to the nature of the political regime (e.g. degree of democracy), and whether there is 'learning' over time-specifically, whether there is an interaction effect of degree of democracy and severity of droughts in the past.

Much has been written on entitlement protection or relief measures (i.e., food imports, price stabilisation, cash transfers through public works, soil conservation and other longer-term development measures (Dreze, 1990 a, b). However, given the preoccupation with entitlement protection in a context of market and government failures, little is said about augmenting crop and technological choices through agricultural research. The present study seeks to redress this imbalance, building on important recent contributions (O'Grada, 2007, 2008, 2009).

Droughts and Devastation

Drought is defined as an extended period of rainfall deficit during which agricultural biomass is severely curtailed (Bryant, 2005)[3]. But there is a wide variation in using this characterisation, and unavoidable vagueness[4]. The classification of droughts as a natural

[3] Droughts are a feature of not just arid and semi-arid but also of humid regions. Also, contrary to the common belief that droughts occur only in low rainfall areas, they are quite frequent also in areas with high rainfall. A case in point is the Indian state of Orissa with an annual rainfall of 1300 mm (Pandey and Bhandari, 2006).

[4] Definitions of drought, including the period of rainfall deficit prior to the event, vary. In southern Canada, for instance, a drought is any period where no rain has fallen for 30 days. In Australia, on the other hand, such a definition is not appropriate, as most of the country receives no rainfall for at least one 30-day period per year. So,a drought is defined as a calendar year in which rainfall registers in the lower 10 per

disaster employed by the Centre for the Epidemiology of Disasters in its compilation of data on all natural disasters (referred to as EM-DAT), however, helps ensure some uniformity.[5]

Some caveats are necessary. As elaborated by Below et al. (2007), droughts are slow-onset phenomena, which generally develop because of sub-normal dryness over an extended period of time. Establishing a strict temporal definition of the hazard (i.e., when it began and ended) is thus somewhat problematic. Drought hazards are often geographically extensive and exhibit a complex spatial pattern because of the localized nature of precipitation. As a consequence, a strict spatial definition of the hazard (i.e., where it occurs) is also problematic. As with the hazard itself, attribution of losses- including mortality- is contentious as these losses may endure for years.

About 38 per cent of the world's area that inhabits nearly 70 per cent of the total population and shares 70 per cent of the agricultural output is exposed to droughts (Dilley et al. 2005). A list of droughts compiled from different sources and the devastation resulting from them are summarized in Annex1. Historically, many droughts turned into famines. In India, for example, major droughts in 1918, 1957-58, and 1965 led to famines (FAO, 2001). Food shortages of varying intensity, if neglected or not dealt with effectively, may have disastrous consequences. During 1978-2003, for example, 14 million hectares of land were exposed to droughts, and direct economic losses were estimated to be 0.5-3.3 per cent of agricultural value added. In Thailand alone, the drought in 2004 was estimated to have affected 2 million hectares of cropped area and over 8 million people (Pandey and Bhandari, 2006).

Loss of agricultural output and food shortage are, however, not the only consequences. There are often large second round effects some of which persist over time. As agriculture continues to be a major source of employment and income in rural areas, there are significant backward and forward linkages with the rest of the economy. There is, for example, contraction of demand for agro-processing industries that cater to the local market. Similarly, suppliers of agricultural inputs face contraction of demand. By the time these effects play out, the overall economic loss is substantially greater than the first round loss of income. Hardships manifest in malnutrition, mortality, poverty, disinvestment in human capital (e.g. withdrawal of children from school), liquidation of

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cent of all the records. Unfortunately, in the southern hemisphere, a calendar year splits the summer growing season in two. So an appropriate criterion is abnormally low rainfall in the summer growing season (Bryant, 2005). For a broader perspective on droughts-including meteorological, hydrological and agricultural-see Pandey and Bhandari (2006, 2009).

5 EM-DAT provides a more detailed description of droughts: 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. However, the criteria used for classifying an event as drought, as stated later, are clear cut.

assets (e.g. sale of livestock) with impairment of future economic prospects and, in extreme cases, death, given the *incompleteness* of credit and insurance markets[6].

Human activity exacerbates droughts through over-cropping of marginalized land, massive vegetation clearing, and poor soil management in semi-arid regions[7].

Consider, for example, the effect of loss of vegetation. It causes a negative, bio-geophysical feedback mechanism, locking a region into aridity. In the Sahel, decreasing precipitation since 1960 has slowed down plant growth, leading to reduced evapotranspiration, decreased moisture content in the atmosphere, and a further reduction in rainfall. Besides, soil moisture diminishes slowly, adding to the reduction in evaporation and cloud cover. With the drying of the soil surface and dying of vegetation, the surface *albedo*-the degree to which short wave solar radiation is reflected from the surface of plants-is reduced, leading to greater ground heating and a rise in near-ground air-temperatures. This also reduces precipitation.

Drought in the Sahel occurred concomitantly with rising population and deteriorating economic conditions. Substitution of kerosene by wood for cooking and heating-induced by soaring fuel prices in the 1970s-inevitably led to rapid harvesting of shrubs and trees. As crop yields fell, fallow lands were cultivated, further reducing soil moisture. Ploughing led to destruction of soil structure, leading to the formation of surface crusts that increased run-off and prevented soil infiltration. All these practices reinforced the negative feedback mechanisms, resulting in drought and desertification (Bryant, 2005).

A predictable sequence of events unfolds. After a poor harvest, farmers seek labouring and other activities. As the drought intensifies, they seek relief from relatives and friends and start disposing of assets. Failure to borrow forces many to out-migrate from drought afflicted areas. Relief organised by governments is typically too little and too late. Child malnutrition is pervasive and migrants succumb to infectious diseases.

Issues

First, a broad brush treatment is given of variation in the frequency of droughts, and their deadliness. Specific issues addressed include the following: have droughts become more frequent in recent years? Does the frequency vary across different regions? Are low income countries more prone to droughts? Have droughts become deadlier in recent years?[8] This is followed by an analysis of the determinants of droughts and their deadliness. A selection of the results is used to simulate the effects of learning to deal with droughts better and capacity building, on the deadliness of droughts. In a subsequent

6 For a comprehensive assessments of these effects, based on a comparative study of droughts in China, Thailand and India, see Pandey and Bhandari (2006, 2009).
7 For a detailed exposition, see Bryant (2005).
8 Sen (1998) argues that mortality information has (i) intrinsic importance (since a longer life is valued in itself), (ii) enabling significance (since being alive is a prerequisite for our capabilities), and (iii) associative relevance (since many correlates of other achievements are inversely related to mortality rates).

section, key elements of a strategy of famine prevention are identified, focusing on how the devastation of supply shocks could be avoided. The concluding section offers some observations from a broad development perspective.

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 source is EM-DAT which covers all countries over the entire 20th century[10]. 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 the 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[11]. As noted earlier, these criteria ensure greater uniformity in classifying an event as a drought.

As the 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 1980-2004, with different sub-periods for specific exercises.

A recent review draws attention to the following problems/gaps in the EM-DAT[12]:

- 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 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 comprise direct and indirect losses. The 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.

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9 An important source on geographical and political regime characteristics is Gallup et al. (1999).

10 Annual rainfall data were obtained from the Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia.

11 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. For elaboration, see Gaiha et al. (2007).

12 For details, see Brooks and Adger (2005).

13 For further validation, see Gaiha et al. (2007).

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 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[15].

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 covered by insurance in the United States, less than 2 per cent of them are covered in the developing world. Moreover, 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).

The focus of the present analysis is on the devastation resulting from droughts. The devastation manifests in loss of agricultural output, food, higher food prices, lower agricultural wages, and, in extreme cases, deaths.

Methodology

For a broad brush treatment of the occurrence of droughts and their deadliness, some cross-tabulations are constructed. These are supplemented by a few graphs.

As few countries experience droughts and their numbers are small over the sample period, their frequency is analysed using the Poisson regression (and related variants). Given the endogeneity of droughts, their effects on agricultural and food output, and food prices are examined in a two-stage procedure. Using the IV estimates of droughts and other relevant variables, the effects of droughts on agricultural output, food production and prices, and agricultural wages are analysed with the help of robust regressions. As the effects of droughts on deaths are reported only in a few cases-in other words, many countries experienced droughts without any excess mortality-a Poisson specification is used[16].

[14] 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).

[15] For another assessment of the reliability of EM-DAT, see Annex 1B.1, and for a brief account of the changes due to the reclassification of droughts and famines, see Annex 1.B.2.

[16] With the logarithmic transformation of deaths, the Poisson distribution is appropriate. When the Poisson is rejected, the negative binomial is used.

A brief exposition of the Poisson specification is given below.

As the frequency of droughts is small and discrete (with a preponderance of zeros), the Poisson regression model is preferred to the OLS.[17] This model has been widely used to analyse count data. It assumes that each observation ($Y_i = y_i$) is drawn from a Poisson distribution with parameter λ_i, which is related to the regressors, $X_{ik.}$ The basic equation of the model is

$$\text{Prob}\ (Y_i = y_i) = \frac{e^{-\lambda}\lambda_i^{y_i}}{y_i!},\ y_i = 0,1,2,\ldots\ldots \quad (1)$$

A common formulation for λ_i is

$$\ln \lambda_i = \Sigma_K \beta_K X_{ik}\ . \quad (2)$$

The expected number of "events" (in this case, the number of droughts in a country over the period 1980-2004) for the ith country is $E\left[y_i \diagup X_i\right] = \lambda = e^{\sum_K \beta_K X_{iK}}$. Consequently, the expected number of events will increase with the value of the kth explanatory variable if $\beta_K > 0$ and will decrease if $\beta_k < 0$.

Although Poisson MLE is a natural first step for count data, it is somewhat restrictive. All of the probabilities and higher moments of the Poisson distribution are determined entirely by the mean. In particular, the variance is equal to the mean:

$$\text{Var}\ (y|\ \mathbf{X}) = E\ (y|\ \mathbf{X}) \quad (3)$$

The Poisson distribution, however, has a robustness property: whether or not the Poisson distribution holds, we get consistent, asymptotically normal estimators of the β_j. When we use the Poisson MLE but do not assume that the Poisson distribution is entirely correct, the analysis is referred to as quasi maximum likelihood estimation (QMLE). However, if the Poisson variance assumption does not hold, the standard errors need to be adjusted.

A simple adjustment to standard errors when the variance is assumed to be proportional to the mean is given below:

$$\text{Var}\ (y\,|\,\mathbf{x}) = \sigma^2 E\ (y\,|\,\mathbf{x}) \quad (4)$$

where $\sigma^2 > 0$ is an unknown parameter. When $\sigma^2 = 1$, we obtain the Poisson variance assumption. When $\sigma^2 > 1$, we get the case of overdispersion, and, when $\sigma^2 < 1$, it is a case of underdispersion.

[17] For an exposition of the Poisson regression, see Wooldrige (2006).

When overdispersion is indicated, a negative binomial regression is appropriate. Instead of assuming as before that the distribution of y, the number of events, is Poisson, we assume that y has a negative binomial distribution. This means relaxing the assumption of equality of mean and variance.

Cross-Tabulations of Droughts and Deaths

In Table 1, the distributions of droughts and deaths resulting from them are examined for all countries in each of two periods: 1985-94, and 1995-2004. Let us first consider these distributions by region.

Out of a total of 71 droughts during 1985-94, the largest number occurred in Sub-Saharan Africa, followed by East Asia and the Pacific, and Latin America and the Caribbean. The number of droughts rose sharply between 1985-94 and 1995-04-from 71 to 115. Each of these regions recorded a markedly higher number of droughts, with Sub-Saharan Africa recording the highest number.

Total number of deaths due to droughts, however, recorded a drastic reduction-from 4801 to 1019. As a result, the deadliness of droughts reduced sharply. Droughts and deaths per million of population follow a consistent pattern except that the values are small. While disasters per million of population rose, deaths per million decreased. Deaths per drought fell sharply- especially in East Asia and the Pacific, and Sub-Saharan Africa. This is illustrated in Fig:1.

Well over 90 per cent of the droughts during 1985-94 occurred in Low and Lower Middle Income countries[18]. This feature remained unchanged during 1995-04. The shares of deaths, however, varied. While Lower Middle Income countries accounted for over 70 per cent of the deaths during 1985-94, their share dropped to about 46 per cent in the next decade. By contrast, the share of Low Income countries doubled. As the ratios of droughts and deaths to population are small, our comment is restricted to deaths per drought. The reduction in the deadliness of droughts in Lower Middle Income countries was considerably greater than in Low Income countries, as shown in Table 2, and illustrated in Fig.2.

Figures 3 and 4 throw further light on the frequency and deadliness of droughts. As Fig: 3 illustrates, there were sharp fluctuations over 1985-2004. There was a marked rise in the frequency of droughts after 1995 until 2001, followed by a steady decline. Total deaths due to droughts peaked in 1991, followed by no deaths during 1992-1996, and small numbers of deaths in subsequent years.

As droughts are typically associated with deficiency of rainfall, Table 3 gives the distribution of droughts and associated deaths by range of rainfall (average during 1980-85). The first three ranges accounted for the bulk of the droughts-about 88 per cent-with

[18] For details of the income classification used, see Table A.1.1 in Annex 1A.

the highest frequency in the rainfall range of 1001-2000 mm. However, a large majority of deaths-about 69 per cent-occurred in the lower rainfall range of 501-1000 mm.

Duration of droughts and their deadliness seem largely unrelated, as shown in Table 4. It must, however, be noted that, in the absence of other controls, all that is captured below is bivariate correlation. A vast majority of droughts (about 90 per cent) lasted no more than a year. They also accounted for the bulk of the deaths (over 95 per cent). So the severity of droughts –assessed in terms of mortality-need not necessarily imply long-lasting droughts[19].

[19] This is of course subject to measurement problems summarized in Annex 1.B.2.

Table 1
Frequency of Droughts and Deaths by Region

Region	Number of Droughts (85-94)	Number of Droughts (95-04)	Deaths (85-94)	Deaths (95-04)	Deaths per million (85-94)	Deaths per million (95-04)	Deaths per Drought (85-94)	Deaths per Drought (95-04)	Droughts per million (85-94)	Droughts per million (95-04)
	%	%	%	%						
11 Latin America & Caribbean	16	27	0	0	0.00	0.00	0.00	0.00	0.04	0.05
	(22.54)	(23.48)	0.00	0.00						
21 South Asia	5	6	300	200	0.27	0.15	60.00	33.33	0.00	0.00
	(7.04)	(5.22)	(6.25)	(19.63)						
22 East Asia & Pacific	18	32	3484	528	2.20	0.30	193.56	16.50	0.01	0.02
	(25.35)	(27.83)	(72.57)	(51.82)						
31 Europe & Central Asia	4	8	0	2	0.00	0.00	0.00	0.25	0.01	0.02
	(5.63)	(6.96)	0.00	(0.20)						
41 Middle East & North Africa	2	7	0	0	0.00	0.00	0.00	0.00	0.01	0.03
	(2.82)	(6.09)	0.00	0.00						
51 Sub-Saharan Africa	26	35	1017	289	2.35	0.52	39.12	8.26	0.06	0.06
	(36.62)	(30.43)	(21.18)	(28.36)						
Total	71	115	4801	1019	1.15	0.21	67.62	8.86	0.02	0.02
	(100.00)	(100.00)	(100.00)	(100.00)						

Table 2
Frequency of Droughts and Deaths by Income

INCOME	Number of Droughts (85-94)	Number of Droughts (95-04)	Deaths (85-94)	Deaths (95-04)	Deaths per million (85-94)	Deaths per million (95-04)	Deaths per Drought (85-94)	Deaths per Drought (95-04)	Droughts per million (85-94)	Droughts per million (95-04)
	%	%	%	%						
1 Low Income	34	53	1317	551	1	0	39	10	0.02	0.03
	(47.89)	(46.09)	(27.43)	(54.07)						
2 Lower Middle Income	33	54	3484	468	2	0	106	9	0.01	0.02
	(46.48)	(46.96)	(72.57)	(45.93)						
3 Upper Middle Iincome	4	8	0	0	0	0	0	0	0.02	0.03
	(5.63)	(6.96)	0.00	0.00						
Total	71	115	4801	1019	1.15	0.21	67.62	8.86	0.017	0.023
	(100.00)	(100.00)	(100.00)	(100.00)						

Fig 1: Deaths per Drought by Region

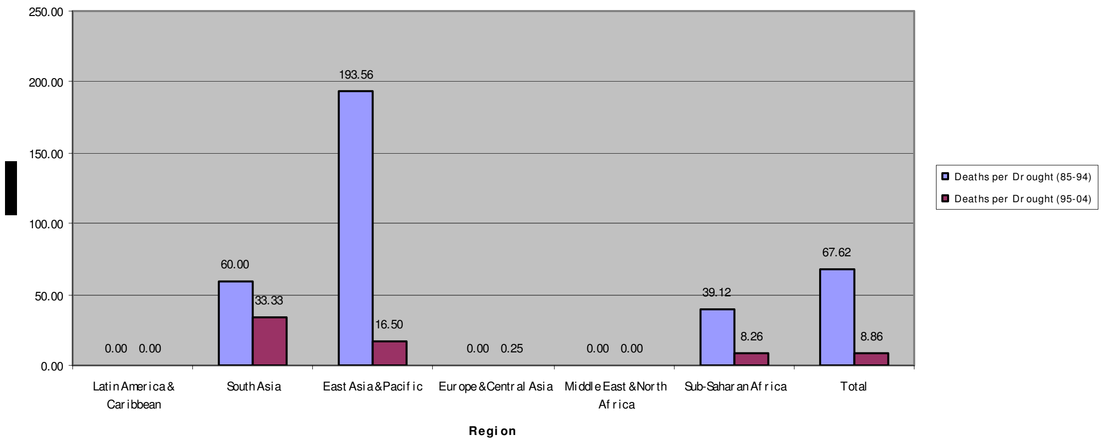


Fig. 2: Deaths per Drought by Income

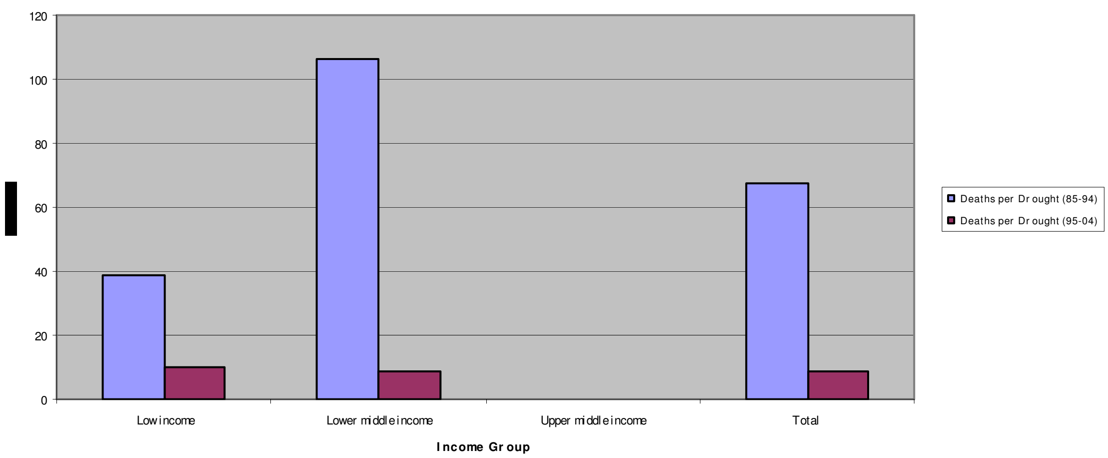


Table 3
Distribution of Droughts by Rainfall (mean mm.) during 1980-85

Rainfall (mm.)	Frequency of Droughts	Deaths
0-500	40	801
501-1000	52	4002
1001-2000	66	405
>2000	22	612
Total	180	5620

Table 4
Duration of Droughts and Deaths during 1985-2004

Duration	Frequency of Droughts (% share in total)	Deaths (% share in total)
Upto 1 year	166 (89.73)	5549 (95.34)
1-2 years	11 (5.95)	43 (0.74)
>2 years	8 (4.32)	228 ((3.92)
Total	185 (100)	5820 (100)

Fig:3 Number of Droughts during 1985-2004

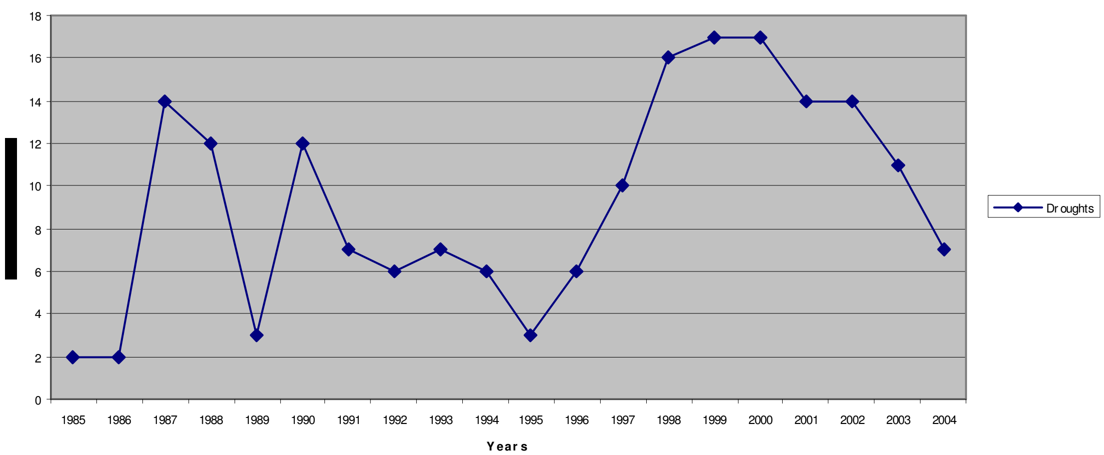
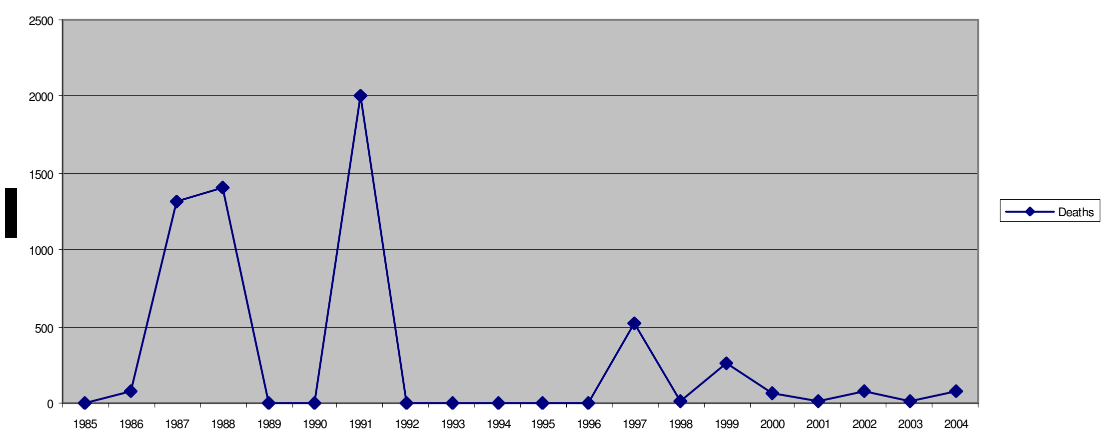


Fig: 4 Deaths Due to Droughts during 1985-2004



Determinants of Droughts

A Poisson model with different specifications was estimated. The dependent variable is number of droughts in each year over the period 1980-2004. The explanatory variables include average rainfall (during 1980-2000), its square, a dummy variable that takes the value 1 when the rainfall deficit was 10 per cent or more from the average, arable area ranges, regional affiliation of a country/ income level grouping, shares of land in different climatic zones, whether the country is landlocked, elevation, suitability of soil for rainfed crops, and distance from the coast. As these variables may not capture all relevant determinants of droughts-for example, we lack data on monthly rainfall and its distribution-the number of droughts in 1970-79 serves as a catch-all variable[20]. A selection of the results is given below[21].

Table 5
Determinants of Droughts (1980-2004)

Poisson regression	Number of obs = 1806
	Wald chi2(14) = 66.65
	Prob > chi2 = 0.0000
Log pseudolikelihood = -568.39882	Pseudo R2 = 0.0436

Number of Droughts	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Mean rainfall 1980-2000	-.000132	.0004339	-0.30	0.761	-.0009825	.0007185
Square rainfall 1980-00	1.31e-08	1.43e-07	0.09	0.927	-2.68e-07	2.94e-07
rain deficit > 10%	.69608	.1516854	4.59	0.000	.3987821	.9933778
Arable land area<.5m	-.6091787	.28376	-2.15	0.032	-1.165338	-.0530192
Arable land area .5-2.5m	-.5933121	.2071219	-2.86	0.004	-.9992635	-.1873607
Arable land area 2.5-5m	-.5304885	.2078761	-2.55	0.011	-.9379182	-.1230588
South Asia	-.2005662	.3311264	-0.61	0.545	-.8495621	.4484297
Mid. East and No. Africa	-1.097631	.3981808	-2.76	0.006	-1.878051	-.3172105
Sub-Saharan Africa	.0626019	.2089732	0.30	0.765	-.346978	.4721818
landlock	-.1338425	.2622918	-0.51	0.610	-.6479249	.38024
mean elevation	.0001006	.0001562	0.64	0.520	-.0002056	.0004067
Soil suitability	-.0155769	.0085895	-1.81	0.070	-.032412	.0012582
Distance coastline (km)	-.0002311	.0002157	-1.07	0.284	-.0006539	.0001917
Number of Droughts 70-79	.831621	.2768497	3.00	0.003	.2890056	1.374236
_cons	-1.755744	.4315005	-4.07	0.000	-2.60147	-.9100187

Let us first consider the results in Table 5.

- The coefficients of average rainfall and its square are not significant. However, the coefficient of years of deficit rainfall is positive and significant.

[20] For a list of variables used in the regressions, see Table A.1.5 in Annex 1 A.
[21] Other diagnostic results are available on request.

- Frequency of droughts is lower in each of the three ranges of arable land area, relative to the benchmark/default range[22].
- Out of the three regional dummies, that for Middle East and North Africa has a significant negative coefficient, implying a lower frequency of droughts relative to the default category.
- Whether a country is landlocked is unrelated to the frequency of droughts, as also the elevation of a country.
- As expected, droughts are less frequent in areas with greater soil suitability for rainfed crops[23].
- Droughts and distance from a coast are unrelated.
- Finally, the higher the frequency of droughts during 1970-79, the greater was the frequency during 1980-04.
- The overall specification is validated by a Wald test.

Table 6
Determinants of Droughts

```
Poisson regression                                Number of obs   =       1806
                                                  Wald chi2(15)   =      74.73
                                                  Prob > chi2     =     0.0000
Log pseudolikelihood = -567.66011                 Pseudo R2       =     0.0448
```

Number of Droughts	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Mean rainfall 1980-2000	.0004223	.0003854	1.10	0.273	-.000333	.0011776
Square rainfall 1980-00	-1.31e-07	1.32e-07	-0.99	0.320	-3.90e-07	1.28e-07
rain deficit > 10%	.6837755	.1528536	4.47	0.000	.384188	.9833631
Arable land area<.5m	-.4896821	.2749238	-1.78	0.075	-1.028523	.0491587
Arable land area .5-2.5m	-.625032	.1982499	-3.15	0.002	-1.013595	-.2364694
Arable land area 2.5-5m	-.5488957	.2070531	-2.65	0.008	-.9547123	-.1430791
zdrytemp	-.4777292	.6174809	-0.77	0.439	-1.68797	.7325111
ztropics	1.214167	.3720363	3.26	0.001	.4849898	1.943345
landlock	-.0546344	.2652057	-0.21	0.837	-.574428	.4651593
elevation dummy < 300	-.5249619	.2653443	-1.98	0.048	-1.045027	-.0048967
elevation dummy 300-600	-.3013007	.2097666	-1.44	0.151	-.7124356	.1098342
elevation dummy 600-900	-.3665443	.2627486	-1.40	0.163	-.8815222	.1484335
Soil suitability	.0052754	.0091422	0.58	0.564	-.0126431	.0231938
Distance coastline (km)	.0000755	.0002349	0.32	0.748	-.0003848	.0005359
Number of Droughts 70-79	.844335	.2761867	3.06	0.002	.303019	1.385651
_cons	-2.53979	.34118	-7.44	0.000	-3.20849	-1.871089

In Table 6, we report the results of another specification in which regional dummies are replaced by shares of land in dry temperate and tropical conditions, and elevation is

[22] Arable area is divided into 4 ranges: <.5 million hectares, .5 million-2.5 million hectares, 2.5million-5million hectares, and >5 million hectares.

[23] For a measure of soil suitability, see the list of variables in Table A.1.5 in Annex 1A.

replaced by four ranges (and three dummies, with the highest range serving as the benchmark case[24]).

While most of the results are similar-the robustness of some key relationships remains intact-some change. For example, the soil suitability coefficient ceases to be significant; and those of lowest range of elevation are negative, implying lower frequencies of droughts relative to the omitted range. Finally, controlling for other effects, the frequency of droughts is higher in countries with higher share of land in tropical conditions.[25]

Table 7

Determinants of Droughts

Poisson regression — Number of obs = 1806; Wald chi2(13) = 56.10; Prob > chi2 = 0.0000; Pseudo R2 = 0.0454

Log pseudolikelihood = -567.30734

Number of Droughts	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Mean rainfall 1980-2000	.0005665	.0003592	1.58	0.115	-.0001374	.0012705
Square rainfall 1980-00	-1.67e-07	1.28e-07	-1.31	0.192	-4.19e-07	8.39e-08
rain deficit > 10%	.6433844	.1526182	4.22	0.000	.3442583	.9425106
Arable land area<.5m	-.3212567	.2699435	-1.19	0.234	-.8503362	.2078227
Arable land area .5-2.5m	-.6129502	.2090909	-2.93	0.003	-1.022761	-.2031396
Arable land area 2.5-5m	-.3871141	.2034198	-1.90	0.057	-.7858097	.0115814
Low Income countries	.772276	.3348228	2.31	0.021	.1160354	1.428517
Lower Middle Income countries	1.037218	.3278951	3.16	0.002	.3945554	1.67988
landlock	.1094186	.2794334	0.39	0.695	-.4382609	.657098
mean elevation	.0000307	.0001467	0.21	0.834	-.0002568	.0003182
Soil suitability	-.0092417	.0076274	-1.21	0.226	-.0241911	.0057078
Distance coastline (km)	-.0000907	.0002016	-0.45	0.653	-.0004859	.0003044
Number of Droughts 70-79	.8217702	.2709901	3.03	0.002	.2906394	1.352901
_cons	-3.283796	.4612517	-7.12	0.000	-4.187833	-2.37976

24

RECODE of elev (mean m above sea level)	Freq.	Percent	Cum.
<300	18	19.78	19.78
300-600	30	32.97	52.75
600-900	15	16.48	69.23
>900	28	30.77	100.00
Total	91	100.00	

25 For details, see the note on climatic classification in Table A.1.2 in Annex 1A.

In Table 7, the results of yet another classification that replaces the regional classification with income dummies (i.e. one for Low Income and another for Lower Middle Income countries) are given[26]. Again, most of the key relationships are corroborated-rain deficit years record a higher frequency of droughts; it is lower in lower ranges of arable land; the greater the frequency of droughts in the past, the greater was the frequency in 1980-2004. Both Low Income and Lower Middle Income countries are associated with higher frequencies of droughts relative to the omitted countries. This specification is used to predict the frequency of droughts for its use in the mortality equation.

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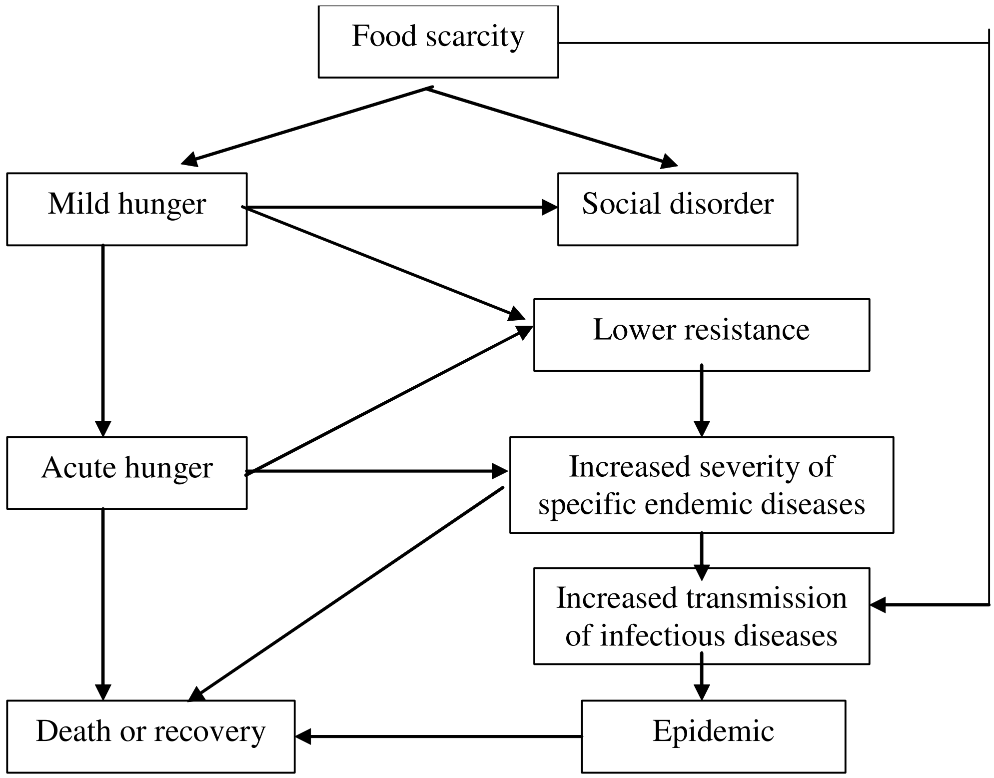
Determinants of Mortality

Let us first review the evidence on food scarcity, hunger and deaths. Here a distinction between food scarcity in a famine or a drought is not made, as we draw upon a vast literature that focuses on the link between malnutrition and mortality[27].

Much of famine mortality is directly or indirectly attributed to malnutrition and starvation (e.g. Appleby, 1978, Sen, 1981).More recent literature is somewhat sceptical of this view. Three issues have figured prominently. These include (i) whether excess mortality is due to starvation or to infectious diseases. Some recent evidence favours the latter (e.g. de Waal, 1989). A second issue is the cause of increased exposure to the risk of infection. One set of factors includes deterioration in the standards of hygiene or greater population mobility or both. An alternative view is that it is a result of lower resistance due to declining nutritional level. A related issue then is whether the immune system is sensitive to moderate malnutrition. Some recent evidence suggests that even moderate malnutrition can impair immunity and increase the case fatality/ severity of an infection (Chandra, 1997). A third contentious issue is the lethality of an infection. More specifically, independently of how an infection is contracted, the question is whether the risk of it being lethal is affected by whether the person is well- nourished or not.

[26] For details of the income classification, see Annex 1.

[27] These include important contributions by Deaton (2005, 2006), Cutler et al. (2005), Fogel (2004), Watkins and de Waal (1983), Dyson and O'Grada (2002), Scrimshaw et al. (1997), Ravallion (1997), Hionidou (2002), among others.



Source: Hionidou (2002).

Fig: 4 Interactions between Food Scarcity, Epidemic Outbreaks and Deaths

Significantly, there is a growing consensus that malnutrition and starvation play an important role in explaining famine mortality[28]. A broad schema linking food deprivation to mortality is delineated in Fig: 4, drawing upon Hionidou (2002).

Food scarcity initially leads to mild hunger. A subset-especially the poor-reaches starvation level fairly quickly even before food scarcity becomes widespread. Resistance to infection declines and the severity of endemic infections rises. Many succumb either to acute hunger or disease. As food scarcity spreads, the pool of the malnourished increases, contributing to further transmission of the infection. Intervention at this stage could prevent a further deterioration. But, even if epidemics are avoided, some individuals will succumb to infectious diseases and die. In the absence of intervention, as food becomes more scarce and hunger more pervasive, social unrest, violence, extensive migration and more deaths are likely.

From a broader perspective, however, the public health environment matters too. In recent contributions, Deaton (2005) is emphatic that 'nutritional traps are easier to

[28] See, for example, a detailed analysis of the 1941-43 famine on the Greek islands of Syros, Mykonos, and Hiros in Hionidou (2002).

understand once disease is given its proper place in the story. Disease interacts with nutrition, and each reinforces the other. Malnutrition compromises the immune system, so that people who do not have enough to eat are more likely to succumb to infectious diseases. At the same time, disease prevents the absorption of nutrients so that, even when food is obtainable-through own cultivation, or in exchange for work-it cannot be turned into nutrition" (p.10). He takes issue with Fogel (2004) for neglecting the primacy of the germ theory and of public health in preventing deaths, as also for overemphasizing the "close tracking of health and income" (p.11). The point is that, "if growth by itself is no guarantee of health improvement, then some sort of public action, whether through public health or provision of health systems, is required to turn growth into improvements in health" (p. 11).

For completing the above schema, some other links need further elaboration and refinement, along the lines of Ravallion (1997).

Recognising the tenuousness of the relationship between food deprivation and mortality, he notes the following:

- Small food price increases may entail large increases in mortality among sub-groups of the poor if survival chances are increasing and sufficiently concave in income. Under such conditions, greater price variability will result in greater mortality.
- A sharp increase in mortality could be preceded by a steady (even slow) deterioration in food consumption. This non-linearity could be exacerbated by shifts in survival function associated with a worsening of the health environment. So the point is not to look for just a sudden and sizable shock (e.g. food decline) but also at the consumption history in the recent past[29].
- He also makes a somewhat sweeping and contentious remark that there is little hard evidence on the impact of the health environment and access to health care on mortality during periods of food scarcity-especially famines.

We cannot address these issues with required econometric rigour because of the limitations of cross-country data. Our formulations are no more than reduced forms that allow for some linkages between droughts and mortalities controlling for geographic, institutional and development indicators.

Migration

The patterns of migration in anticipation of and/or following a drought have received considerable attention in the literature. A recent study, Bhandari and Pandey (2009), has carefully examined migration as a coping mechanism in India, China and Thailand. The remarks below are, however, confined to the effects of the drought in Jharkand, Chattisgarh and Orissa (three Indian states) in 2002. The loss in rice yield was estimated

[29] For econometric evidence based on Bangladesh data, see Ravallion (1987).

to be in the range of 25-40 per cent. Although seasonal migration is high in these states, the overall incidence of migration rose by 6-18 per centage points, while the working days increased from 32 in normal years to 94 in drought years. There are of course long-term effects of living in ghetto-like conditions, and spread of diseases that are lethal.

A richer but with strikingly different findings is a study by Findley (1994).The author focuses on migration from rural Mali during the 1983-85 drought. Contrary to a widely shared view that migration rises both immediately and as a long-run response to the threat of recurrent droughts, Findley (1994) demonstrates that the average rate of migration in the region sampled did not rise. However, the composition of migration changed.

Although precise definitions differ, a common threshold for permanent migration is 6 months. A circular migrant, by contrast, is away for 1-6 months and after returning participates in household activities. Permanent migrants typically do not return to participate in such activities.

In the Sahel, there are two forms of labour circulation, reflecting differences in duration and distance travelled. In the short-cycle pattern, adolescents and younger married men , usually from poorer families, go to nearby cities to work as petty traders, helpers and other low categories of work. They return within a year to help with farm work (e.g., Niger, Burkina Faso, Senegal). Given the poor quality of roads and transportation, they return once a year for cultivation or harvest. By contrast, the long-cycle pattern involves long duration, long-distance circulation, often to a foreign location (in this context, to France). Between visits, they send remittances.

Some of the hypotheses tested are: Does short-cycle migration rise during a drought? In the case of Mali, a related hypothesis is whether migration to major African countries and regions less affected by the drought also increases? If migration is viewed as a strategy to adjust household size, is it reflected in earlier marriage of daughters? Alternatively, are women and children sent to their kin elsewhere for extended periods as circular migrants?

During the 1983-85 period, the average rainfall was 30 per cent lower than the fifty year average, resulting in a production decline of one-third of the pre-drought level. The forage levels were down to one-fourth their pre-drought levels. Local herds were cut in half. Each family lost an average of 4.5 cattle and another 5.4 were sold. The survey was conducted before and after the drought to throw light on how households coped with the hardships.

The average level of migration did not rise. During the 1982-89 period, 1907 individuals, or 30 per cent of the total sample population, reported at least one migration. On the assumption that migrations were equally distributed over the 7 year period, an average of 14 per cent migrations occurred each year. This implies a migration of 43 per cent during the drought period. In fact, this matches the actual migration of 44 per cent during the drought period.

The pattern of migration, however, changed. There was a marked increase in short-cycle circulation. In 1982, 29 per cent of the migrants had circulated. In contrast, over two times that level, or 63 per cent of the 1983-85 migrants, circulated at least once during the drought years. Migration destinations also shifted. Before the drought half of the migrants went to France and the remainder were distributed between Mali and other African countries. During the drought the preferred destination was Mali which accounted for 42 per cent of all destinations. Migration to France was cut in half, to 27 per cent of all migrations.

The short-cycle circular migrants were twice as likely to go to nearby destinations in Mali. 51 per cent stayed in Mali, and another 24 per cent went to other African countries (viz., Senegal and Ivory Coast/ now Côte d'Ivoire). About one third (23 per cent) travelled to France. Among the permanent migrants for whom the destinations were known, 46 per cent went to France. Well over one third (about 38 per cent) stayed within Mali, and 16 per cent went to other African countries.

Another compositional shift among the migrants was that much larger shares of women and children migrated during the drought years. The proportion of children (<15 years) who migrated rose from 17 per cent in 1982 to 24 per cent during the drought period. Among adult migrants, the proportion female doubled from 17 per cent to 34 per cent.

A large majority of the women and children who migrated (about 62 per cent) were circular migrants. Among adult migrants, 44 per cent of all circulator or short-cycle migrants were women. Their motives, however, require a nuanced and contextual interpretation. About one half (48 per cent) of all drought migrations were related to family or marriage, compared with 21 per cent among the 1982 migrants. During the drought, the proportion of migrants who moved for marriage rose from 2 per cent to 17 per cent.

The long and short-cycle female migrants moving for marriage differed sharply. Half (about 52 per cent) of the women who migrated permanently left for marriage, compared to a little over one-fourth (27 per cent) who came back. Among the short-cycle migrant women, other family reasons (e.g., visiting family) dominated, accounting for 50 per cent of the moves.

On average, the short-cycle migrants were poorer than the long-cycle or permanent migrant families. About one half (44 per cent) of the short-cycle migrant families were the poorest, as against 38 per cent of the long-cycle migrants.

What do these responses suggest? First, migration levels may not rise if there is already a great deal of migration in an environment of economic insecurity and volatility. Second, even with slight changes in migration levels, the composition changes, encompassing a broad range of survival strategies-including encouraging women to marry earlier. Third, some of these responses are muted, as droughts are slow –onset events that sometimes cover large areas.

Is There a Female Mortality Advantage?

A puzzle is: while women enter famines in a more physically vulnerable condition than

Table 8
Female Mortality Advantage in Famines

Famine country/year	Authors	Female advantage	Explanation
Ireland 1846-50	Boyle and O'Grada (1986); Fitzpatrick (1997)	Yes	Biological: body fat and fertility, entitlements/socio-cultural
Finland 1860s	Pitkanen and Mielke (1993), Pitkanen (2002)	Yes	Migration
India 1890s	Dyson (1991); McAlpin (1983)	Yes	Migration, famine foods, prostitution, and biological: body fat, fertility decline
Greece 1941-2	Valaoras (1946); Hionidou (2002)	Yes Yes	None given; Biological: body fat; differential access to food
Warsaw 1940s	Livi-Bacci (1991, 1993)	Yes	Biological: body fat/immune responses
Dutch Famine 1944	Henry (1990)	Yes	Biological: body fat/immune responses
India-Bengal 1943-44	Sen (1981)	No	Artefact of poor data
Russia 1930s	Livi-Bacci (1993)	Yes	Poor conditions affect men more-for example, labour camps and deportation
Malawi 1949	Vaughan (1987)	Insufficient data	Survival strategies favour female advantage
China 1959-61	Kane (1988); Sands and Buelow (1999)	No Yes	Female infanticide gave male children advantage (one province only) Biological: body fat
Bangladesh 1974-75	Chowdhury and Chen (1977); Razzaque et al. (1990)	No Yes	Migration of males, fertility decline
Ethiopia 1984-85	Lindtjorn et al. (1993); Lindtjorn and Alemu (1997); Kidane (1989)	Yes No Yes	No explanation given
Sudan 1984-85	de Waal (1993)	Yes	Boys coming in contact with diseases, other migration factors
Madagascar 1985-87	Garenne et al. (2002)	Yes	Biological: a 'harvesting effect'-differential vulnerability to infectious diseases
Somalia 1992	Collins (1995)	Yes	Biological: body fat, and position of women in society

Source: Macintyre (2002)

men, they seem to survive famines somewhat better. If this is so, what are the underlying factors? Are these biological or social or cultural or a combination of these? Let us first consider the evidence on famine mortality, drawing upon historical as well as studies of more recent famines.

(a) Evidence

A selection of findings is given in Table 8.

The famines are listed chronologically, beginning with the Finnish and Irish famines of the 19th century and ending with the recent famines in the Horn of Africa. A striking feature of the evidence summarized is the almost uniform 'Yes' in the third column. Another is the range of explanations offered.

The Finnish famines of the 1860s suggest a small female mortality advantage. High levels of young adult males led to higher excess mortality through exposure to disease in the towns and the cities (Pitkanen and Mielke, 1993; Pitkanen, 2002).

The Great Irish famines of 1845-51 also point to a female advantage for most of the years of the crisis, and across most regions of Ireland (O'Grada, 1999). He emphasizes that while men appeared to be at a disadvantage, in relative terms this disadvantage was slight.

The two Indian famines of the 1890s show that women had lower excess mortality than men in both Bombay and Madras. The death rates, for example, in the Madras relief camp were 595.3 per thousand for women and 796.4 per thousand for men. McAlpin (1983) attributes this to the greater biological capacity for survival of women. This is also taken as evidence that men succumbed more to infectious and epidemic diseases (largely cholera). In a study of south Asian famines in the late 19th and early 20th centuries, Dyson (1991) further corroborates a slight but consistent mortality advantage of women in most areas.

Another issue is whether the female advantage is confined to a certain age group. Pitkanen and Mielke (1993), for example, report considerable differentials in sex ratios for excess mortality in 1868 for Sweden in high impact regions, and especially for young adult men (i.e., those under 30 years). However, their examination of hospital data reveals very little difference between the sexes in case fatalities due to famine related diseases (especially typhus) for any other age group.

Studies of the Russian famine of the 1930s-notably Livi-Bacci (1993)- show that excess deaths for women in the age group > 10 years ranged between 0.6 and 1.8 million, as against between 2.0 and 3.2 million for men.

The Chinese famine during 1959-61 offers conflicting evidence, depending on the region. Ashton et al. (1984) report a female mortality advantage, especially in older age groups. Sands and Buelow (1998), by contrast, show a considerable advantage. Their estimates suggest that females had on average a 20 per cent higher survival rate than males, but there was sizeable variation both within and between provinces. Kane (1988), however, argues on the basis of the evidence for the province of Anhui that there was little female advantage. She draws attention to large numbers of 'missing' girls born between 1955-56 and 1959-60 as a result of female infanticide and discriminatory feeding practices.

In a comparison of famine (1984-85) with pre-famine mortality (1981) in Ethiopia, Kidane (1989) reports that mortality was greater for females than for males and that the sex ratio was biased in favour of males in all age groups except the very youngest, implying that they survived in greater numbers than did females. A limitation, however, of this analysis is that his sample consists of survivors of refugee camps.

Estimates for Somalia in 1991-92 point to a slight female advantage (Collins, 1995).

(b) Explanations

As may be noted from Table 8, several explanations rely on the biological argument. The female advantage is directly related to the higher proportion of body fat of women, compared to men, which improves their survival rates. It is also suggested that women are less susceptible to deprivation, as they have smaller needs of energy and micronutrients[30]. Women may have an additional advantage through a lower metabolic rate. Compared to men, women should therefore survive acute deprivation better, mainly because they need less energy to support their weight.

Since in famines deaths are not due to starvation but mostly because of infectious or communicable diseases, another explanatory factor of the gender gap in mortality is differences in immunity. Research shows that girls are more likely to survive some diseases than are boys. In particular, excess male mortality due to typhoid, malaria, anthrax and schistosomiasis is reported (Garenne and Lafon, 1998). Of these, the first two are cited in the famine literature. However, other diseases such as measles, smallpox and cholera show considerable female disadvantage-especially in the age group 15-30 years. How these findings could help resolve the puzzle is thus not self-evident.

The final biological explanation relates to declining fertility, which accompanies famine. It is argued that a famine-induced reduction in the risk of pregnancy due to amenorrhoea, malnutrition, physical separation of spouses, or a drop in sexual energy leads to a drop in fertility. While it could explain part of the gender differential in famine mortality, it is no more than a contributory factor. Boyle and O'Grada (1986), for example, estimated that the fertility decline that accompanied the Irish famine translated into 300000 averted births during 1846-51. This implies that as many as 5000 women's lives were saved as they did not go through the stress of pregnancy and child birth.

These explanations are sometimes supplemented with socio-cultural explanations. Migration, for example, is a common survival strategy. Often men migrated earlier, and in several historical famines came in contact with infectious diseases before women did.

[30] O'Grada (2007) reviews the evidence on female mortality advantage. He surmises that the main reason is physiological.: females store proportionately more body fat and less muscle. Has this female advantage changed in recent years? The answer is far from obvious. There is a presumption that the more important is literal starvation as the cause of death, the greater is the female advantage.

Finnish men from regions where there was high migration died in greater numbers than their families who stayed at home. More recently, in Malawi, Somalia and Sudan, women left home later after the support from the spouse ended (as a result of the death of the male spouse). In contrast, in Ethiopia, Lindtjorn et al. (1993) report that men in Wollo stayed at home to plant the next harvest, while women sought help in refugee camps. In Greece in the 1940s there was virtually no migration and yet men died in greater numbers.

Sometimes several survival strategies are pursued at the same time. In the Bengal famine of 1943, many women migrated to Calcutta and turned to prostitution to feed their children while their male spouses stayed behind to protect their property, as also because they believed that the relief camps favoured women and children (Das, 1949). Thus multiple strategies and social factors interacted to favour women.

Whether women have better knowledge of famine foods that helps their survival is disputed. Actual reports from field studies confirm that their availability had a vital role in determining the timing of migration (de Waal, 1989). On the other hand, an eyewitness account from Ethiopia suggests that, although many people were aware of famine foods, they were too weak to seek them out and prepare them (Macintyre, 2002).

Another survival strategy is that women exhibit a stronger willingness to seek help, despite, or perhaps because of, a lower social status during normal times. Indeed, it has been argued that women's status changes radically during severe food crises, allowing women greater freedom in making decisions that affect their own and their children's lives. Mehtabunisa (1984), for example, observes that "women appeared not only to survive the Bengal famine of 1943-44, but also to fight more tenaciously than men" (p. ?).

In conclusion, a plausible explanation requires a combination of gender-specific survival strategies and gender-based institutional factors, with basic human physiology. Their interaction could produce synergistic effects that may be larger than their additive effects. But more data and research are required on the cause and timing of deaths during famines, immune responses, severity and duration of starvation, timing of epidemics and how these factors influence the sex ratios of mortality for a more definitive assessment.

Analysis of Mortality

Here the focus is on understanding why droughts kill more in some countries than in others.

- The higher the frequency of droughts, the higher were the deaths.
- At lower ranges of elevation (the first and the third), there were fewer deaths, relative to the omitted range.
- Ethnic fractionalization did not influence mortality.

Table 9
Determinants of Mortality

Negative binomial regression — Number of obs = 1743
Wald chi2(15) = 2699.06
Log pseudolikelihood = -167.41413 — Prob > chi2 = 0.0

Log of deaths due to droughts	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Predicted no. droughts	23.08838	5.069266	4.55	0.000	13.1528	33.02396
landlock	-.7541495	1.529708	-0.49	0.622	-3.752322	2.244023
elevation dummy < 300	-4.343138	1.941176	-2.24	0.025	-8.147774	-.5385023
elevation dummy 300-600	.028441	.4610022	0.06	0.951	-.8751067	.9319886
elevation dummy 600-900	-2.935564	.576101	-5.10	0.000	-4.064702	-1.806427
ethnic	-1.04584	1.115464	-0.94	0.348	-3.232109	1.140429
Persons/ km2	.0005195	.0016008	0.32	0.746	-.0026181	.0036571
Square of persons/ km2	8.43e-07	8.65e-07	0.97	0.330	-8.53e-07	2.54e-06
Low Income countries	26.85606	6.356358	4.23	0.000	14.39782	39.31429
Lower Middle Income countries	21.26226	5.308724	4.01	0.000	10.85735	31.66717
newstate	-.6812396	.6814326	-1.00	0.317	-2.016823	.6543437
Distance coastline (km)	-.0010314	.0007331	-1.41	0.159	-.0024683	.0004056
polity1	.1246423	.0607745	2.05	0.040	.0055263	.2437582
Log no. affected by drought, 1970-79	-.5540491	.080078	-6.92	0.000	-.710999	-.3970991
polity1 x Log no. affected by drought	-.0933558	.0122752	-7.61	0.000	-.1174148	-.0692968
_cons	-28.25127	4.48427	-6.30	0.000	-37.04027	-19.46226
/lnalpha	4.230443	.2802687			3.681127	4.77976
alpha	68.74769	19.26783			39.69108	119.0757

- Neither population density nor its square influence deaths.
- Deaths are higher in both Low Income and Lower Middle Income countries- relative to the default category. In fact, the coefficient of Low Income dummy is larger than that of Lower Middle Income dummy, implying higher mortalities in the former.
- Whether countries that became independent in more recent years performed as well as others or no worse than others in preventing deaths.
- Nor did distance from a coast have any effect on mortality.
- The larger the numbers affected in the preceding decade, the fewer were the deaths.
- Polity 1 and its interaction with numbers affected during the period 1970-79 are considered for two reasons: one is accountability and the other is learning from past experience of droughts. While the coefficient of Polity is positive, it is compensated by the effect of the interaction term, implying that

the overall effect of democracy is mortality reducing[31]. So when the effect of democracy is assessed-taking also into account the more rapid learning from past experience- there is a mortality decreasing effect of democracy (as illustrated in the simulations below). The overall effect is, however, weak. One possibility is that democracy at the national level is not such a good approximation to state capacity in preventing deaths from droughts-through, for example, speedy relief in remote areas-except perhaps over specific ranges of the former. This is elaborated below[32].

Our case studies drew attention to the unavoidable option of food imports when droughts occur. The adequacy of food imports and speedy distribution among the needy determine how many lives were saved.[33] As an instrumented measure of openness is available for a sub-sample of countries for the early 1990s, we test whether the residuals from the negative binomial regression in Table 9 are systematically related to openness[34]. Specifically, we test whether residual deaths are fewer in a more open economy. Or, given the predicted deaths, are the actual lower. The results are given in Table10. Two points may be noted. First, we present the robust regression results. Second, given the non-linearity between deaths and openness, we have used both an IV measure of openness and its square as right side variables in the regression of residual deaths. The results are as hypothesized. Residual deaths are lower in a more open economy but the effect weakens with higher openness.

Table 10
Residual Deaths and Openness[35]

Robust regression — Number of obs = 1260; F(2, 1257) = 37.92; Prob > F = 0.0000

Deviations of log of deaths from the trend	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Measure of openness	-.1584372	.0241492	-6.56	0.000	-.2058143	-.1110601
Square of Measure of openness	.0195676	.002882	6.79	0.000	.0139136	.0252217
_cons	.313895	.050501	6.22	0.000	.2148195	.4129706

[31] Two observations may be helpful. (i) As there were no drought related deaths during 1970-79, we were forced to rely on numbers affected as an approximation to the deadliness of droughts in the past despite their unreliability. (ii) Since there is a monotonic relationship between numbers affected and their logarithmic values, we use the two interchangeably for expositional convenience.

[32] We are grateful to R. Steckel and Cormac O' Grada for suggesting an examination of sub-national levels of government.

[33] For a more precise proposition, see Ravallion (1997).

[34] For details of the IV estimates of openness, see Gaiha and Imai (2008).

[35]
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         Variables: fitted values of rldeath_dr7
         chi2(1)      =   320.46
         Prob > chi2  =   0.0000
```

In an earlier section, attention was drawn to likely reporting errors in number of deaths- especially given the fact that droughts are slow-onset events that sometimes take two-to - three years to wreak havoc. While the test reported below is far from conclusive, it does point to the better coverage of deaths where newspaper circulation is high, as also higher regression residuals. But this weakens with higher circulation of newspapers, as implied by the significant negative coefficient of the square of this variable.

Table 11
Residual Deaths and Newspaper Circulation[36]

Robust regression — Number of obs = 1155; F(2, 1152) = 76.37; Prob > F = 0.0000

Deviations of log of deaths from the trend	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Mean newspaper circulation	.0002152	.0000211	10.20	0.000	.0001738	.0002566
Square of mean newspaper circulation	-1.19e-06	1.59e-07	-7.44	0.000	-1.50e-06	-8.74e-07
_cons	-.0106984	.0004593	-23.29	0.000	-.0115995	-.0097972

Hence underreporting of deaths in extremely poor countries with limited exposure to mass media cannot be ruled out.

Simulations

A brief and selective discussion of simulation results based on the specification in Table 9 is given here. We consider three scenarios: one in which droughts are less deadly simply because donors, governments and local communities learn to better prevent fatalities (e.g. through quick and effective relief in areas that are worse affected and relatively deprived, as in the Maharashtra drought of 1970-73). In the second scenario, the presumption is that learning constrained by limited resources for drought relief may save fewer lives. In the third scenario, we examine the implications of increasing the mean Polity 1 values of countries in the range (-5-0), and in the range (0-5). As the endogeneity of democracy is hard to model, we treat the values as given[37]. For the first scenario, we assume hypothetical reductions in the coefficient of droughts in the mortality equation- 10 per cent, 20 per cent and 30 per cent. Clearly, there are different

[36] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
```
        Ho: Constant variance
        Variables: fitted values of rldeath_dr7
         chi2(1)      =   829.83
        Prob > chi2  =   0.0000
```

[37] For the results of a descriptive exercise of how the Polity scores have evolved over time, see Table A.1.4 in Annex A.1A.

possibilities of learning and different ways of capturing them[38]. The second scenario is also constructed on somewhat simplistic, if not arbitrary, assumptions-specifically, the higher the per capita income level, the greater is state capacity for saving lives in a drought[39]. This is admittedly an oversimplification as the efficacy of drought relief may be linked to not just accurate identification of the needy but also transparency and accountability of relief agencies. In the third scenario, we assume hypothetical increases in the mean Polity scores of 10 per cent and 50 percent, respectively. These simulations offer useful insights. Specifically,

- Even with moderate learning-10 to 20 per cent reductions in the coefficients of deadliness of droughts-more than proportionate reductions in deaths are likely.
- Even if 10 Low Income countries move up into the next higher group of Lower Middle Income countries-through, for example, macro policy reforms or development assistance conditional on policy reforms-the reduction in deaths would be enormous-about 49 per cent.

Table 12
Simulations of Reduction in Deaths

Scenarios	Reduction in Deaths (%)
Learning	
10 % Reduction in Deadliness of Droughts	-20.55
20 % Reduction in Deadliness of Droughts	-36.87
30 % Reduction in Deadliness of Droughts	-49.84
Capacity Building	
10 Low Income countries move up	-49.03
20 Low Income countries move up	-74.02
Improvement in Polity	
10 % Increase in Polity Mean (-5-0)	-3.71
50 % Increase in Polity Mean (-5-0)	-17.21
10 % Increase in Polity Mean (0-5)	-4.66
50 % Increase in Polity Mean (0-5)	-21.22

[38]It is arguable that the lower coefficient of droughts reflects simply less severe droughts over time. This is plausible but unlikely in view of the control for geographic, population density and a lagged measure of severity of droughts (i.e. the numbers affected during 1970-79). However, the possibility of adaptation by worst-hit communities to food deprivation-an explanation related to the Darwinian conjecture-by forming of more efficient consumption habits, improving storage facilities, or discovering efficient substitutes for grains is not unlikely. In fact, following the famine in China in 1959-61-the worst in recent history as 30 million excess deaths occurred during this period (Ashton et. al (1984)-the death rate returned to normal within a year due to such adjustments (Lin and Yang, 2000).

[39] Kellenberg and Mobarak (2008) argue that for risk-averse individuals below some threshold level of consumption 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 level in the lower part of the income distribution. Above that consumption threshold, the same citizen may choose to spend the marginal dollar of income on disaster mitigation, and, at this point, disaster risk would fall with rising incomes. Extending this reasoning to countries, it is hypothesized that disaster risk rises with income levels in very poor countries but its slope reverses in richer countries. Using cross-country panel data, they show that for the types of disasters whose exposure risk is more closely related to behavioural choices (e.g., floods, landslides rather than extreme temperatures) there is a non-linear relationship where disaster deaths increase with rising income before they decrease. Apart from overstatement of the role of individual choice, especially because disaster damage mitigation is a public good, the empirical analysis fails to distinguish between the roles of governments and individuals.

- In sharp contrast, and subject to the caveats about measurement of democracy, with a 10 per cent higher mean value of Polity 1 among the least democratic countries (in the range (-5-0), there is hardly any reduction in deaths. With a 50 per cent higher mean, there is, however, a moderate reduction in mortality. The effects are slightly better for the moderately democratic countries (0-5 range) but far from impressive.

Even if these results are not acceptable at face value-indeed, there are strong grounds for scepticism-a combination of learning with more resources for drought relief may help avert a large fraction of deaths. These findings are broadly consistent with the insights from the case studies reviewed earlier- specifically, fatalities are often greater in countries/regions with weak governments and pervasive poverty[40].

Droughts, Governments, and Relief

(a) Comparisons

That much of the devastation due to droughts is avoidable is illustrated by Botswana[41]. In 1986, it was in its fifth consecutive year of drought- a record similar to that of a Sahelian country. Yet no one died from starvation, although two thirds of its population were dependent on drought relief[42].

Botswana is located in the southern hemisphere equivalent of the Sahel region of Africa, at the edge of the Kalahari desert, and is thus equally vulnerable to droughts[43]. However, unlike the Sahelian countries, Botswana has a highly democratic political regime and a comparatively efficient administration. Also, it has enjoyed a growth rate estimated as one of the highest in the world[44]. But the growth has been highly uneven. 1981-2 marked the beginning of a prolonged and severe drought which lasted until 1986-7.

By 1981-2, Botswana had set up an entitlement protection system, an outcome of a long

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[40] In a meticulous but somewhat cryptic comment on drought-linked mortality in the Sahel, Hill (1989) makes the following observations: (i) excess mortality estimates are often exaggerated; (ii) advances in transportation and communication networks have facilitated speedier and more effective relief; (iii) while greater involvement of governments and donors in mitigating distress has helped avert fatalities, the changes in the exposure of the communities in areas prone to droughts are mixed, if not uncertain, as the buffers provided by local communities have weakened, if not destroyed altogether. Some of these observations are generalisable to other developing countries with contextual adaptation.

[41] Botswana's success in damage mitigation stands out in an admirably comprehensive comparison of droughts/famines in Zimbabwe, Kenya, and Cape Verde in Dreze (1990b).

[42] These draw upon Dreze (1990 a, b).

[43] As a land-locked country experiencing rapid population growth, ecological degradation and shrinking food production, Botswana bears a high degree of similarity to the Sahelian countries highly vulnerable to droughts and famines.

[44] Much of the rapid growth was due to the expansion of diamond mining which mattered little to the rural poor.

process of experimentation, evaluation and learning, during its earlier famine relief efforts in the 1960s and the 1970s. An important lesson learnt was that the strategy of 'direct delivery' of food into the affected areas and its distribution among the destitute was considerably hampered by transportation constraints. Food deliveries in different parts of the county matched poorly with the extent of distress. Food allocation within the rural population was largely indiscriminate because selective food distribution was 'socially divisive'. However, subcontracting to the private sector produced promising results. While a large- scale famine was averted, the relief operations did not succeed in preventing increased malnutrition, excess mortality or even starvation deaths.

- Given the accountability of the ruling party to the electorate, activism of the opposition, vigilance of the press and pressure from the affected population, it is not surprising that early action was forthcoming during the drought of 1981-2. The areas of public action included (i) restoration of adequate food availability, (ii) large- scale provision of employment for cash wages, and (iii) direct food distribution among selected groups.[45]
- The famine prevention system relied on a combination of adequate political incentives and insightful administrative guidelines. In spite of the 1982-7 drought being more prolonged and severe than that of 1979-80, the extent of human suffering was small as evidenced by no starvation deaths or distress migration on any significant scale. Children's nutritional status deteriorated but marginally and temporarily, and the decline in suffering among the disadvantaged was dramatic. Drought measures successfully prevented human suffering and also preserved the productive potential of the rural economy.
- Several components of drought relief – food distribution among the vulnerable groups, rehabilitation of malnourished children and financial assistance to the destitute- have become a permanent and integral part of Botswana's social security system.

In sum, this approach to the protection of entitlements during crises has much to commend in terms of administrative flexibility, likelihood of early response, simplification of logistic requirements, and ability to elicit broad political support.

A comparison of two droughts in India further illustrates the difference that public action makes[46].

A widespread drought hit the country consecutively in 1965-6 and 1966-7, and a terrible famine was widely predicted. However, while there was some success in preventing it, few states suffered considerable devastation. Bihar was one.

- Massive food imports were undertaken under the American PL-480 programme, and an internal 'zoning' policy was in force to facilitate procurement from surplus

[45] The drought relief programme as a whole went beyond these measures of short term entitlement protection. Public intervention was also very significant in areas such as the provision of water and the promotion of agricultural recovery (Dreze, 1990 b).
[46] This draws upon Dreze (1990 a).

zones –presumably to transfer this to deficit zones[47]. Further, traditional relief measures –relief works and unconditional relief – were undertaken.

- Foodgrain availability declined precipitously in 1966-67-the reduction was about 30 per cent of the 'normal'. Also, foodgrain intake recorded an equally sharp decline. Numerous eye-witness accounts of people eating wild leaves and roots, picking pieces of grain from the dust around railway sidings, undergoing appalling 'skeletonization', and starving to death testify to the severity of food deprivation (Dreze, 1990 a).
- There was acute and widespread malnutrition, and alarming excess mortality. The death rate was 34% higher in 1967 than in 1968. Infant mortality was twice as high.
- Bihar alone accounted for almost half of the all-India total of 2353 officially acknowledged 'starvation deaths'.
- There was a pronounced maldistribution of hardship across areas more or less severely affected by crop failure, and the peak of hardship occurred towards the end of 1966 (before the beginning of large- scale relief operations), and subsided considerably in the following weeks.

A key question is: were all these disastrous outcomes the inevitable consequence of an extremely precarious situation, or did they partly betray a failure of the relief system? On the basis of the available evidence, the latter cannot be ruled out.

- Famine was 'declared' in Bihar on 20 April, 1967, which was late by any criterion. Though relief operations did take place before the declaration, they were rather *ad hoc*. All that the declaration did was to intensify the *ad hoc* measures.
- The delay was political and closely connected to the general election of February 1967. The belated and *ad hoc* response was correctable.
- According to the Bihar Famine Code, employment through small-scale village works is a key element of the relief system. In fact, however, free-feeding programmes dominated. Whether there was large-scale withdrawal of labour supply from public works as a consequence of these programmes is unlikely, given the severity of distress (food deprivation, nutritional damage, excess mortality, distress sale of assets). What is more plausible is that the state government failed to honour the 'employment guarantee'. Dreze (1990 a) is emphatic that "the Bihar government …not only delayed the application of the Famine Code, but also violated one of its most crucial provisions throughout the crisis" (p.63).
- The zoning restrictions on private trade in food across different states aggravated food deprivation. These restrictions -equivalent to a tax on private trade in food across different states in a competitive market-amplified the food price dispersion. In fact, the dispersion of wheat prices reached an all-time high for the post-independence period precisely during the 1965-67 drought.

[47] Private trade in foodgrains across broad zones within the country was prohibited.

Let us contrast this with the Maharashtra experience of famine prevention during 1970-73. This comparison sheds additional light on how entitlement protection through various measures-specially public works- helped redistribute the hardships and successfully prevented the drought from turning into a famine (Dreze, 1990 a).

At the onset of the 1970-3 drought, Maharashtra faced problems of agriculture decline similar to Bihar- stagnant yields, and rapidly increasing population, leading to a marked downward trend of per capita food production. This turned into a disastrous crash in the early 1970s with three successive droughts. The devastation, however, was considerably less severe than expected, given the near complete collapse of agricultural incomes, employment and wages in many areas for a prolonged period. Mortality rose only marginally, if at all. Although loss of livestock was considerable, disposal of other assets was small and migration was moderate.

- During 1972-73, as inter-state movement of foodgrains on private account was banned, the Food Corporation of India (FCI) organised distribution of foodgrains through fair price shops (under the Public Distribution System or PDS). However, the actual allocation fell considerably short of requirements. Meanwhile, the purchasing power injected by huge public works programmes inflated food prices, widening inter-state dispersion. As the profitability of private food trade grew, illegal smuggling of food increased.[48] As a result, there was a surprising evenness of the distribution of cereal intake across different groups and districts. The protection of the productive base took precedence over the protection of consumption standards. This is striking as famines are generally believed to exacerbate existing inequalities.[49]
- Further investigations reveal that during the drought (i) the distribution of *current incomes* was considerably more equal than in a normal year; (ii) there was much greater equality in *current expenditure*; (iii) greater equality was the outcome of reduction in *average* real incomes and expenditure; and (iv) the latter was due to the combination of a dramatic loss of output (pushing most households into the ‘food deficit’ category) and sharply rising prices.
- The observed changes in income distribution are not difficult to understand. In an ordinary year, large cultivators reap the profits of better endowments. In a drought year, by contrast, ‘net profits’ per acre drop to very low- even negative –values. What happens to the distribution of income then depends largely on whether or not cultivators in different landholding size- groups join the relief works (when they exist). However, when droughts continue for several years in succession, cultivators gradually lose their resilience and start flocking to public works in increasing numbers. This is precisely what happened in Maharashtra in 1972-3. As a result, the distribution of current incomes was much less unequal than in a normal year.
- It is of course not easy to predict how pronounced declines in current income translate into expenditure declines across different groups, given the protective roles of credit and insurance. During droughts, the effectiveness of insurance mechanisms is considerably eroded. In particular, the strategy of temporarily depleting assets to

[48] Official agencies tacitly colluded for fear of social unrest (Dreze, 1990 a).
[49] For an exposition of the link between poverty and inequality-in the context of a supply shock (e.g. drought)-see Dasgupta (1987).

preserve ordinary consumption standards becomes extremely costly as widespread sales drive asset prices down[50]. Understandably, therefore, droughts in India do entail large cuts in household expenditures, not only for labourers but also for small and large cultivators. Moreover, the evidence suggests that propertied classes displayed a stronger inclination to protect their asset base. This explains, among other reasons, why household consumption expenditure (in food intake) during the peak year of the drought was remarkably constant over a wide range of landholding sizes. Thus, even when some reduction of aggregate consumption appears inevitable, there is no reason why the burden of readjustment should necessarily fall on the most vulnerable groups. In principle, suitable income support measures (e.g., employment generation) can succeed in protecting their consumption levels. Besides, food consumption is widely responsive to price changes, if only through income effects. Hence, as long as the food deficit is not too large, income support policies for the most vulnerable groups are likely to redistribute the burden of consumption reduction over a broad section of the population.

- By any criterion the drought of 1970-3 in Maharashtra marked an all time record for the scale and reach of public works programmes in a drought relief operation[51]. The resilience of public works as the main income transfer mechanism ensured both a sharp concentration of resources on the needy (the targeting objective)[52] and, perhaps more importantly, the provision of a nearly universal protection against starvation (the security objective). Thus, prompted by public pressure, public works helped avert a huge tragedy in Maharashtra (Dreze, 1990 a).

As argued later, while the case for entitlement protection is persuasive, the longer-term potential of accelerated agricultural growth through better rural infrastructure, technology and agricultural research ought not to be overlooked.

(b) Are Governments Punished for Their Failure?

The simulations, discussed earlier, point to the conditions under which democracy helps avert mortality. What the results show is that if and when numbers affected (in this case in the initial period or 1970-79) were large overall mortality reduction increases with higher Polity scores. This of course implies but does not pinpoint the mechanisms through which democratic regimes do so. Does it imply greater drought relief? Does greater relief improve chances of electoral success? Underlying the latter is an issue whether rational voters punish elected representative for disasters beyond their control (e.g., floods, droughts)? A related issue is whether responses of governments vary between extreme and moderate catastrophic events? These and related issues are analysed

[50] In a survey conducted in Ethiopia, Seaman et al. (1978) report a jump of food grain prices of about 200 per cent while livestock prices plummeted due to distress sales by herdsmen. So the value of livestock relative to grain was drastically reduced. For example, the value of an adult camel dropped from 17 quintals of maize before the drought to 5 quintals in mid-1974.

[51] Nearly five million labourers attended relief works every day at the peak of employment in May, 1973.

[52] Unlike the usual participation of agricultural labourers (and marginal or small farmers in non- irrigated areas), participation of large farmers who are notoriously reluctant to join the crowd of lesser mortals on relief works, also eventually did so, driven by acute hardship in the Maharashtra drought (Dreze, 1990 a).

using district level data for India by Cole et al. (2009). The motivation stems from Sen's (1999) observation that democracies are better at responding to " ..those disasters that are easy to understand and where sympathy can take a particularly immediate form than to less salient deprivation" (p. 154).The methodology is both innovative and rigorous and the findings are plausible and illuminating. A summary is given below, followed by a few critical remarks.

Three key relationships and their variants are estimated with district level data over the period 1977-1999. The first is a relationship between yields and weather that allows for fixed district and year effects. Two measures of rainfall proxy for weather (one, for example, is normalised rainfall, $\frac{Rain_{dt} - \overline{Rain_d}}{S_d}$, where $Rain_{dt}$ is millimetres of rainfall in a district during the *kharif* season, $\overline{Rain_d}$ is the average (district) *kharif* rainfall, and S_d is the standard deviation of annual *kharif* rainfall)[53]. The relationship between normalised rainfall and outcomes need not be linear, and accordingly a quadratic form is also used. The second relationship is between rainfall and relief, with one year lag. (As the relief expenditure data are available at the state level, this regression is run at the state level). Log of state expenditure on relief is regressed on total state spending (excluding relief expenditure), state and fixed year effects. The third is a relationship between weather and voting. The dependent variable is the vote share in a constituency for the candidate from the incumbent ruling party, and the right side variables include rainfall in t-1, and fixed district and year effects. The main findings are summarised below.

- All specifications confirm a strong relationship between rainfall and agricultural output. On average, a one standard deviation increase in rainfall results in a 3-4 per cent increase in the value of the output. With a quadratic rainfall variable, revenues rise upto an optimal level. The adverse effects of rainfall deficiency are not confined to land owners. As the demand for agricultural labour varies with rainfall, available evidence suggests that wage workers suffer sharp reductions in wages (Jaychandran, 2006).
- More rain, on average, is associated with less disaster relief. When a squared term for rainfall is included, extremely low rainfall leads to higher amounts of drought spending. Specifically, as rainfall moves one standard deviation away from the optimum, disaster spending rises by 18-25 percentage points.
- The coefficient on rain is positive and significant across all specifications of vote share of the ruling party; the coefficient on the quadratic term is negative and significant. With year and district fixed effects, rainfall one standard deviation away from the optimum causes a drop of more than 3 percentage points in the ruling party vote. Interestingly, using standard deviation from optimum rain with year and district

53 The second measure is the absolute deviation of normalized rainfall from the district optimum: This is meant to represent the degree to which rain varies from the optimal amount, measured in standard deviations from the district mean. $\left[\frac{Rain_{dt} - \overline{Rain_d}}{s_d} - 1\right]$.

effects, the ruling coalition suffers a loss of 4.2 percentage points when it controls the constituency, compared to a penalty of 1.8 for politicians not affiliated with the incumbent party.

- In a variant that includes an interaction term (weather is interacted with relief), an attempt is made to check whether voters condition their response on how well politicians respond to extreme weather. The results confirm that voters reward politicians for disaster spending in response to extreme weather. A party which responds to bad rainfall with an average increase in disaster spending will gain about 0.52 percentage points of vote share compared to a coalition that does not increase its disaster response when the weather shock occurs. Since a one deviation worsening in weather costs the ruling party 3.25 percentage points of the vote share on average, failing to respond leads to a cost of 3.77 percentage points. In brief, the weather hurts even when there is a vigorous response, but less than without it.
- A related issue is whether voters are more sensitive to government responsiveness to major crises than they are to moderate ones. Defining bad weather as rainfall in the 80^{th} or 90^{th} percentiles away from the optimal amount, and extreme weather as rainfall in the 90^{th} to 100^{th} percentiles away from the same benchmark, it is reported that bad weather (relative to the omitted category of good weather) results in a 16 per cent increase in relief spending as against a much greater response of a 57 per cent increase during bouts of extreme weather. So what this analysis points to is that, while governments respond to both bad and extreme weather, there are large responses only in cases of the latter.
- Finally, this analysis also confirms that voters are twice as sensitive to relief spending during extreme weather as they are to relief spending during bad weather. Voters thus punish the ruling coalition for events beyond a government's control, but respond much more to government action during a severe crisis than in a less severe one.

In sum, the 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 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. (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.

(c) Severity of Droughts and Local Institutions

A comparative review of drought mitigation in Kalahandi (Orissa) and Purulia (West Bengal) by Banik (2007) extends in important ways an earlier comparison of droughts in Bihar and Maharashtra (Dreze, 1990 a).

Orissa and West Bengal present a striking contrast in terms of both prevalence of and responses to starvation. Kalahandi is widely regarded as a district with the worst record of starvation. In fact, in the last few decades it has experienced recurrent droughts and food crises. The 1993 drought, for example, affected thousands of people and about 500 people starved to death.

Purulia is one of the most backward districts of West Bengal. Most of the villages suffer from water scarcity and food shortage when the monsoon rains are erratic. However, despite recurrent droughts, and high population density, no starvation death has been reported.

Banik (2007) offers an explanation of difference in starvation deaths in terms of democracy and public action. Concurring with Sen (1981) that democracy and public action –including an independent press-have helped avert famine in India, he draws attention to a mixed picture on India's ability to prevent starvation deaths. There are of course difficulties in defining such deaths. Besides, most of these occur in rural-often remote-areas, far removed from the seats of power. Given this relative invisibility, severe malnutrition causing death is often not seen as a crisis and not surprisingly does not get the attention reserved for famines.

The contrast between Purulia and Kalahandi is instructive, as it illustrates that within the Indian democratic regime there are marked differences in the ability to prevent starvation deaths. In Purulia, there seems a consensus that, despite widespread malnutrition, starvation deaths must be prevented. Competitive political parties and vigilant village panchayats act not just as conduits of information on distress but also pressure district administration to take appropriate action. Banik (2007) thus observes "…..the role of local parties….and effective structures of decentralized government is crucial" (p.308). But these were conspicuous by their absence in Kalahandi. Far from complementing each other, institutional interactions were one of mutual suspicion and lack of cooperation among bureaucrats, political parties and the press. A strong political opposition does not guarantee effective action against starvation- especially if it remains preoccupied with undermining the ruling party and in hurling accusations at it which are conveniently denied. Poorly paid local journalists have no incentive for investigative reporting and frequently sensational reports in the print media lack political credibility as these are owned by prominent politicians.

Droughts, Food and Prices

Our case studies drew attention to the devastating effects of droughts on agricultural and food production, and the loss of food entitlements of various groups living on the margin of subsistence through lower wages and higher food prices. We have supplemented this review with econometric analysis.

(a) Agricultural Productivity and its Growth

Agricultural productivity is measured by agricultural value added in constant prices per hectare of arable land.

Table 13
Determinants of Agricultural Productivity[54]

Robust regression — Number of obs = 1475; F(20, 1454) = 117.86; Prob > F = 0.0000

Agricultural value added per hectare of arable land (avpal)	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Mean rainfall 0-500	-351.6813	41.5801	-8.46	0.000	-433.2447	-270.1179
Mean rainfall 500-1000	-325.6763	42.47928	-7.67	0.000	-409.0035	-242.3491
Mean rainfall 1000-2000	-217.8083	30.77754	-7.08	0.000	-278.1814	-157.4351
rain deficit > 10%	38.89903	24.00282	1.62	0.105	-8.184825	85.98289
Arable land area<.5m	128.1817	33.84882	3.79	0.000	61.78397	194.5794
Arable land area .5-2.5m	424.3404	28.13962	15.08	0.000	369.1418	479.539
Arable land area 2.5-5m	240.3858	28.34102	8.48	0.000	184.7922	295.9795
Low Income countries	-463.5024	46.38501	-9.99	0.000	-554.4911	-372.5138
Lower Middle Income countries	-122.127	47.37885	-2.58	0.010	-215.0652	-29.18876
elevation dummy < 300	-308.4887	29.96733	-10.29	0.000	-367.2725	-249.7049
elevation dummy 300-600	-7.345977	25.57739	-0.29	0.774	-57.5185	42.82655
elevation dummy 600-900	30.78165	31.26477	0.98	0.325	-30.54723	92.11053
Soil suitability	1.948516	1.335484	1.46	0.145	-.6711642	4.568197
Distance coastline (km)	-.2246219	.0299547	-7.50	0.000	-.2833811	-.1658628
(Low) Predicted number of droughts (dummy)	156.9383	42.40955	3.70	0.000	73.74786	240.1287
polity1 score <(-) 5	56.78448	31.81425	1.78	0.074	-5.62225	119.1912
polity1 score (-) 5 to 0	142.2928	35.56918	4.00	0.000	72.52042	212.0652
polity1 score (-) 0 to 5	-53.55735	32.03477	-1.67	0.095	-116.3967	9.281947
Persons/ km2	.956944	.0483396	19.80	0.000	.8621211	1.051767
Square of persons/ km2	-.0002881	.0000176	-16.39	0.000	-.0003226	-.0002536
_cons	796.63	61.40669	12.97	0.000	676.1748	917.0852

[54] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of avpal
chi2(1) = 899.47
Prob > chi2 = 0.0000

Incremental values are defined as log avpal $_t$ -log avpal $_{t-1}$ (denoted as gr_avpal). This is also referred to as growth of agricultural productivity.

Let us first consider the specification in Table 13. We confine our discussion to robust regression results. The subsequent specifications used differ in so far as income level dummies are replaced by shares of land in tropical and dry temperate conditions, and by regional dummies. As may be inferred from the results in Tables 13-15, most of the *key* relationships are robust to alternative specifications.

The main findings from Table 13 are as follows:

- As expected, the lower ranges of average rainfall are associated with significantly lower agricultural productivity, relative to the default category of rainfall. However, rain deficit years are associated with higher productivity..
- Each of the arable land area dummy has a significant positive effect on agricultural productivity, implying higher productivity relative to the default case. So productivity is higher in lower ranges of arable land area, controlling for other effects.
- Not surprisingly, agricultural productivity is also lower in Low Income and Lower Middle Income groups, relative to the default case.
- Out of the three elevation dummies, only the first has a significant negative coefficient, implying lower productivity than in the default case. Or, productivity is lower in the lowest range of elevation.
- While soil suitability has a positive but non-significant effect on productivity, the distance from a coast has a negative effect.
- Controlling for these and other effects, the dummy for low or negligible frequency of drought has a positive effect on productivity, relative to the default category of (more frequent) droughts[55]. What is important is that this effect remains intact in different specifications.
- Whether democratic regimes tend to promote agricultural productivity is corroborated except that at lower ranges the coefficients are positive, and for the third Polity dummy it is negative[56]. The implications are that at lower ranges the productivity is higher relative to the highest range of Polity, while it is lower in moderately democratic regimes. These results are counter-intuitive. With alternative specifications, however, the relationship between democracy and productivity changes, as discussed below.
- The relationship between population density and productivity is positive but it weakens with higher densities. That higher density economies rely on more labour- intensive technologies associated with higher productivity per hectare is plausible.

[55] The dummy takes the value 1 if the predicted frequency of droughts < 0.05, and 0 otherwise.
[56] Note that the Polity index is the net democracy score. For details, see Polity IV, Centre for International Development and Conflict, University of Maryland.

As shown in Table 14, when income level dummies are replaced by shares of land in tropical and temperate conditions, some results gain in plausibility. The rainfall effects are similar to those in Table 13, as also those of arable area dummies; not surprisingly, the shares of land in tropical and dry temperate conditions are associated with lower productivity; the elevation effects are similar except that the coefficient of the third dummy is negative too, implying significantly lower productivity at lower elevations, relative to the default category; soil suitability does not have a significant effect while the distance from a coast continues to have a negative effect on productivity; the positive effect of low frequency of droughts is again corroborated (or, by implication, the negative effect of greater frequency of droughts); what is indeed striking is the reversal of the effects of the dummies for different ranges of democracy-each of the three dummies has a significant negative effect on productivity, implying higher productivity in the default case of highest range of democracy; and, finally, the non-linear relationship between population density and (log of) productivity is further corroborated.

When income dummies are replaced by regional dummies, many of the key relationships remain intact, as shown in Table 15. Each of the three regional dummies-for South Asia, Middle East and North Africa- has a significant negative effect on agricultural productivity, relative to the default category of all other regions (including Latin America and the Caribbean, East Asia and the Pacific, and Europe and Central Asia). The positive effect of low or negligible frequency of droughts on agricultural productivity is confirmed again. However, the relationship between democracy and productivity is not so robust, as the coefficient for the second dummy is positive and that for the third is negative. Besides, there are two other counter-intuitive results: (i) the positive effect of rain deficit years, and (ii) the negative effect of soil suitability on productivity.

Table 14
Determinants of Agricultural Productivity[57]

Robust regression

Number of obs = 1475
F(20, 1454) = 92.14
Prob > F = 0.0000

Agricultural value added per hectare of arable land	Coef.	Std. Err.	t	P> t	[95% Conf.	Interval]
Mean rainfall 0-500	-269.4818	42.68545	-6.31	0.000	-353.2135	-185.7502
Mean rainfall 500-1000	-131.9654	45.73593	-2.89	0.004	-221.6808	-42.24991
Mean rainfall 1000-2000	-191.9788	31.63369	-6.07	0.000	-254.0314	-129.9263
rain deficit < 10%	30.31209	23.64314	1.28	0.200	-16.06623	76.6904
Arable land area<.5m	135.7416	34.45462	3.94	0.000	68.15554	203.3277
Arable land area .5-2.5m	306.2287	28.39416	10.78	0.000	250.5308	361.9266
Arable land area 2.5-5m	190.016	28.96679	6.56	0.000	133.1948	246.8372
zdrytemp	-570.7023	79.82644	-7.15	0.000	-727.2896	-414.115
ztropics	-352.8862	54.27152	-6.50	0.000	-459.3451	-246.4274
elevation dummy < 300	-320.7702	34.82742	-9.21	0.000	-389.0876	-252.4529
elevation dummy 300-600	-3.954796	26.74519	-0.15	0.882	-56.41807	48.50848
elevation dummy 600-900	-144.7879	32.15043	-4.50	0.000	-207.8541	-81.72174
Soil suitability	.0830466	1.496154	0.06	0.956	-2.851805	3.017899
Distance coastline (km)	-.3622333	.0289822	-12.50	0.000	-.4190847	-.305382
(Low)Predicted no. droughts	126.0898	28.92702	4.36	0.000	69.34663	182.8329
polity1 score <(-) 5	-189.913	29.758	-6.38	0.000	-248.2862	-131.5398
polity1 score (-) 5 to 0	-81.73685	32.61718	-2.51	0.012	-145.7186	-17.7551
polity1 score (-) 0 to 5	-205.2272	32.13651	-6.39	0.000	-268.2661	-142.1883
Persons/ km2	.8638849	.0489361	17.65	0.000	.767892	.9598778
Square of persons/ km2	-.0002411	.0000178	-13.56	0.000	-.000276	-.0002063
_cons	915.7814	59.46144	15.40	0.000	799.142	1032.421

[57] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of avpal
chi2(1) = 703.93
Prob > chi2 = 0.0000

Table 15
Determinants of Agricultural Productivity[58]

Robust regression

Number of obs = 1475
F(21, 1453) = 109.05
Prob > F = 0.0000

Agricultural value added per hectare of arable land	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Mean rainfall 0-500	-161.8136	47.60924	-3.40	0.001	-255.2038	-68.42336
Mean rainfall 500-1000	-210.6096	41.0504	-5.13	0.000	-291.1339	-130.0852
Mean rainfall 1000-2000	-138.2416	30.21444	-4.58	0.000	-197.5102	-78.97301
rain deficit > 10%	42.14913	22.39775	1.88	0.060	-1.786246	86.08451
Arable land area<.5m	238.3265	33.29932	7.16	0.000	173.0066	303.6464
Arable land area .5-2.5m	291.7415	26.41517	11.04	0.000	239.9256	343.5575
Arable land area 2.5-5m	247.4824	27.32847	9.06	0.000	193.875	301.0899
South Asia	-255.6497	41.98392	-6.09	0.000	-338.0053	-173.2942
Mid. East and No. Africa	-252.3572	54.09954	-4.66	0.000	-358.4788	-146.2357
Sub-Saharan Africa	-443.2039	31.11674	-14.24	0.000	-504.2425	-382.1654
elevation dummy < 300	-373.7055	28.56813	-13.08	0.000	-429.7446	-317.6663
elevation dummy 300-600	-78.40583	25.47787	-3.08	0.002	-128.3832	-28.4285
elevation dummy 600-900	-56.54715	29.56566	-1.91	0.056	-114.5431	1.448789
Soil suitability	-2.438272	1.367849	-1.78	0.075	-5.121441	.2448982
Distance coastline (km)	-.3153151	.0329576	-9.57	0.000	-.3799647	-.2506654
(Low)Predicted no. droughts	137.1711	27.05282	5.07	0.000	84.10438	190.2379
polity1 score <(-) 5	-17.2082	33.88941	-0.51	0.612	-83.68559	49.2692
polity1 score (-) 5 to 0	50.40874	32.90534	1.53	0.126	-14.1383	114.9558
polity1 score (-) 0 to 5	-239.3789	31.9753	-7.49	0.000	-302.1016	-176.6562
Persons/ km2	.8859592	.0477946	18.54	0.000	.7922054	.979713
Square of persons/ km2	-.0002677	.0000173	-15.51	0.000	-.0003016	-.0002339
_cons	885.3947	49.93475	17.73	0.000	787.4428	983.3466

To check whether productivity is underestimated in our (preferred) specification, we regress the residuals on an instrumented measure of openness and its square. The results are given in Table 16.

[58] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of avpal
chi2(1) = 927.95
Prob > chi2 = 0.0000

Table 16
Residuals of Agricultural Productivity and Openness[59]

```
Robust regression                                        Number of obs =    1150
                                                         F(  2,  1147) =    7.95
                                                         Prob > F      =  0.0004

------------------------------------------------------------------------------------
ravpal_dr14                  Coef.   Std. Err.      t    P>|t|      [95% Conf.
                   Interval]
------------------------------------------------------------------------------------
measure of openness      -2662.257   982.8265    -2.71   0.007    -4590.596   -733.9175
Square of measure of      331.5262   117.2485     2.83   0.005     101.4807    561.5717
opennes
_cons                     5327.823   2056.278     2.59   0.010     1293.335    9362.311
```

These results imply that, although productivity residuals are lower in open economies, they are larger in more open ones. This implies higher productivity in more open economies and its underestimation in the specification employed. The only reason we could not incorporate this measure in our productivity regression is that it is endogenous to various factors-especially institutional quality. Since there is only a cross-section of this measure, and the values have changed in the last two decades, inclusion of openness could have distorted the results.

In sum, agricultural productivity is low in countries with negligible or low frequencies of droughts, as also in countries with low or moderate degrees of democracy.

In the next set of regressions, we examine the effects of droughts on growth of agricultural productivity, as specified earlier. To avoid repetition, a selection of results is discussed here.

Let us first consider the results in Table 17.

- Out of the rainfall variables, incremental rainfall and productivity are significantly positively related.
- Each of the three arable land area dummies has a significant negative coefficient, implying lower growth rates relative to the default case.

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[59] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
```
        Ho: Constant variance
        Variables: fitted values of ravpal_dr14
        chi2(1)      =    39.61
        Prob > chi2  =   0.0000
```

Table 17
Determinants of Growth of Agricultural Productivity[60]

Robust regression — Number of obs = 1451; F(20, 1430) = 2.57; Prob > F = 0.0002

Log (avpal)t -log (avpal)t-1	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Mean rainfall 0-500	.0120305	.0079262	1.52	0.129	-.0035178	.0275787
Mean rainfall 500-1000	.0076551	.0085231	0.90	0.369	-.009064	.0243742
Mean rainfall 1000-2000	.0014795	.005861	0.25	0.801	-.0100176	.0129767
rain deficit > 10%	-.0113234	.0043873	-2.58	0.010	-.0199296	-.0027171
Arable land area<.5m	-.0129768	.0064177	-2.02	0.043	-.025566	-.0003876
Arable land area .5-2.5m	-.0119168	.0052919	-2.25	0.024	-.0222976	-.0015361
Arable land area 2.5-5m	-.0062393	.0054106	-1.15	0.249	-.0168528	.0043742
zdrytemp	-.0269997	.0149859	-1.80	0.072	-.0563964	.0023969
ztropics	.0089087	.0101583	0.88	0.381	-.0110181	.0288354
elevation dummy < 300	-.0183899	.0065539	-2.81	0.005	-.0312463	-.0055335
elevation dummy 300-600	-.0197182	.00501	-3.94	0.000	-.0295459	-.0098904
elevation dummy 600-900	-.0074196	.0060095	-1.23	0.217	-.0192081	.0043689
soilsui1	-.0001903	.0002806	-0.68	0.498	-.0007409	.0003602
Distance coastline (km)	-.0000181	5.47e-06	-3.32	0.001	-.0000289	-7.42e-06
(Low)Predicted no. droughts	.006228	.0054085	1.15	0.250	-.0043814	.0168374
polity1 score <(-) 5	.0030338	.0055401	0.55	0.584	-.0078338	.0139015
polity1 score (-) 5 to 0	-.0029742	.0060773	-0.49	0.625	-.0148955	.0089472
polity1 score (-) 0 to 5	.0020292	.0059931	0.34	0.735	-.009727	.0137855
Persons/ km2	.000014	9.10e-06	1.54	0.124	-3.85e-06	.0000318
Square of persons/ km2	-6.47e-09	3.31e-09	-1.96	0.051	-1.30e-08	1.45e-11
_cons	.0402042	.0110915	3.62	0.000	.0184469	.0619615

- The higher the share of land in dry temperate conditions, the lower is the growth.
- Both lower elevation dummies (i.e. for the two lowest ranges) have significant negative coefficients, implying lower growth rates relative to the default category.
- The longer the distance from a coast, the lower was the growth rate.
- Controlling for these and other effects, countries with low or negligible frequencies of droughts did not register lower growth.
- None of the Polity dummies had a significant coefficient.

[60] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of gr_avpal
chi2(1) = 60.66
Prob > chi2 = 0.0000

- While population density has a (weakly) significant positive effect on growth of productivity, its magnitude diminishes at higher population densities.
- The overall explanatory power of the specification used, as reflected in the F-statistic, is low but significant.

Table 18
Determinants of Growth of Agricultural Productivity[61,62]

Robust regression — Number of obs = 1451; F(21, 1429) = 2.66; Prob > F = 0.0001

Log (avpal)t -log (avpal)t-1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Mean rainfall 0-500	.0092574	.0093104	0.99	0.320	-.0090061	.0275208
Mean rainfall 500-1000	.0062115	.008001	0.78	0.438	-.0094835	.0219064
Mean rainfall 1000-2000	.0020055	.0058669	0.34	0.733	-.0095032	.0135142
rain deficit > 10%	-.0112105	.0043498	-2.58	0.010	-.0197433	-.0026777
Arable land area<.5m	-.007568	.006491	-1.17	0.244	-.020301	.0051649
Arable land area .5-2.5m	-.0100597	.005143	-1.96	0.051	-.0201483	.000029
Arable land area 2.5-5m	-.0006235	.0053403	-0.12	0.907	-.0110992	.0098522
South Asia	.012512	.0081633	1.53	0.126	-.0035014	.0285254
Middle East and North Africa	-.0054902	.0107019	-0.51	0.608	-.0264833	.0155028
Sub-Saharan Africa	-.0147782	.0061262	-2.41	0.016	-.0267955	-.0027609
elevation dummy < 300	-.011284	.0056078	-2.01	0.044	-.0222844	-.0002837
elevation dummy 300-600	-.0160599	.0049797	-3.23	0.001	-.0258282	-.0062917
elevation dummy 600-900	-.0031997	.0057721	-0.55	0.579	-.0145224	.008123
Soil suitability	-.0006898	.0002689	-2.57	0.010	-.0012172	-.0001624
Distance coastline (km)	-.0000171	6.50e-06	-2.64	0.008	-.0000299	-4.40e-06
(Low)Predicted no. droughts	.0068024	.0052982	1.28	0.199	-.0035908	.0171956
polity1 score <(-) 5	.0100076	.0066473	1.51	0.132	-.0030318	.0230471
polity1 score (-) 5 to 0	.0015172	.00643	0.24	0.813	-.011096	.0141305
polity1 score (-) 0 to 5	-.0023414	.0062484	-0.37	0.708	-.0145985	.0099157
Persons/ km2	8.27e-06	9.29e-06	0.89	0.373	-9.95e-06	.0000265
Square of persons/ km2	-5.07e-09	3.36e-09	-1.51	0.131	-1.17e-08	1.51e-09
cons	.0443048	.009702	4.57	0.000	.0252732	.0633364

When the climatic dummies are replaced by regional dummies, as shown in Table 18, some of the key relationships remain largely unchanged. For example, the inverse relationship between deficit rainfall years and productivity growth remains intact; the

[61] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of gr_avpal
chi2(1) = 101.53
Prob > chi2 = 0.0000

[62] Note that in the OLS without a correction for heteroscedasticity, at low frequencies of droughts growth of agricultural productivity is higher. Details will be furnished on request.

lower ranges of elevation exhibit lower productivity growth; the latter and the distance from a coast are inversely related; and negligible or low frequency of droughts does not influence growth. However, there are a few differences (e.g. a somewhat counter-intuitive result is the negative relationship between soil suitability and growth). Allowing for these effects, Sub-Saharan Africa exhibits a significantly lower growth rate than the default category.

Table 19
Determinants of Growth of Agricultural Productivity[63]

Robust regression — Number of obs = 1451; F(20, 1430) = 2.31; Prob > F = 0.0009

Log (avpal)t -log (avpal)t-1	Coef.	Std. Err.	t	P|t|	[95% Conf.	Interval]
Mean rainfall 0-500	.0077911	.0078206	1.00	0.319	-.0075501	.0231322
Mean rainfall 500-1000	.001346	.0080075	0.17	0.867	-.0143618	.0170537
Mean rainfall 1000-2000	.0005116	.0057773	0.09	0.929	-.0108213	.0118444
rain deficit > 10%	-.0113431	.0045095	-2.52	0.012	-.020189	-.0024972
Arable land area<.5m	-.0130828	.0063844	-2.05	0.041	-.0256066	-.000559
Arable land area .5-2.5m	-.010762	.0053012	-2.03	0.043	-.021161	-.0003629
Arable land area 2.5-5m	-.003186	.0053575	-0.59	0.552	-.0136955	.0073235
Low Income countries	-.0013751	.008772	-0.16	0.875	-.0185825	.0158324
Lower Middle Income countries	-.0004897	.0089455	-0.05	0.956	-.0180374	.017058
elevation dummy < 300	-.0116874	.0056936	-2.05	0.040	-.0228562	-.0005187
elevation dummy 300-600	-.0166751	.004842	-3.44	0.001	-.0261733	-.007177
elevation dummy 600-900	-.0040241	.0059127	-0.68	0.496	-.0156227	.0075744
Soil suitability	-.0003565	.0002531	-1.41	0.159	-.000853	.0001401
Distance coastline (km)	-.0000161	5.73e-06	-2.81	0.005	-.0000273	-4.88e-06
(Low)Predicted no. droughts	.0064779	.0080332	0.81	0.420	-.0092801	.0222359
polity1 score <(-) 5	.003767	.0059914	0.63	0.530	-.0079859	.0155199
polity1 score (-) 5 to 0	-.0025105	.0067437	-0.37	0.710	-.0157391	.0107182
polity1 score (-) 0 to 5	.0024119	.006057	0.40	0.691	-.0094698	.0142935
Persons/ km2	.0000143	9.10e-06	1.57	0.116	-3.53e-06	.0000322
Square of persons/ km2	-6.33e-09	3.31e-09	-1.91	0.056	-1.28e-08	1.59e-10
_cons	.0403089	.0115972	3.48	0.001	.0175596	.0630583

With income dummies in Table 19, similar results are obtained. Rain deficit years are associated with a lower growth of productivity, as also lower ranges of arable land area. However, somewhat surprisingly, there is no relationship between income level dummies and growth. Nor do low frequencies of drought matter. Population density has a weakly

[63] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of gr_avpal
chi2(1) = 56.94
Prob > chi2 = 0.0000

significant positive effect on productivity growth but this effect is lower in magnitude at higher population densities.

In sum, the growth regressions are less robust than the level regressions.

(b) Food Production, Prices and Wages

To assess the impact of droughts on food production, we have employed a two-stage procedure. In the absence of food production estimates, we have used the food production index over the period 1980-2004 (with 1999-2001=100). As this index exhibits a time trend, our analysis focuses on deviations from the trend. So in the first stage we fit a non-linear trend:

$$lfprod_{i,t} = \alpha + \beta_1 t80\_04 + \beta_2 tsq + \varepsilon_{it} \quad (5)$$

where lfprod denotes the (log of) food index for country i in year t, t80_04 denotes the year (1 for the first year of the sample, 2 for the second, and so on, during the period 1980-04), *tsq* denotes the square of each year (i.e.1, 2, 3, 4….), and ε is the error term. This is estimated using robust regression[64]. In the next stage, first, the deviations between the actual and estimated food production index i.e. log $Food_{i,t}$ - $\widehat{\log}$ $Food_{i\,t}$ (denoted as rlfprod), is computed. A robust regression analysis of these deviations from the trend in food production is then carried out, based on the following specification:

$$rlfprod_{i,t} = \gamma + \lambda_1 \; pno\_dr\_t7_{it} + \lambda_2 pno\_dr\_tt\ L1_{i1} + \varepsilon_{i,t} \quad (6).$$

where IV estimates of droughts in t and t-1, denoted as pno_dr_t7, and pno_dr_t7 L1, respectively, are obtained from our preferred specification. The results are given in Table 20.

As may be inferred from these results , the effect of a drought on the (deviation of) food production in the same year is negative, as also of that in the previous year. In the absence of imports, food entitlements are likely to decline for fixed nominal wages in rural areas as a consequence of higher food prices.

[64] For estimates of time trends in food production by level of income and by region, see Annex 2.

Table 20
Impact of Droughts on Food Production[65]

Robust regression — Number of obs = 1552; F(2, 1549) = 9.86; Prob > F = 0.0001

Deviation of log of food production	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Predicted no. droughts						
--.	-.1937432	.1176975	-1.65	0.100	-.4246065	.0371201
L1.	-.2111351	.1208579	-1.75	0.081	-.4481974	.0259272
_cons	.0101975	.0103785	0.98	0.326	-.0101599	.0305549

Now let us examine the impact of droughts on food prices. As the food price index also exhibits a time trend, the dependent variable is the deviation from a trend, denoted by, rlfprice (with Food Price Index 2000=100). However, apart from IV estimates of droughts in t and t-1, pno_dr_m4, and pno_dr_m4 L1, respectively, we have also used average rainfall over 1980-2000, $mr80\_00$, its square, $\text{Im}\, rxmr_i$, a dummy variable that takes the value 1 when the rainfall deficit in a year is 10 per cent or more and 0 otherwise, $rain10d$, log of food price index, $1fprice$, its lag, $1fpriceL1$, and a dummy variable that takes the value 1 for Low Income countries and 0 otherwise, $incm-d1$. The results are given in Tables 21.

Table 21
Impact of Droughts on Food Prices[66]

Robust regression — Number of obs = 1187; F(7, 1179) = 8415.18; Prob > F = 0.0000

Deviation of log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Predicted no. droughts						
--.	-.9665303	.3812187	-2.54	0.011	-1.714473	-.2185875
L1.	.7007728	.331391	2.11	0.035	.0505909	1.350955
Mean rainfall 1980-2000	-.0001164	.0000549	-2.12	0.034	-.0002242	-8.60e-06
Square rainfall 1980-00	4.55e-08	1.84e-08	2.48	0.013	9.44e-09	8.16e-08
rain deficit >10%	.1136672	.0390299	2.91	0.004	.0370913	.1902431
Log of food price index						
L1.	.8361575	.0035638	234.63	0.000	.8291654	.8431496
Low Income countries	.070391	.0244852	2.87	0.004	.0223516	.1184304
_cons	-3.242046	.0378717	-85.61	0.000	-3.316349	-3.167742

[65] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of rlfprod
chi2(1) = 9.65
Prob > chi2 = 0.0019

[66] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of rlfprice
chi2(1) = 1149.95

These results point to a significant positive effect of lagged food price index. Food price deviations vary inversely with average rainfall, with a weakening of this effect at higher averages. Rainfall deficit years witness larger positive price deviations. Controlling for these effects, there is a significant negative effect of droughts on food prices, conditional upon a positive effect of lagged droughts. This presumably reflects a substantial loss of real income of (net) buyers of food, leading to erosion of demand for food in the next year. The conclusion therefore is that droughts are inflationary if and when the frequencies of lagged droughts are considerably higher. .

Table 22
Impact of Droughts on Agricultural Wage Rates[67](1)

Robust regression — Number of obs = 163; F(4, 158) = 16.11; Prob > F = 0.0000

Log of agricultural wages	Coef.	Std. Err.	T	P>|t|	[95% Conf. Interval]	
Predicted no. droughts L1.	-2.060265	.6786193	-3.04	0.003	-3.400601	-.7199294
Mean rainfall 1980-2000	.0012832	.0002278	5.63	0.000	.0008333	.001733
Square rainfall 1980-00	-3.38e-07	7.75e-08	-4.36	0.000	-4.91e-07	-1.85e-07
rain deficit > 10%	-.1526268	.1030984	-1.48	0.141	-.3562556	.0510019
_cons	5.651213	.1289679	43.82	0.000	5.396489	5.905936

.

Before commenting on the impact of droughts on agricultural wages, a few caveats are in order. (i) Agricultural wage series is available for a small sample of countries over the period 1995-2004. (ii) Although local currency units were converted into PPP adjusted estimates, agricultural wage data are generally not-so-reliable, as there is considerable variation by season, agricultural task and gender. (iii) Given the short time series, we could estimate an exponential form with a fixed growth rate. However, few countries display a significant trend[68]. Hence the dependent variable is (log of) agricultural wage rate. The results given below are illustrative of certain links and of course require further validation.

The results in Table 22 confirm a positive effect of rainfall on wage rates. This effect, however, weakens at higher averages. The effect of rain deficit years is not significant.

[67] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of lawageppc
chi2(1) = 1.47
Prob > chi2 = 0.2261

[68] For details, see Annex 2.

Controlling for these effects, lagged droughts lower agricultural wage rates, as demand for labour falls.

In Table 23, insertion of a Low Income dummy does not change these results. However, it confirms that agricultural wage rates are significantly lower in Low Income countries.

A lagged food price variable is included in the specification used in Table 24. While the effects of average rainfall and its square remain intact, that of lagged droughts ceases to be significant. However, the effect of lagged food prices is positive. Going by the coefficient value, real wages adjust after a year and partially (Bliss, 1985).

Table 23
Impact of Droughts on Agricultural Wage Rates[69] (2)

Robust regression — Number of obs = 163; F(5, 157) = 21.55; Prob > F = 0.0000

Log of agricultural wages	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Predicted no. droughts						
L1.	-1.824337	.648582	-2.81	0.006	-3.105409	-.5432646
Mean rainfall 1980-2000	.0009327	.000218	4.28	0.000	.0005021	.0013633
Square rainfall 1980-00	-2.29e-07	7.41e-08	-3.09	0.002	-3.75e-07	-8.25e-08
rain deficit > 10%	-.1692759	.0988538	-1.71	0.089	-.3645309	.0259791
Low Income countries	-.7591979	.1107119	-6.86	0.000	-.9778748	-.540521
_cons	5.908457	.1264952	46.71	0.000	5.658605	6.158309

Table 24
Impact of Droughts on Agricultural Wage Rates(3) [70]

Robust regression — Number of obs = 147; F(5, 141) = 7.29; Prob > F = 0.0000

Log of agricultural wages	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Predicted no. droughts						
L1.	-1.012211	.7471626	-1.35	0.178	-2.4893	.4648783
Mean rainfall 1980-2000	.0005448	.0002194	2.48	0.014	.000111	.0009785
Square rainfall 1980-00	-1.30e-07	7.35e-08	-1.76	0.080	-2.75e-07	1.58e-08
rain deficit > 10%	-.1532183	.1009225	-1.52	0.131	-.3527352	.0462986
Log of food price index						
L1.	.2492708	.0659343	3.78	0.000	.1189233	.3796183
_cons	5.00779	.2978147	16.82	0.000	4.419031	5.596549

[69] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of lawageppc
chi2(1) = 0.94
Prob > chi2 = 0.3322

[70] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of lawageppc
chi2(1) = 79.29
Prob > chi2 = 0.0000

Combining this with the preceding analysis of the effect of droughts on food prices, the following inferences can be drawn:

- Droughts have a negative effect on food production; the effect is considerably stronger if there are droughts in two consecutive years.
- (Lagged) droughts result in higher food price deviations (from its trend).
- So real wages fall as a consequence of drought in a previous year.
- However, the price shock is absorbed partially in a year, and so real wages are higher in t+1.

In sum**,** the loss of food entitlements among agricultural labourers is likely to be high.

Household-Level Impact and Coping Strategy

As these findings are based on cross-country data, some supplementary evidence from a recent household survey in three Indian states (viz. Chattisgarh, Jharkhand and Orissa) which suffered a major drought in 2002 is summarized below[71]. While generalizations are risky, these findings illustrate the severity of the impact and the coping mechanisms that the preceding analysis did not capture fully. Briefly,

- During the 2002 drought, total income losses in Jharkhand and Orissa were 24 per cent and 26 per cent, respectively. The loss in Chattisgarh was markedly higher (58 per cent).
- The proportionate loss of total income was lower among small and marginal farmers (17-42 per cent), relative to medium and large farmers (25-67 per cent).
- There was a substantial increase in poverty (33 percent points in Chattisgarh, 12 percent points in Jharkhand, and 16 percent points in Orissa).
- The coping mechanisms involved seeking work in non-farm activities (e.g. construction), sale of livestock, and other assets, and borrowing. However, despite recourse to these mechanisms, households failed to compensate except partly for the loss of income (barely 3-7 per cent of the loss in total income).
- Borrowing as a coping mechanism varied across the three states studied. In Orissa, for example, 21 per cent more farmers borrowed cash relative to a normal year. Interest rates in drought years were typically higher by 5-9 percentage points.
- On the expenditure side, the adjustments involved reduction of meals among 54 to 70 per cent of the households in the three states studied; delayed medical treatment among 60-80 per cent of the households; and curtailment of children’s education among 52 to 68 per cent of the households.
- Migration rose by 6-18 percentage points while the number of working days increased from 32 to 94 days.
- Switching from rice to other crops was not much of an option, as the droughts occurred in the late season. However, farmers did plant the second crop early where possible or by devoting more acreage to cash crops such as vegetables.

[71] For details, see Pandey and Bhandari (2006, 2009).

- In the farmers' assessments, migration seemed a more rewarding option than adjustments in the post-rainy season.

A comparative analysis of households in three countries-eastern India, southern China and northeastern Thailand- offers additionall insights into coping mechanisms. The first important point is that crop losses were highest in eastern India-36 per cent as a fraction of average value of production, as against 3 per cent in southern China and 10 per cent in northeastern Thailand. So the severity of droughts differed. Consequently, the adjustments were most drastic in eastern India, as shown below in Table 25**.** First**,** as the dependence on rice as a source of household income was twice as high in eastern India

Table 25
Drought Coping Mechanisms of Farm Households in China, India and Thailand*

Drought coping strategies	Southern China	Eastern India	Northeastern Thailand
Migration	+	++	+
Asset sale			
Livestock	0	++	+
Land	0	+	0
Borrowing	0	++	+
Consumption decline	0	+	0
Expenditure on social functions, medical treatment, and children's education	0	–	0
Use of cash and kind savings	+	+	+
Use of social network	+	++	+
Employment through food-for-work programme.	0	+	0

* "–" means a decrease, "+" means an increase, and "0" means no change. Double marks imply larger change while a single mark implies marginal change.
Source: Pandey and Bhandari (2006, 2009)

(40 per cent), relative to the regions in China and Thailand, the proportionate income losses due to drought were much larger. Given limited crop-diversification, and commercialization of agriculture, there were fewer options within this sector. Besides, non-farm activities were much less vibrant. Finally, differences in asset portfolios (e.g. sale (or mortgage) of land is not practiced in southern China and northeastern Thailand) also influenced the adjustments made.

Entitlements, Agricultural Research and Technology

Much has been written on entitlement protection in the context of famine prevention (notably Dreze, 1990, a, b, and others, following Sen's (1981) seminal contribution). Contrary to the assertion in Dreze (1990 b) that famine prevention is confined to or essentially concerned with entitlement protection, it will be argued below that it is equally imperative to promote agricultural research that would expand technology choice, and adoption by farmers in regions subject to biotic and abiotic stress, towards more sustainable agricultural development and enhanced food security.

Let us first review the salient features of entitlement protection.

- Starvation deaths are linked to spread of infectious diseases, helped by debilitation, unhygienic sanitary conditions and overcrowding in relief camps. So entitlement protection has to be broader than food entitlement protection in so far as it must encompass health care and epidemiological control.
- Given short-term constraints to expanding food supply-except perhaps through imports-food price stabilization through Public Distribution System, with easy access of vulnerable groups (e.g. pregnant women, undernourished children and the elderly) and regions (e.g., inaccessible remote areas) is a priority.
- Expansion of public works, with self-selection at low (cash) wages, would generate additional demand for food and help avoid or restrict export of food from food-deficit areas. Two successful cases are Botswana (1982-87) and Maharashtra (1970-73)-an Indian state.
- The potential of private trade in moving food to vulnerable areas – subcontracting private traders in transporting food in Botswana is a case in point – and, consequently, in food price stabilization is often overlooked, and sometimes hampered by zonal restrictions on movement of food, as in India and elsewhere. Nevertheless, the public sector will continue to have a significant role in food supply management primarily to check collusion and speculative hoarding by private traders.
- While international donors have helped alleviate the hardships-Botswana, Cape Verde and Kenya, among others, benefited from food aid in large measure-there is often a risk of overstating their contribution, as the effectiveness of relief efforts is largely contingent upon national and local agencies.[72]
- Of particular significance is the nature of the political regime-whether it is open, democratic, and competitive- and whether there are political debates, and a free press. All these contribute to quick and speedy relief[73]. Recent data on quality of institutions point to significant improvements in several developing countries-especially those in Asia and Africa that are prone to droughts (*WDI 2006*).
- If the goal of development is to ensure security of livelihoods and human lives, it is vital that the separation of relief from development is not overemphasized. As noted by Dreze (1990 b), while entitlement protection is

[72] Typically, food aid arrives much later when a food shortage turns into a crisis (Dreze, 1990 b).

[73] In the Zimbabwe drought of 1982-84, for example, there was ample evidence of favouritism in food distribution among party cadres, patchy coverage of drought relief in the stronghold of political dissidents, and restriction of food distribution to rural areas, given the nature of ZANU politics and its predominantly rural power base (Dreze, 1990 b). The belated and politicized nature of drought relief in Bihar-an Indian state- in 1967 is yet another example of government failure.

intrinsically a short-term task, building up flexible and effective response mechanisms is a long-term one. So a more comprehensive strategy is called for-especially in the context of countries/regions characterized by low and variable yields, with limited opportunities for trade with the rest of the world. From this perspective, a case is made for prioritization of agricultural research, strengthening of agricultural extension and expansion of technology choice-especially because of the threat from climate change to livelihoods and agricultural productivity[74].

Recent reviews of the international agricultural research system have drawn attention to the reconfiguration of roles of the public and private sectors in promoting yield-enhancing and poverty-reducing technological change (Pingali and Traxler, 2002, Timmer, 2003, Pender, 2006, and Spielman, 2007). A selective summary of the main points is given below.

- There is need for strategic leadership from the public sector in agricultural research (i.e. developing country NARS, the CGIAR, and donor agencies). This involves designing policies and channeling both public and private research into activities that would facilitate development of yield-enhancing and poverty –reducing technologies. Specifically, the objective is to identify the crops, traits and technology choices that matter most to marginalized groups and agro-ecologically fragile regions. Some are sceptical of this proposal on the ground that few developing countries have the resources to do so. Besides, those who have the resources-for example, Brazil, China and India- have not demonstrated the enthusiasm for pro-poor biotechnology research agenda. Even the CGIAR's track record is far from satisfactory.
- There is also a strong case for outsourcing of many public research functions to the private sector, thereby creating new markets for research, and reducing inefficiencies caused by poor public administration and management.
- No less important are incentive mechanisms to address public research priorities through private research execution in a manner that ensures more equitable distribution of benefits and costs across various stakeholders[75]. Examples include public-private research partnerships, competitive research grants, and tax incentives.
- Finally, careful attention must be given to creating an enabling environment for private research in developing countries. The key elements include improvements in varietal registration procedures, biosafety regulation processes, and IPR enforcement at the national level; improvements in

[74] For a broad brush treatment of likely scenarios of climate change, see Annex 1A.

[75] As improved rice is self-pollinating, it offers limited profitability to private companies. This applies to wheat as well but not to maize. Hence the far greater private investment in developing improved varieties of maize than of rice or wheat. This constraint is overcome to some extent by high yielding hybrid rice varieties. Their offspring displays a high rate of sterility and genetic variation, making it impractical for farmers to use such seeds for planting. Hybrid rice was developed and heavily promoted by the government in China in the 1980s, and was widely adopted (Pender, 2006).

communications infrastructure; and harmonization of regional and international regulations to create larger markets for private research investment.

From this broad perspective, a few specific proposals in the context of drought-prevention are reviewed below.[76]

- The agricultural research intensity (i.e. ratio of agricultural research expenditure to agricultural GDP) is estimated to be as low as 0.62 per cent. In India and China, the corresponding estimates are even lower, 0.29 per cent and 0.43 per cent, respectively, as against about 2.6 per cent in developed countries. The allocation of research resources to rainfed areas –specifically to address abiotic constraints such as drought and submergence-is a small fraction despite their high equity and efficiency impacts[77]. In India, for example, the share of research resources is under 10 per cent (Pandey and Bhandari, 2006).
- Important progress has been made in developing drought-tolerant rice germplasm. Complementary crop management research for avoiding drought stress, better utilization of available soil moisture and enhancing plant's ability to recover rapidly from drought is likely to substantially enhance returns.
- Technologies must display greater flexibility in crop choice, and in the timing and quantity of various inputs. Current rice varieties and general crop management practices are so rigid in drought-prone parts of India that they hardly change between normal years and early season drought. Rice technologies that allow for late transplanting in early season drought, for example, would help protect yields better.
- However, in some cases, late season droughts are more common and disastrous[78]. In addition to low or no harvest, farmers lose their investment in seeds, fertilizer and labour. Development of technologies that reduce the severity of the impact of a late season drought are thus a priority.
- Crop diversification is yet another drought coping option. In rainfed areas, for example, short duration rice varieties could facilitate planting of another crop using the residual moisture.
- In recent years, emphasis has shifted from large-scale irrigation schemes that were a feature of the Green Revolution to small and minor irrigation schemes and land use practices that generally enhance soil moisture and water retention. In China and Thailand, for example, the use of farm and community ponds is common. These small private or community –owned schemes tend to be low cost and sufficiently responsive to the local needs[79]. Similarly

[76] Two useful contributions are Pender (2006), and Pandey and Bhandari (2006).
[77] See, for example, Fan et al. (2003).
[78] See, for example, the case studies of eastern states in India (Pandey and Bhandari, 2006, 2009).
[79] Dsgupta (2007) points out that farmers typically overextract water as they are not required to pay "rent"-the real price of water underground. A sensible policy is to set a quota on the aggregate rate of water

watershed-based approaches that are implemented in drought-prone areas of India provide opportunities for achieving long-term drought-proofing by improving the overall moisture retention within the watersheds[80].

- Recent advances in meteorology have contributed to greater accuracy in forecasting droughts. Various indicators such as the Southern Oscillation Index (SOI) are now routinely employed in several countries to forecast droughts. However, a priority is to match the scientific advance with better preparedness to deal with droughts.

Insurance

Public crop insurance, with a few exceptions, has had abysmal failure due to high costs of monitoring, adverse selection, and moral hazard[81].

In *all* cases, programmes are heavily subsidised and governments not only pay part of the premium, but also most of the service and delivery costs, and bear the losses. A viable insurance scheme is one in which

$$Z = \frac{A+I}{P} < 1 ,$$

where A denotes average administrative costs, I denotes indemnities, P is the average premium collected. For a viable insurance scheme, Z<1. The values of Z for public insurance schemes for Brazil, Costa Rica, India, Japan, Mexico, Philippines and USA range from 2.42 (USA) to 5.74 (the Philippines). Thus agricultural insurance schemes had much higher costs than revenue, and failed the financial solvency criterion (Hazell, 1992). A more recent assessment of People's Insurance Co. in China is equally dismal.

Not only have the costs of crop insurance been high but it has not had positive impacts on agricultural lending, production or farm income. In fact, available evidence shows negligible social returns. Indeed, crop insurance, when heavily subsidised, could lead to negative impacts. The deadweight loss of the subsidy is greater than the combined benefits to producers and consumers (Siamwalla and Valdes, 1986).

The reasons underlying failure of crop insurance include: attempts to insure uninsurable risks, frequency of hazards, and high administrative costs. But there are deeper problems.

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extraction, issue licences to farmers,and allow trade in them. This will ensure that the rents are not dissipated as they are under free access to water.

[80] Two examples –one from Gansu Province in China, and another from the Indo-Gangetic Plain- are instructive. In 1995, the Gangsu government launched a programme, called the 1-2-1 system, to help farmers build one small concrete water collection surface, two concrete storage wells, and irrigate one *mu* (i/15 ha) of high value cash crops. Farm income per capita increased by 340 per cent, and the sediment inflow into the Yellow River decreased. Zero tillage in the rice-wheat system of the Indo-Gangetic plain, on the other hand, saves 75 per cent or more fuel, uses about half the herbicide, and requires at least 10 per cent less water than conventional tillage, resulting in savings of at least $65/ha in production costs. From a modest level of adoption on 3,000 hectares in the 1998/99 season, it has grown to more than 1 million farmers using zero-tillage on an estimated 5.6 million hectares in 2005 (Pender, 2006).

[81] This draws upon Hazell (1992), Gaiha and Thapa (2005), and Skees et al. (2005), among others.

These relate to perverse incentives. Collusion of insurance staff and farmers in filing exaggerated claims or losses (e.g., high bribery rates in claiming indemnities); undermining of sound insurance practices by governments during election cycles (larger compensation paid than required); direct assistance provided by governments in disaster areas, weakening the farmers' incentive to buy insurance; pervasiveness of moral hazard, reflected in neglect of sound husbandry practices when losses are insured; design of insurance contracts is also problematic, as indemnities are determined by the difference between normal and actual yields; the former are set too high- especially when insurance is tied to credit; premium rates are set by government decree at unrealistically low level; excessive specialisation of insurance schemes on specific crops (in the Philippines, for example, it is concentrated on rice); so without a diversified portfolio, insurers are susceptible to big losses; coverage of small farmers results in high administrative costs; there is also an adverse selection problem, since farmers in the riskiest context are most eager to buy insurance. In case the same premium is charged, this discourages safer farmers (Hazell, 1992).

Would weather insurance overcome these difficulties- arising largely from high transaction costs and ubiquitous information problems? We shall not comment in detail on what the measurement and data problems are except to draw attention to some merits and limitations of weather insurance, and then assess the potential of private provision.

A merit of weather/rainfall insurance is that it pays the insured when rainfall falls short of a specified target, irrespective of actual crop yields. Client behaviour and characteristics do not determine the occurrence of the event or the actual damage. So moral hazard and adverse selection problems cease to be important. The key issue then is setting an appropriate price for the specified weather patterns. Other merits are:

- the insurance is open to all (including labourers who may fear a drop in labour demand and/or a drop in wages).
- Administrative simplicity-speedy disbursals of relief, free of the usual politics and bureaucracy.
- Improved ground instruments together with satellite and remote sensing technologies make measurement of rainfall/soil moisture less expensive than in the past.
- Recent developments in micro-finance – specifically, self-help groups could serve as a conduit for selling index insurance. This could also facilitate development of new insurance product by the private sector.

But there are some hurdles too. One is reinsurance. An insurance company may not be able to handle a very large number of claims, when, for example, there is a regional drought. A large company could diversify its portfolio by selling insurance in different agro-climatic regions. So part of the portfolio could be handled by an international insurance company. The second difficulty is "basis risk"- for example, how small changes in elevation translate into changes in weather conditions. So even within small regions there may be large changes in weather /rainfall patterns[82]. Hence the greater the degree of basis risk, the less useful is rainfall insurance to potential clients (but the portfolio of the insurer gets more diversified).

Finally, from a broader perspective, it should not be overlooked that much vulnerability can be reduced without involving insurance *per se*. Both efficiency and equity, for instance, could be enhanced through better information about risks, and by encouraging savings as a form of self-insurance (through buffer stocks of grains)[83].

Concluding Observations

The main findings are summarized below from a broad policy perspective.

About 38 per cent of the world's area that inhabits nearly 70 per cent of the total population and shares 70 per cent of the agricultural output is exposed to droughts. Historically, many droughts turned into famines. Food shortages of varying intensity-if neglected or not dealt with effectively-have disastrous consequences.

Loss of agricultural output and food shortage are, however, not the only consequences. There are often large second round effects some of which persist over time. By the time these effects play out, the overall economic loss is substantially greater than the first round loss of income. Hardships manifest in malnutrition, poverty, disinvestment in human capital (e.g. withdrawal of children from school), liquidation of assets (e.g. sale of livestock) with impairment of future economic prospects, and, in extreme cases, death, given the incompleteness of credit and insurance markets.

Our analysis with cross-country data builds on the extant literature. The main findings are summarized below.

Out of a total of 71 droughts during 1985-94, the largest number occurred in Sub-Saharan Africa, followed by East Asia and the Pacific and Latin America and the Caribbean. The number of droughts rose sharply over the period 1995-04-from 71 to 115. Each of these regions recorded a markedly higher number of droughts, with Sub-Saharan Africa recording the highest number. Total number of deaths due to droughts, however, recorded a drastic reduction-from 4801 to 1019. As a result, the deadliness of droughts reduced sharply.

Well over 90 per cent of the droughts during 1985-94 occurred in Low and Lower Middle Income countries. This feature remained unchanged during 1995-04. The shares of deaths, however, varied. While Lower Middle Income countries accounted for over 70 per cent of the deaths during 1985-94, their share dropped to about 46 per cent in the next

[82] Understanding income-rainfall correlation requires crop yield modeling. Farm income risks for certain crops, for example, may be more sensitive to rainfall shortfalls at different times in the crop cycle. For details, see Skees et al.(2005).

[83] See, for example, Gaiha and Nandhi (2009).

decade. By contrast, the share of Low Income countries doubled. The reduction in the deadliness of droughts in Lower Middle Income countries was considerably greater than in Low Income countries.

Our analysis confirms the important role of (different measures of) rainfall, regional differences, soil conditions, whether a country is landlocked, and unobserved country-specific effects in explaining differences in the frequency of droughts.

Controlling for the effects of geographical variables (e.g. ranges of elevation, whether landlocked), population density, distance from a sea coast, among others, on mortality due to droughts, there are significant effects of level of income, nature of political regime, droughts, and their interaction with the severity of droughts in the past. Specifically, the mortalities were higher in Low Income and Lower Middle Income countries, relative to Upper Middle Income countries; newly independent countries were more successful in averting deaths than others; the effect of democracy –taking also into account its interaction with severity of droughts in the past- reduces deaths but the effect is weak. However, this is not intended to be a complete or definitive analysis of how the nature of the polity matters in saving human lives during a natural catastrophe such as drought, as there are a few unanswered questions.

Although the inter-relationships between droughts, mortalitiy and openness of the macro-policy regime are of vital importance- mortalities, for example, are likely to be fewer in a more open economy because of the greater ability to import food in adequate quantities, other things being equal-it was not feasible to carry out a detailed investigation of these inter-relationships. Nevertheless, a tentative conclusion from the analysis carried out confirms this hypothesis.

That much of this devastation is avoidable- through a timely and speedy entitlement protection strategy- is illustrated. Our simulations yield some additional insights. Even moderate learning has the potential to avert a large fraction of deaths. But capacity-building-synonymous with availability of more resources for disaster prevention-also has considerable potential in averting deaths. In fact, these findings are broadly consistent with the view that fatalities are greater in countries with weak governments and pervasive poverty.

Attention is drawn to the mechanisms through which democratic regimes help avert mortalities. Is it through greater drought relief? Does greater relief improve chances of electoral success? Whether rational voters punish elected representatives for disasters beyond their control? Whether responses of governments vary between moderate or extreme catastrophic events? Although generalizations are risky, available evidence suggests that government responsiveness is greater when the severity of the crisis is greater. Also, voters punish incumbent politicians for crises beyond their control. But voters also reward politicians for responding well to climatic events but not sufficiently to compensate them for their “bad luck”.

Even within a democratic regime, there are marked differences in the ability to prevent starvation deaths. Available evidence suggests that competitive local politics and decentralized structures of governance are crucial in preventing deaths. Specifically, local political parties and vigilant village councils act not just as conduits of information on distress but also pressure district administration to take appropriate action.

Our analysis also points to significant dampening effects of droughts on agricultural productivity and food production. Besides, as expected, food entitlements are eroded through the inflationary impact of droughts and loss of wages over time. Although data limitations precluded investigation of the adjustment mechanisms (e.g. through, for example, liquidation of assets, and cuts in medical and educational expenses), supplementary household evidence confirms these mechanisms.

If the goal of development is *security* of livelihoods and human lives, a broader strategy is called for- a strategy that goes well beyond protection of food entitlements of the vulnerable. Some key elements of the broader strategy include higher agricultural research outlays, public-private partnerships in promoting pro-poor technologies, a compatible incentive structure, and more effective extension systems. Specifically, soil and water conservation technologies with effective community participation deserve high priority in arid, semi- arid and sub-humid regions/areas.

As large sections of the rural population in developing countries will continue to be vulnerable to various catastrophes-droughts, pests, famines, floods, among others- insurance also has a potentially important role in mitigating the hardships.

In conclusion, while building resilience against natural disasters such as droughts is a challenge for developing countries, the prospects are far from bleak.

Annex 1

Table A.1. 1
Impact of Droughts in Recent Years

Drought year	Affected country	Impact of drought
1980-84	Horn of Africa	About 40 million people affected by drought during 1980-84 in the Horn of Africa.
1980-85	Africa	During 1980-85, drought affected 150 million people in Africa.
1983-84	USA, Europe and Africa	World grain production declined by 5% as compared to previous year.
1991-92	Africa	Maize production declined by 60% and caused import of 5 million tons of maize in the following year.
2002	Sub-Saharan Africa	Over 40 million people faced food crisis.
2004	Africa	Famine, malnutrition, and starvation deaths in many parts of Africa.
2004	China	Drought affected 23 million people, 52% of the provinces, 16 million ha of crop area, and agricultural GDP declined by 1.3%.
Annual	China	Annual loss due to drought is estimated to be 0.5-3.3% of agricultural GDP.
1957-58	India	Agriculture production loss was 50% as compared to the previous year.
1987	India	Drought affected 60% of the crop area and 285 million people.
2002	India	Drought affected 55% of the country's area and 300 million people. The foodgrain and rice production declined by 15% and 19% from trend values, respectively.
1998	Thailand	Drought affected 95% of the provinces, 0.9 million ha of cropped area, and resulted in a loss of agricultural GDP of 2.4 %.
2004	Thailand	Drought affected over 8 million people in 92% of the provinces, and a crop area of over two million ha; and production loss is estimated to be 2.2% of agricultural GDP.
2004	Vietnam	Drought affected about one million people in eight highland provinces, and agricultural production loss is estimated to be $80 million.

Source: Compiled from various sources. For details, see Pandey and Bhandari (2006).

Table A.1.2

Climate Classification

Koeppen-Geiger Climate Classification

There are a large number of alternative classification systems, based on temperature, precipitation, growing season, natural vegetation cover, and other characteristics. Temperature patterns are typically combined with precipitation patterns to distinguish categories such as the humid tropics, wet-dry tropics, and arid tropics. Of course, specific ecological characteristics of an economy also depend on topography (slope and elevation); geology including bedrock, mineral deposits, and seismic activity; orientation to large landmasses, oceans, rivers, ocean currents; proximity to markets; endemic fauna and flora, including pests, parasites and disease vectors. In short, a classification into tropical and or temperate ecozones is only a first approximation to an economy's ecological characteristics.

In this system, regions are differentiated by temperature and precipitation. There are three tropical zones: humid, dry winter, and monsoon; two arid zones (desert, and steppe); three temperate zones (sub-tropical dry winter, Mediterranean dry summer, and humid temperate); two snow zones (humid snow, and dry winter); and high elevation regions. The tropical zones comprise humid, dry winter, monsoon and sub-tropical dry winter; the temperate zones are humid temperate, Mediterranean dry summer, humid snow and dry winter. All the remaining are clubbed together as non-tropical and non-temperate. This is the default case in the regression analysis carried out in this study.
Source: Sachs (2000).

Climate Change

Although there is a growing consensus on the seriousness of the climate threat to agriculture, there is little agreement on the magnitude of this impact primarily because of the complexity of the interaction between the ecosystems and the economy (World Bank, 2008).

Five factors are identified that will affect agricultural productivity. These comprise: changes in temperature, precipitation, carbon dioxide (CO_2) fertilisation, climate variability and surface water runoff. A broad brush treatment is given below.

Under moderate to medium estimates of rising global temperatures (1-3^0 C), a small impact on agricultural production is likely, as negative impacts in tropical and mostly developing countries are mostly offset by gains in temperate and largely industrial countries. In tropical countries even moderate warming (1^0 C for wheat and maize and 2^0 C for rice) will significantly lower yields. For temperature increases above 3^0 C, yield losses are likely to be more pervasive and particularly severe in tropical regions. In parts of Africa, Asia, and Central America, wheat and maize yields are likely to be lower by 20-40 per cent as temperature rises by 3-4^0 C, even after making an allowance for farm – level adjustments to higher average temperatures. Full CO_2 fertilisation, on the other hand, will reduces the losses by half. Rice yields are likely to decline less than wheat and maize yields.

These are plausible as setting the floor as there will be other crop and livestock losses through more intense droughts and floods, changes in surface water runoff, and threshold effects on crop growth through temperature changes.

Agriculture in low lying areas will suffer from flooding and salinisation caused by higher sea levels and salt water intrusion in groundwater acquifers. Less precipitation would reduce water for irrigation. In all regions, the poor are likely to bear the brunt of these losses, given their dependence on agriculture and lower capacity to adapt[84].

Barriers to adaptation vary by country, but for many a major barrier is the lack of credit or savings. Adaptation would be facilitated by crop and livestock insurance, safety nets, and research on and dissemination of flood-, heat-, and drought resistant crops. Better climate information is another option. An agrometeorological support programme in Mali, for example, in response to the Sahelian drought helped farmers better manage climate risk and economic hardships.

Adding together the GHG emissions from livestock, crops and deforestation (agriculture is the main cause of it), agriculture's global contribution to GHG is in the range 26-35 per cent. About 80 per cent of these emissions from agriculture are from developing countries.

Changes in agricultural land use can be reduced by slowing deforestation. Opportunities for this reduction through carbon trading seem large because of the low returns from forest conversion to agriculture. Other promising approaches include changes in agricultural land management (conservation tillage, agroforestry, and rehabilitation of degraded land).

Mitigation is contingent on a future treaty with a better incentive structure for full participation and compliance. Adaptation, however, raises more complex issues as the distribution of benefits is uneven between developed and developing countries. This has come in the way of equitable sharing of the burden of adaptation. But the manifestation of climate change adds to the urgency of coordinated mitigation and adaptation (Stern, 2006, Dasgupta, 2006)[85].

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[84] A recent study (Alcali et al. 2009) makes a persuasive case for location-specific integrated management of natural resources for higher resilience to erratic climatic events. A priority, therefore, is receptivity to local/traditional knowledge. Since small farmers and rural communities are the starting point for adaptation to climate change, the solutions require their active participation. Little, however, is known about incentive compatible mechanisms mainly because of the dearth of examples in different contexts. This is emphatically endorsed by Sachs (2009). He observes that lasting solutions to water challenge require a broad range of expert knowledge about climate, ecology, farming, population, economics, community politics, and local cultures.Government officials need the skill and flexibility to work with local communities, private businesses, and international organizations.

[85] These two, among others, have sharply different views on the urgency of collective action on climate change.

Table A.1.3

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.

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

Changes in Polity Scores, 1985-1994 to 1995-2003

In order to understand how levels of democracy have changed, a supplementary analysis was carried out[86]. A slective summary is given below.

As may be noted from the regression analysis, the average values in 1985-1994 and in the subsequent period were highly correlated-implying countries with moderately high values initially recorded higher values in the next period. Somewhat surprisingly, among all the regions, Sub-Saharan Africa recorded a significantly higher value. This augurs well for this region not only because of its extreme poverty but also because of its relatively high vulnerability to natural shocks, armed conflicts and generally weak governments. Equally surprising is the result that the more recent the year of independence, the lower was the level of democracy, controlling for other effects.

[86] Our attention was drawn by some participants in the NBER conference, May, 2008, to extend the analysis of the impact of democracy on prevention of deaths, and to examine the endogeneity of Polity scores.

Table A.1.4
Changes in Polity Scores

Robust regression[1]

Number of obs = 86
F(5, 80) = 34.81
Prob > F = 0.0000

polity2 (1995-2004)	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
polity1	.8074813	.0759601	10.63	0.000	.6563159	.9586466
South Asia	-1.127275	1.568206	-0.72	0.474	-4.248104	1.993554
Middle East and North Africa	-1.36945	1.539684	-0.89	0.376	-4.433519	1.694618
Sub-Saharan Africa	2.309575	1.013781	2.28	0.025	.2920862	4.327065
newstate	-.8434294	.4119611	-2.05	0.044	-1.663258	-.0236008
_cons	3.449173	.7111566	4.85	0.000	2.033927	4.86442

1. Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
   Ho: Constant variance
   Variables: fitted values of polity2
   chi2(1) = 3.78
   Prob > chi2 = 0.0518

Table A.1.5
List of Variables Used in Regression Analysis

Stata Variable Names	Description
al_d1	Arable land area<.5 million ha
al_d2	Arable land area .5 million ha-2.5 million ha
al_d3	Arable land area2.5 million ha-5 million ha
Largest range	Arable land area >5 million ha
no_dr	Number of droughts
no_dr_70_79	Number of droughts, 1970-79
pno_dr_t7	Predicted number of droughts from preferred specification
pno_dr_t7 L1	Predicted number of droughts from preferred specification lagged by one year
pno_dr_t7 r	Dummy variable takes the value 1 if predicted frequency of drought <0.05, and 0 otherwise
laff_dr_7-79	Log number of persons affected by drought, 1970-79
Ipo3xla	Polity dummy 3x log of afftected persons, 1970-79
ldeath_dr	Log of deaths due to droughts
avpal	Agricultural value added per hectare of arable land
gr_avpal	Log $(\text{avpal})_t$ –log $(\text{avpal})_{t-1}$
ravpal_dr14	Residual productivity (actual-predicted)
$mr80\_00$	Mean annual rainfall, 1980-2000
Imrxmr	Square of mean annual rainfall, 1980-2000
mrain_d1	Dummy takes the value 1 if rainfall<500mm, 1980-2000, and 0 otherwise
mrain_d2	Dummy takes the value 1 if rainfall between 501-1000mm, 1980-2000, and 0 otherwise
mrain_d3	Dummy takes the value 1 if rainfall between 1001-2000mm, 1980-2000, and 0 otherwise
rain10d	Whether rain deficit more than 10 per cent in a year (the dummy takes the value 1, 0 otherwise)
Polity 1 d1 (1985-94)	Dummy takes the value 1 if polity score <(-) 5 and 0 otherwise
Polity 1 d2 (1985-94)	Dummy takes the value 1 if polity score between (-)5-0, and 0 otherwise
Polity 1 d3 (1985-94)	Dummy takes the value 1 if polity score between 0-5, and 0 otherwise
newstate	Timing of independence (designed to measure the influence of colonial legacy):0 if before 1914, 1 if between 1914-45, 2 if between 1946-1989, and 3 if after 1989
elev	mean elevation (metres above sea level)
elev_d1	elevation dummy for range 1, <300 m above sea level
elev_d2	elevation dummy for range 2, 300-600 m above sea level
elev_d3	elevation dummy for range 3, 600-900 m above sea level
(default case)	highest range
distc	mean distance to nearest coastline (km)
pdenpavg	persons/ km^2
zdrytemp	(%)land area in dry temperate
ztropics	(%) land area in tropics
landlock	whether a country is landlocked (outside of Western and Central Europe)
regd11	Latin America and the Caribbean
regd21	South Asia
regd22	East Asia and the Pacific
regd31	Europe and Central Asia
regd41	Middle East and North Africa

Regd51	Sub-Saharan Africa (The default case varies in some cases)
incm_d1	dummy takes the value 1 for Low Income countries
incm_d2	dummy takes the value 1 for Lower Middle Income countries
(default case)	Upper Middle Income countries
iv_tradesh-e	Instrumented measure of openness (Gaiha and Imai, 2005)
Iivxiv	Square of measure of openness
lfprod	Log of food production index (WDI 2006)
rlfprod	Deviation of log of food production from its trend value
lfprice	Log of food price index (WDI 2006)
Lfprice L1	Log of food price index lagged by one year
rlfprice	Deviation of log of food price index from its trend value
lawageppc	Log of agricultural wages (purchasing power parity), ILO
Lawageppc L1	Log of agricultural wages (purchasing power parity) lagged by one year
rldeath_dr7	residual deaths (difference between log actual and log predicted)
soilsui1 .	Soil suitability is an estimate of the percentage of each soil type that is very suitable, moderately suitable and unsuitable for each of six rainfed crops. See the document \faosoil\document\suit.met on the CD-ROM listed below for the methodology of these suitability classifications. From the crop-specific soil suitability indices, we took the maximum percent of each soil type across six rainfed crops that was very suitable and moderately suitable, and similarly the maximum percent that each soil type was very and moderately suitable for the two irrigated rice crops. Maps of these four values were then summarized by country. Measured as % share of arable land. FAO. 1995. *The Digital Soils Map of the World, Version 3.5*. Rome:FAO

Annex 1.B.1

More on the Reliability of EM-DAT

Another review of EM-DAT (Guha-Sapir et al. 2002) is somewhat inconclusive but not without merit. This review is based on three global disaster data sets: NatCat maintained by Munich Reinsurance Company; Sigma maintained by Swiss Reinsurance Company, and EM-DAT maintained by CRED. Their comparative strengths are evaluated on the basis of estimates for four countries (viz. Vietnam, India, Honduras and Mozambique), selected from four disaster prone regions of the developing world. All records on natural disasters from these three data sets cover a period of 15 years (1985-1999). Three sets of exercises were carried out: the first involved comparison of similarities and differences between EM-DAT, NatCat and Sigma for the selected countries; the second focused on the presence and absence of disaster events in these data sets; and, finally, a comparison of the contents of the common fields (e.g., number of persons killed).

These comparisons are rendered difficult because of differences in the coverage and classification criteria used. For example, EM-DAT covers natural disasters (including epidemics) and man- made disasters and conflicts while the other two are confined to either natural disasters (NatCat) or natural and man- made ones (Sigma). Also, the criteria used for classifying a disaster differ. In EM-DAT, the criteria are 10 or more deaths and/or 100 or more affected and /or declaration of a state of emergency/ call for international assistance. By contrast, Sigma classifies a disaster on the criteria whether 20 or more deaths occurred and/or 50 or more were injured and/or 2000 or more were rendered homeless and/ or insured losses of $14 million or more. Some of the findings are listed below.

(i) NatCat has the largest number of entries, followed by EM-DAT and Sigma. This is not surprising given that NatCat does not use any exclusion criteria while Sigma uses the most stringent criteria.

(ii) Regarding the number killed, the totals for Vietnam, Honduras and India are similar between NatCat and EM-DAT. The total for Mozambique, however, differs widely. Two major events in Mozambique (a famine and an acute food shortage) accounted for 100,000 and 5200 dead, respectively, recorded in EM-DAT, largely explain the discrepancy.

(iii) Of the total number of events, 120 or about a quarter were common to all three. (iii) Sigma had only 4 per cent of its total entries that did not record any deaths, followed by EM-DAT with 8 per cent and NatCat with about 21 per cent.

(iv) Confining to the events reported in all datasets (n=120), a very small percentage of the records missed a value for the number killed. Moreover, the match for deaths accounted for two thirds of the records.

So while doubts about the reliability of EM-DAT cannot be set aside, it is a fair presumption that the quality is largely satisfactory.

Annex 1 B.2

Reclassification of Droughts and Famines, and Other Measurement Problems

An attempt to reclassify the drought data over the period 1900-2004 is important not so much for a more accurate classification of droughts and associated losses but for drawing attention to some difficult problems of measurement (Below et al. 2007). They lay down two conditions as the minimal requirements for correct classification of droughts. These are: (i) The losses must have been attributed in the original reporting as related to droughts and/or in their manifestation as famines. (ii) There is evidence of drought-like physical conditions associated with the recorded losses. The second condition could take several forms. One is lack of rainfall in the original reports. Another is an index called the Weighted Anomaly of Standardized Precipitation (WASP), which is also used for identifying multi-country and multi-year droughts.

Each disaster entry in EM-DAT consists of a set of fields that are universal for all entries in the database. These include the start and end dates of the disaster; the affected country; the numbers of people killed, missing, or otherwise affected; and economic losses, among other details. All disasters that meet the EM-DAT criteria stated earlier are recorded in the database and labeled with a unique disaster number identifier, called a DisNo. EM-DAT developed a set of stringent rules for determining the start and end dates of droughts. When the sources differ on the start date, the disaster date was assigned according to when losses began. If there is no information, the date on which the report was published is taken as the start date. Similar problems arise in determining the end date. If a robust relationship is found between a hazard definition and disaster incidence, then this hazard definition is used to assign the end date. When, however, no end dates are specified, and in the absence of other evidence, then the start year is also taken as the end year.

Below et al. (2007) used a hierarchy of binary decisions to determine whether a reported drought disaster was a multi-year event. The WASP index was used to evaluate whether a given entry was likely a continuation of cumulative losses associated with on-going drought. The issue here is whether the disaster was associated with a drought hazard that extended through several years or with multiple hazards in consecutive years. Drawing attention to the risk of double or triple counting of losses including mortality in the EM-DAT procedure used earlier, it is argued that these risks are substantially reduced by the most recent loss estimates available for all the years the drought affected the country.

Another hierarchy of binary decisions was used to determine whether a single drought hazard event affected multiple countries. The WASP was used to check which disaster entries in multiple countries were associated with a single, spatially continuous, precipitation anomaly. Where a single hazard event affected multiple countries, a common DisNo was assigned to each drought event but with an individual entry for each country in the database. This allows losses associated with a particular drought to be aggregated across the event, while facilitating the assignment of country-specific start and end dates.

As summarized below, the effects of the recalculation were quite drastic relative to the erstwhile estimates in EM-DAT.

(i) One effect was reclassification of 68 of the 76 famine entries. The remaining famines were classified as complex emergencies. (ii) There was a reduction of the original 883 entries (i.e., 807 droughts and 76 famines) into 392 multi-year and multi-country events, each with its own unique DisNo. The procedure for consolidating entries resulted in 446 events, which were reduced to 392 as some involved multiple countries. (iii) There was a substantially higher estimate of mortality associated with droughts-in fact, it rose by 20 per cent, from 10 to 12 million people. The largest increase was in Asia and the Middle East (25 per cent), followed by Africa (8 per cent). Moreover, as a result of reclassification of famines as droughts, more than half of the 22 million deaths associated with natural disasters recorded in EM-DAT from 1900 to 2004 were attributed to droughts.

Are these calculations more plausible than the earlier figures? We are somewhat sceptical for two reasons. One is that famines arising from food supply shortages are excluded without a clear justification. If supply shortages due to deviations in precipitation turn into famines over a period, it is not obvious that such events are unambiguously droughts instead of famines. A case, however, could be made for the new drought series for being more comprehensive and accurate in so far as double-counting of multi-year and multi-country droughts are sought to be avoided. But there is another difficulty as some important droughts and associated mortality are not satisfactorily dealt with. A case in point is that the Sahel drought (1972 to 1975) in which 250, 000 deaths were recorded. In EM-DAT these losses are given as a regional total, with "NA" given for country name. So without apportioning these deaths among the Sahel countries, just the regional total is included in the revised estimates. Thus gaps and anomalies persist in the revised estimates of droughts and losses.

A brief analysis is given below.

Table A.1.6
Frequency of Droughts and Deaths by Income

Income	Number of Droughts (85-94)	Number of Droughts (95-04)	Deaths (85-94)	Deaths (95-04)	pop95	Deaths per million (85-94)	Deaths per million (95-04)	Deaths per Drought (85-94)	Deaths per Drought (95-04)	Droughts per million (85-94)	Droughts per million (95-04)
Low	41	65	1754	1166	1,908	0.92	0.61	42.78	17.94	0.021	0.034
Lower Middle	38	58	3484	721	2,400	1.45	0.30	91.68	12.43	0.016	0.024
Upper Middle	5	8	0	0	268	0	0		0	0.019	0.030
Total	84	131	5238	1887	4,576	1.14	0.41	62.36	14.40	0.018	0.029

Table A.1.7
Frequency of Droughts and Deaths by Region

Region	Number of Droughts (85-94)	Number of Droughts (95-04)	Deaths (85-94)	Deaths (95-04)	pop95	Deaths per million (85-94)	Deaths per million (95-04)	Deaths per Drought (85-94)	Deaths per Drought (95-04)	Droughts per million (85-94)	Droughts per million (95-04)
Latin America & Caribbean	21	32	0	41	464	0.00	0.09	0.00	0.00	0.045	0.069
South Asia	5	6	300	200	1,242	0.24	0.16	60.00	33.33	0.004	0.005
East Asia & Pacific	19	32	3484	740	1,705	2.04	0.43	183.37	23.13	0.011	0.019
Europe & Central Asia	4	8	0	2	418	0.00	0.00	0.00	0.25	0.010	0.019
Middle East & North Africa	2	7	0	0	248	0.00	0.00	0.00	0.00	0.008	0.028
Sub-Saharan Africa	33	46	1454	904	500	2.91	1.81	44.06	19.65	0.066	0.092
total	84	131	5238	1887	4,576	1.14	0.41	62.36	14.40	0.018	0.029

Fig: A.1.1Frequency of Droughts by Income

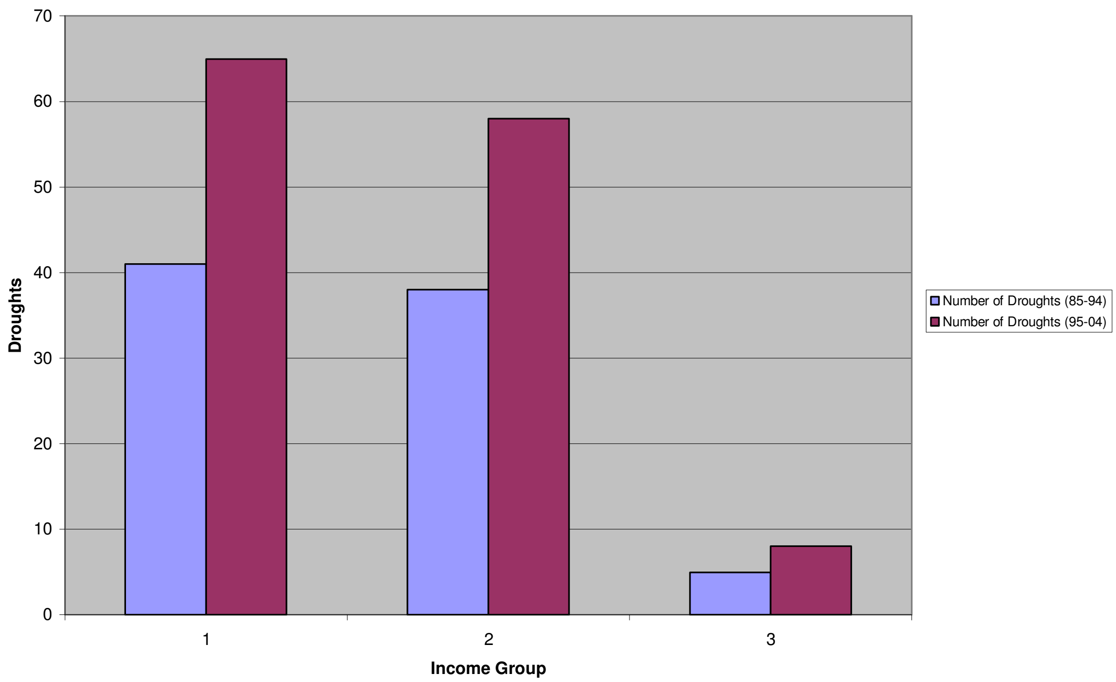

Fig: A.1.2 Number of Deaths due to droughts by Income

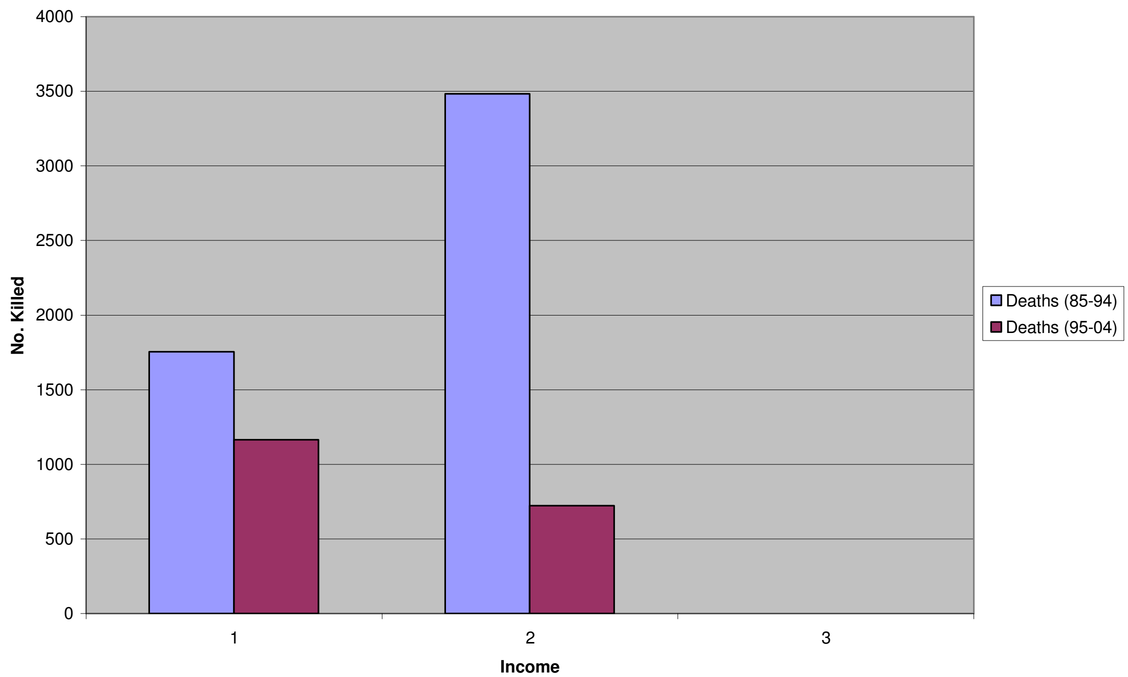

Fig: A.1.3 Frequency of Droughts by Region

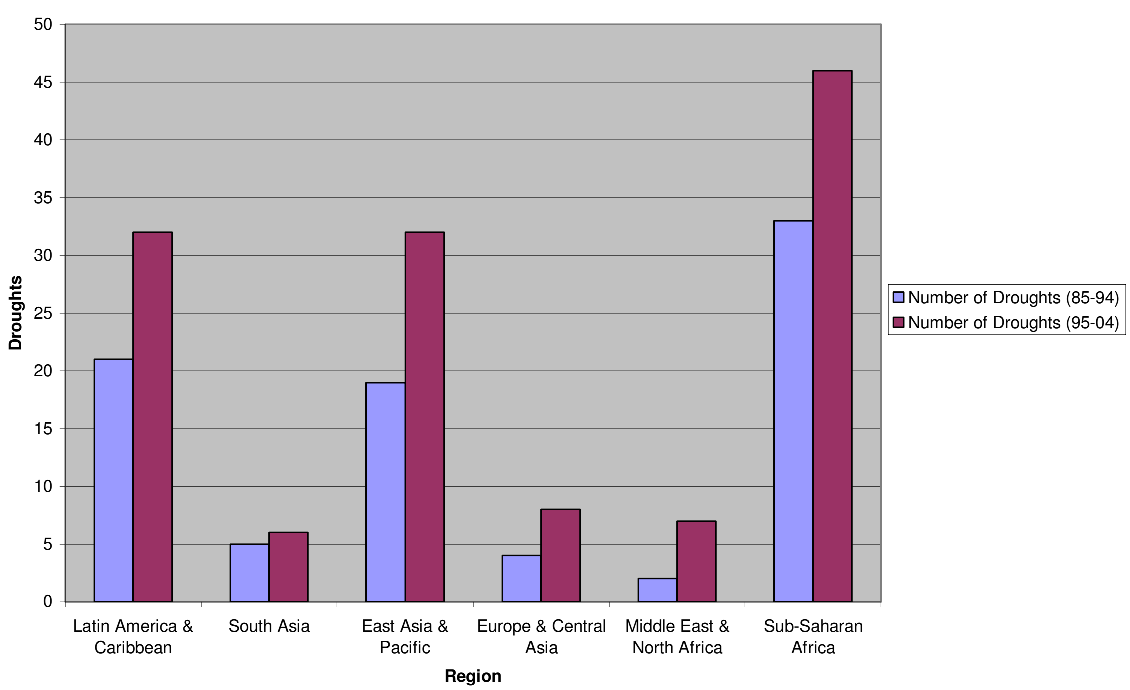

Fig: A.1.4 Number of Deaths by Region

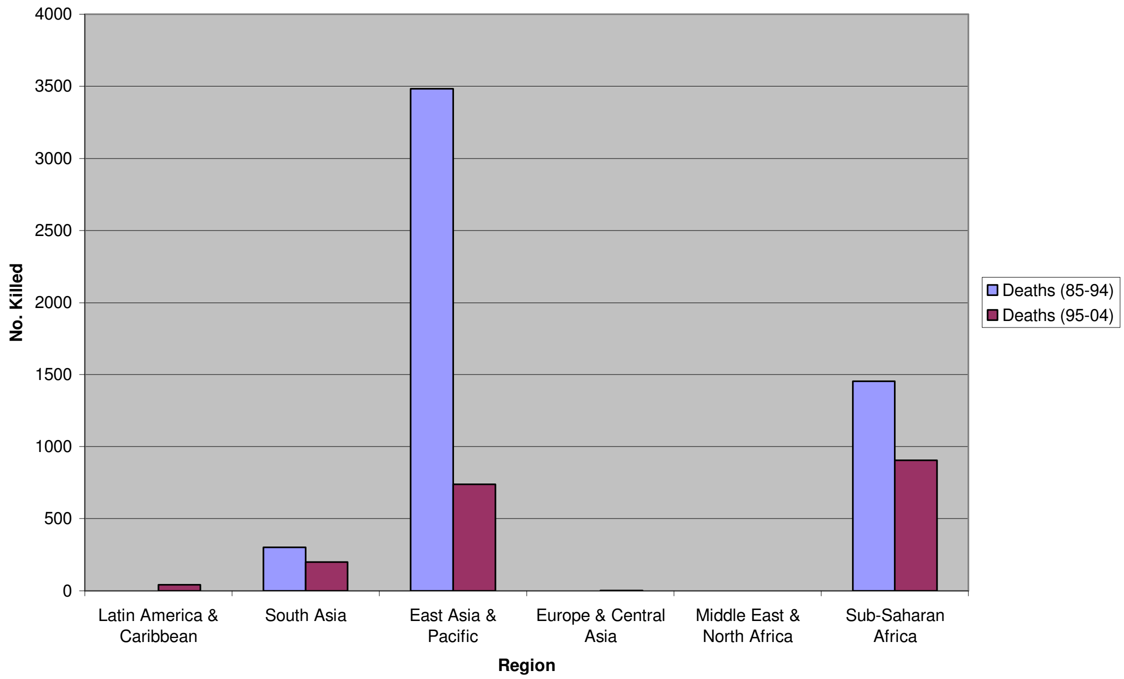

Table A.1.8
Determinants of Droughts

Poisson regression

Log pseudolikelihood = -603.26505

Number of obs	= 1806
Wald chi2(14)	= 98.58
Prob > chi2	= 0.0000
Pseudo R2	= 0.0568

Number of Droughts	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Mean rainfall 1980-2000	-.0002717	.0003901	-0.70	0.486	-.0010363	.0004929
Square rainfall 1980-00	7.53e-08	1.30e-07	0.58	0.563	-1.80e-07	3.30e-07
rain deficit > 10%	.704758	.1435967	4.91	0.000	.4233136	.9862023
Arable land area<.5m	-.7329732	.2682747	-2.73	0.006	-1.258782	-.2071644
Arable land area .5-2.5m	-.5454399	.1835126	-2.97	0.003	-.9051179	-.1857618
Arable land area 2.5-5m	-.3221397	.1834182	-1.76	0.079	-.6816329	.0373534
South Asia	-.5832998	.3060397	-1.91	0.057	-1.183127	.016527
Mid. East and No. Africa	-1.239643	.3986774	-3.11	0.002	-2.021036	-.4582497
Sub-Saharan Africa	.2423919	.1816989	1.33	0.182	-.1137314	.5985151
landlock	.0009467	.2409472	0.00	0.997	-.4713013	.4731946
mean elevation	.0002663	.0001434	1.86	0.063	-.0000148	.0005474
Soil suitability	-.0066256	.0080929	-0.82	0.413	-.0224874	.0092363
Distance coastline (km)	-.0002692	.0002247	-1.20	0.231	-.0007095	.0001711
Number of Droughts 70-79	.4018983	.0680671	5.90	0.000	.2684892	.5353074
_cons	-2.150266	.3968983	-5.42	0.000	-2.928173	-1.37236

Table A.1.9
Determinants of Droughts

Poisson regression			Number of obs =	1806		
			Wald chi2(15) =	85.94		
			Prob > chi2 =	0.0000		
Log pseudolikelihood = -611.08806			Pseudo R2 =	0.0445		

Number of Droughts	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Mean rainfall 1980-2000	.0005267	.0003318	1.59	0.112	-.0001236	.001177
Square rainfall 1980-00	-1.66e-07	1.16e-07	-1.43	0.153	-3.93e-07	6.14e-08
rain deficit > 10%	.674175	.1447397	4.66	0.000	.3904904	.9578596
Arable land area<.5m	-.4010579	.2581322	-1.55	0.120	-.9069877	.1048719
Arable land area .5-2.5m	-.5336702	.1870582	-2.85	0.004	-.9002975	-.1670428
Arable land area 2.5-5m	-.2518838	.1903315	-1.32	0.186	-.6249267	.1211592
zdrytemp	-.2355402	.5650413	-0.42	0.677	-1.343001	.8719204
ztropics	.7423023	.3476466	2.14	0.033	.0609275	1.423677
landlock	.1055856	.2419039	0.44	0.662	-.3685373	.5797084
elevation dummy < 300	-.5093122	.251171	-2.03	0.043	-1.001598	-.017026
elevation dummy 300-600	-.281398	.2030884	-1.39	0.166	-.6794439	.1166479
elevation dummy 600-900	-.2373735	.2392387	-0.99	0.321	-.7062726	.2315257
Soil suitability	.0008279	.0090384	0.09	0.927	-.0168871	.0185429
Distance coastline (km)	.0000644	.0002345	0.27	0.784	-.0003952	.0005239
Number of Droughts 70-79	.311095	.0660348	4.71	0.000	.1816691	.4405208
_cons	-2.634705	.3360667	-7.84	0.000	-3.293384	-1.976026

Table A.1.10
Determinants of Droughts

Poisson regression			Number of obs =	1806		
			Wald chi2(13) =	84.88		
			Prob > chi2 =	0.0000		
Log pseudolikelihood = -607.87443			Pseudo R2 =	0.0496		

Number of Droughts	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Mean rainfall 1980-2000	.0005425	.0003129	1.73	0.083	-.0000708	.0011558
Square rainfall 1980-00	-1.66e-07	1.14e-07	-1.46	0.145	-3.90e-07	5.73e-08
rain deficit >10%	.6369973	.1455571	4.38	0.000	.3517106	.9222841
Arable land area<.5m	-.2395958	.2567691	-0.93	0.351	-.742854	.2636624
Arable land area .5-2.5m	-.5587868	.1897097	-2.95	0.003	-.930611	-.1869627
Arable land area 2.5-5m	-.1390285	.1884137	-0.74	0.461	-.5083127	.2302556
Low Income countries	.7897101	.3115842	2.53	0.011	.1790163	1.400404
Lower Middle Income countries	.9814043	.3141008	3.12	0.002	.3657781	1.597031
landlock	.209074	.2586538	0.81	0.419	-.2978781	.7160261
mean elevation	.0001408	.0001373	1.03	0.305	-.0001283	.00041
Soil suitability	-.0064313	.0075985	-0.85	0.397	-.0213241	.0084615
Distance coastline (km)	-.0000841	.0002076	-0.41	0.685	-.0004911	.0003228
Number of Droughts 70-79	.3178071	.0632651	5.02	0.000	.1938097	.4418045
_cons	-3.508696	.4440063	-7.90	0.000	-4.378932	-2.638459

Table A.1.11
Determinants of Mortality

Poisson regression			Number of obs = 1743			
			Wald chi2(15) = 3251.39			
			Prob > chi2 = 0.0000			
Log pseudolikelihood = -471.31591			Pseudo R2 = 0.2822			

Log of deaths due to droughts	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Predicted no. droughts	8.805056	2.647891	3.33	0.001	3.615285	13.99483
landlock	-1.04335	.7926716	-1.32	0.188	-2.596958	.5102576
elevation dummy < 300	-4.057679	1.102955	-3.68	0.000	-6.21943	-1.895927
elevation dummy 300-600	.2115973	.6180508	0.34	0.732	-.99976	1.422955
elevation dummy 600-900	-1.123879	.5858788	-1.92	0.055	-2.27218	.0244221
ethnic	.0769116	1.096483	0.07	0.944	-2.072155	2.225979
Persons/ km2	.0014261	.0016355	0.87	0.383	-.0017795	.0046317
Square of persons/ km2	-9.67e-08	7.15e-07	-0.14	0.892	-1.50e-06	1.30e-06
Low Income countries	17.23135	2.17547	7.92	0.000	12.96751	21.49519
Lower Middle Income countries	14.60404	1.827734	7.99	0.000	11.02175	18.18633
newstate	-.0041231	.3582299	-0.01	0.991	-.7062408	.6979945
Distance coastline (km)	.0006145	.0009588	0.64	0.522	-.0012647	.0024936
polity1	.168683	.0763504	2.21	0.027	.019039	.318327
Log no. affected by drought, 1970-79	.0609676	.0569742	1.07	0.285	-.0506998	.172635
polity1 x Log no. affected by drought	-.0179636	.0060919	-2.95	0.003	-.0299034	-.0060237
_cons	-21.22822	1.641442	-12.93	0.000	-24.44539	-18.01106

Let us first consider the cross-tabulations in Tables A.1.6-A.1.7.

The main findings are as follows:

- The number of droughts rose over the period 1985-94 to 1995-04.
- However, the number of deaths decreased sharply.
- About 48 per cent of the droughts occurred in Low Income countries and 45 per cent in Lower Middle Income countries in 1985-94. So the vast majority of droughts (about 93 per cent) were confined to these countries. This distribution did not change during 1995-2004.
- The distribution of deaths, however, changed drastically. While Low Income countries accounted for one-third of the deaths in 1985-94 and Lower Middle Income countries for the two-thirds, there was a reversal during 1995-2004.
- Droughts became less deadly over time, as the number of deaths per drought declined from about 62 to about 14. The decline in the deadliness of droughts among Lower Middle Income countries was far more pronounced. Although these findings are similar to those with the drought data used earlier, the magnitudes differ.
- The number droughts rose in Latin America and the Caribbean, East Asia and the Pacific, and Sub Saharan Africa.
- The deaths decreased in South Asia, East Asia and the Pacific and Sub Saharan Africa. Latin America and the Caribbean was an exception in the sense that there were no deaths in 1985-94 but 41 in 1995-2004.
- In most regions, deaths per drought decreased sharply in most regions-especially East Asia and the Pacific.

- Although these results are similar to those with the data used earlier, the magnitudes differ.

For graphical illustrations, see Fig: A.1.1 to A.1.4.

Let us turn to the determinants of occurrence of droughts and the mortality associated with them. To avoid repetition, our comments are confined to Tables A.1.10 and A.1.11.

Several results in Table A.1.10 are largely similar to those in Table 7 but there are slight differences in the magnitudes.

- Mean rainfall and frequency of droughts are positively linked but the latter diminishes at higher average rainfall. However, the coefficient of square of mean rainfall is not significant.
- Rainfall deficit years are associated with higher frequencies of droughts.
- Arable area dummy for the second range records fewer droughts relative to the omitted category.
- Both Low income and Lower Middle Income countries record higher frequencies of droughts relative to the omitted income category.
- Finally, the more frequent were the droughts in the period 1970-79, the higher was the frequency in the period 1980-2004.

Let us now turn to the results in Table A.1.11. Again, many of the key results in Table 9, with differences in the magnitude, are reproduced by the new drought mortality data. Briefly,

- The higher the (predicted) frequency of droughts, the greater were the deaths.
- The first and third elevation ranges were associated with fewer deaths.
- Both Low Income and Lower Middle Income countries recorded more deaths than the omitted group of Upper Middle Income countries.
- While the Polity scores were associated with higher deaths, the interaction of Polity and number of affected persons in 1970-79 diminished this effect. So to the extent that more democratic regimes learnt from past disaster experience, there are likely to be fewer deaths in more democratic regimes.

Annex 1.B.3

Are Droughts Cyclical?

Droughts have occurred frequently and are likely to do so in the future. However, the time between consecutive droughts, as well as their duration, intensity, and spatial extent are uncertain. Many investigators have looked for cyclical behaviour in the time-series of precipitation and water-resource variables related to droughts. Glantz and Katz (2000), for example, are emphatic that these cycles explain only a small fraction of the inter-annual variations in precipitation. In fact, there are some specialists who question whether cycles even exist. So, they assert, it is best to consider droughts as *aperiodic* as well as *recurring* phenomena.

Let us first consider that precipitation is cyclical. In a meticulous analysis of drought and rainfall patterns in India during 1875-1999, Sivasami (2000) identifies three large cycles- from 1877 to1907, 1907to 52 and 1952 to 87. While the cycles from 1877 to1907 and from 1952 to 87 are similar and characterized by frequent occurrence of droughts in the latter part of the cycle, the cycle from 1907 to 52 recorded far fewer droughts. In fact, there were two shorter cycles-one from 1907 to 1932 (26 years) and another from 1932 to 1952. 1939, 1940 and 1941 were consecutive drought years. Drawing upon the results of different methods used, Sivasami (2000) reports that (i) a strong monsoon pulse-defined as a period of years when monsoon rainfall is within 10 per cent of the normal-did not last more than 13 years. (ii) Severe widespread drought invariably followed a strong monsoon pulse. A year of a strong monsoon pulse was followed by a short strong monsoon spell and then by frequent monsoon rainfall failure over large parts. (iii) Although there were cases of a strong monsoon pulse followed by droughts –occasionally in two or three consecutive years-some randomness prevails, ruling out extrapolation of these events into the future.

Another important analysis of droughts in India covers a much longer period (i.e., 1771 to 1977)[87]. Whether droughts over this period exhibited non-randomness is examined with the help of the Mann-Kendall rank statistic test for randomness against trend, and the Swed-Eisenhart runs test for runs above and below the median. If the number of runs is too large, it suggests oscillation, and, if it is too small, it suggests trend. If it is neither too large (i.e. not greater than the 95 per cent value), nor too small (i.e. not less than the 5 per cent value), the series is taken to be random.

The Mann-Kendall statistic suggests that the time interval between droughts is random. The Swed-Eisenhart runs leads to the same conclusion. Thus the occurrence of droughts is random in time.

A related issue is whether the occurrence of droughts, 0, 1, 2, 3,… in a 5-10 year period, is approximated by a probability distribution. As the mean probability of occurrence of a drought year is low, the Poisson distribution fits the data well in terms of a chi-square test. The probabilities of 0, 1, 2, 3, 4 droughts in a 10-year period are 0.212, 0.329, 0.255 and 0.046, respectively. These probabilities may change slightly, depending on when the 10-year period commenced. Such probabilities are useful for planning anticipatory measures.

Annex 2
Trends in Food Production

Here trends in the food production index (1999-2001=100) are summarized by level of income and region. The general form used is:

$$\text{lfprod}_{it} = \alpha + \beta\,\text{t80\_04} + \gamma\,\text{tsq} + \varepsilon_{it} \qquad \text{(A.2.1)}$$

where lfprod denotes the food production index for country i in year t (=1 for 1980), t80_04 is the sample period (1980-2004), and tsq denotes square of t(=1 for 1980), and ε is the error term. All results are based on robust regression.

[87] For details, see Mooley and Pant (1981).

(a) By Level of Income

Table A.2.1
Trend in Food Production in Low Income Countries[88]

Robust regression — Number of obs = 1034; F(2, 1031) = 711.38; Prob > F = 0.0000

lfprod	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.0242011	.0030813	7.85	0.000	.0181548	.0302474
tsq	.0001378	.000114	1.21	0.227	-.0000859	.0003615
_cons	4.022865	.0177671	226.42	0.000	3.988001	4.057729

Table A.2.2
Trend in Food Production in Lower Middle Income Countries[89]

Robust regression — Number of obs = 883; F(2, 880) = 600.38; Prob > F = 0.0000

lfprod	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.0448766	.0032036	14.01	0.000	.038589	.0511642
tsq	-.0007122	.0001183	-6.02	0.000	-.0009444	-.00048
_cons	3.995088	.0185361	215.53	0.000	3.958708	4.031468

In both Lower Middle Income and Upper Middle Income countries, there is a quadratic trend in the (log) of food production index. So, while food production has increased over time, it did so at a decreasing rate. In Low Income countries, by contrast, food production grew at a constant rate (2.42 per cent per annum). Note that the results for groups of countries need not necessarily apply to each individual country.

Table A.2.3
Trend in Food Production in Upper Middle Income Countries[90]

Robust regression — Number of obs = 452; F(2, 449) = 50.73; Prob > F = 0.0000

lfprod	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.0241261	.0057877	4.17	0.000	.0127518	.0355005
tsq	-.0003976	.0002146	-1.85	0.065	-.0008194	.0000242
_cons	4.292774	.0331664	129.43	0.000	4.227594	4.357955

88 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 239.27
Prob > chi2 = 0.0000

89 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 357.46
Prob > chi2 = 0.0000

90 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 203.01
Prob > chi2 = 0.0000

(b) By Region

As regional differences in food production are of considerable interest too, the results of a quadratic trend in food production are given below.

Table A.2.4
Trend in Food Production in Latin America and the Caribbean[91]

```
Robust regression                                     Number of obs =      600
                                                      F(  2,    597) =  253.48
                                                      Prob > F      =  0.0000
lfprod                          Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------------------------------------------------------------------------------
t80_04                       .0233617   .0042503     5.50   0.000     .0150144    .0317091
tsq                         -.0000143   .0001587    -0.09   0.928    -.000326     .0002973
_cons                        4.117899   .0239812   171.71   0.000     4.070801    4.164997
```

There are significant differences. In Latin America and the Caribbean, food production grew at a constant rate (2.33 per cent per annum). In East Asia and the Pacific, the growth rate was constant but slower (1.15 per cent per annum). Central Asia and Europe stands out as the only region where food production did not exhibit a trend. In Middle East and North Africa, food production grew at a diminishing rate while in Sub-Saharan Africa it grew at a faster rate over the sample period. In the case of the latter, a better than expected performance in recent years presumably underlies the increasing trend in food production.

Table A.2.5
Trend in Food Production in South Asia[92]

```
Robust regression                                     Number of obs =      150
                                                      F(  2,    147) =  408.28
                                                      Prob > F      =  0.0000
lfprod                        Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
t80_04                     .0526949   .0047413    11.11   0.000     .0433249    .0620649
tsq                       -.0007903    .000177    -4.46   0.000    -.0011401   -.0004404
_cons                      3.832444   .0267518   143.26   0.000     3.779576    3.885311
```

Table A.2.6
Trend in Food Production in East Asia and the Pacific[93]

```
Robust regression                                     Number of obs =      435
                                                      F(  2,    432) =   84.17
                                                      Prob > F      =  0.0000
      lfprod                  Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------------------------------------------------------------------------------
      t80_04               .0114628   .0063887     1.79   0.073    -.001094     .0240196
         tsq                .000315   .0002377     1.33   0.186    -.0001523    .0007823
       _cons               4.218749   .0362163   116.49   0.000     4.147567    4.289932
```

91
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
        Ho: Constant variance
        chi2(1)      =   178.54
        Prob > chi2  =   0.0000
```

92
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
        Ho: Constant variance
        chi2(1)      =    59.45
        Prob > chi2  =   0.0000
```

93
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
        Ho: Constant variance
        chi2(1)      =   164.17
        Prob > chi2  =   0.0000
```

Table A.2.7
Trend in Food Production in Europe and Central Asia[94]

Robust regression — Number of obs = 285; F(2, 282) = 0.99; Prob > F = 0.3744

lfprod	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	-.0061731	.0070833	-0.87	0.384	-.020116	.0077698
tsq	.0001411	.0002423	0.58	0.561	-.0003358	.000618
cons	4.706741	.0482242	97.60	0.000	4.611816	4.801666

Table A.2.8
Trend in Food Production in Near East and North Africa[95]

Robust regression — Number of obs = 250; F(2, 247) = 375.55; Prob > F = 0.0000

lfprod	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.0563035	.0052403	10.74	0.000	.0459821	.0666249
tsq	-.0008556	.0001956	-4.37	0.000	-.0012409	-.0004702
_cons	3.831895	.0295671	129.60	0.000	3.773659	3.890131

Table A.2.9
Trend in Food Production in Sub-Saharan Africa[96]

Robust regression — Number of obs = 649; F(2, 646) = 246.08; Prob > F = 0.0000

lfprod	Coef.	Std. Err.	t	P> t	[95% Conf.	Interval]
t80_04	.0125409	.0040428	3.10	0.002	.0046023	.0204795
tsq	.0003365	.0001503	2.24	0.025	.0000414	.0006316
_cons	4.180604	.0230119	181.67	0.000	4.135417	4.225791

Trends in Food Prices

From a cross-country perspective, a food production shock due to a drought need not necessarily imply higher food prices and loss of food entitlements of, say, agricultural labourers if the supply

94 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 56.86
Prob > chi2 = 0.0000

95 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 46.70
Prob > chi2 = 0.0000

96 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 167.39
Prob > chi2 = 0.0000

deficit is overcome through imports or food stocks held domestically. So it is necessary to analyse trends in food prices as well.

(a) By Level of Income

The contrast among groups of countries by level of income is striking. Among Low Income countries, the rate of growth of food prices increased over time (or, inflation accelerated). By contrast, Lower Middle Income countries witnessed a fixed but more than moderate increase (11.34 per cent per annum). In Upper Middle Income countries, food prices increased with time (as only the quadratic term possessed a significant positive coefficient).

Table A.2.10
Trend in Food Prices in Low Income Countries[97]

Robust regression — Number of obs = 572; F(2, 569) = 433.88; Prob > F = 0.0000

Log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.0404851	.0098688	4.10	0.000	.0211014	.0598688
tsq	.0010713	.0003782	2.83	0.005	.0003286	.0018141
_cons	3.267601	.0554903	58.89	0.000	3.158611	3.376592

Table A.2.11
Trend in Food Prices in Lower Middle Income Countries[98]

Robust regression — Number of obs = 720; F(2, 717) = 477.81; Prob > F = 0.0000

Log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.1134646	.0135978	8.34	0.000	.0867683	.140161
tsq	-.0005576	.0005193	-1.07	0.283	-.0015772	.0004619
_cons	2.463234	.0764807	32.21	0.000	2.313081	2.613387

97 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 513.64
Prob > chi2 = 0.0000

98 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 407.22
Prob > chi2 = 0.0000

Table A.2.12
Trend in Food Prices in Upper Middle Income Countries[99]

Robust regression — Number of obs = 382; F(2, 379) = 97.46; Prob > F = 0.0000

Log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	-.0016074	.0143869	-0.11	0.911	-.0298956	.0266808
tsq	.0018467	.0005478	3.37	0.001	.0007695	.0029238
_cons	3.826574	.0811914	47.13	0.000	3.666932	3.986216

(b) By Region

The regional contrast in growth of food prices varied a great deal. In latin America and the Caribbean, food prices rose but at a diminishing rate, as also in South Asia, Central

Table A.2.13
Trend in Food Prices in Latin America and the Caribbean[100]

Robust regression — Number of obs = 464; F(2, 461) = 1201.26; Prob > F = 0.0000

Log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.2806132	.013179	21.29	0.000	.2547149	.3065116
tsq	-.0051989	.0005052	-10.29	0.000	-.0061917	-.004206
_cons	1.043757	.0733924	14.22	0.000	.8995321	1.187982

Asia and Europe, and Middle East and North Africa. In East Asia, and the Pacific, by contrast, food prices rose at a constant rate (5.44 per cent per annum) while in Sub-Saharan Africa at an accelerated rate.

Table A.2.14
Trend in Food Prices in South Asia[101]

Robust regression — Number of obs = 132; F(2, 129) = 2457.79; Prob > F = 0.0000

Log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.1318303	.0056443	23.36	0.000	.1206629	.1429977
tsq	-.0016091	.0002153	-7.47	0.000	-.002035	-.0011831
_cons	2.547421	.0315473	80.75	0.000	2.485004	2.609838

99 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 239.23
Prob > chi2 = 0.0000

100 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 349.51
Prob > chi2 = 0.0000

101 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 57.09
Prob > chi2 = 0.0000

Table A.2.15
Trend in Food Prices in East Asia and the Pacific[102]

Robust regression — Number of obs = 242; F(2, 239) = 321.53; Prob > F = 0.0000

Log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.0543744	.00765	7.11	0.000	.0393044	.0694444
tsq	-.0003377	.0002962	-1.14	0.255	-.0009212	.0002459
_cons	3.613983	.0419861	86.08	0.000	3.531273	3.696693

Table A.2.16
Trend in Food Prices in Europe and Central Asia[103]

Robust regression — Number of obs = 238; F(2, 235) = 450.91; Prob > F = 0.0000

Log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.5457065	.0577704	9.45	0.000	.4318925	.6595205
tsq	-.0052236	.0021197	-2.46	0.014	-.0093996	-.0010475
_cons	-4.59944	.356764	-12.89	0.000	-5.302304	-3.896576

Table A.2.17
Trend in Food Prices in Middle East and North Africa[104]

Robust regression — Number of obs = 163; F(2, 160) = 428.47; Prob > F = 0.0000

Log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.0877	.0073877	11.87	0.000	.0731099	.10229
tsq	-.0014595	.0002835	-5.15	0.000	-.0020193	-.0008997
_cons	3.416319	.0411108	83.10	0.000	3.335129	3.497509

102 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 79.05
Prob > chi2 = 0.0000

103 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 32.29
Prob > chi2 = 0.0000

104 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 73.60
Prob > chi2 = 0.0000

Table A.2.18
Trend in Food Prices in Sub-Saharan Africa[105]

Robust regression — Number of obs = 435; F(2, 432) = 256.96; Prob > F = 0.0000

Log of food price index	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t80_04	.0450888	.0133633	3.37	0.001	.0188237	.071354
tsq	.0010181	.0005136	1.98	0.048	8.68e-06	.0020276
_cons	3.220964	.0744338	43.27	0.000	3.074667	3.367262

Trends in Agricultural Wage Rates

(a) By Income

Among Low Income countries, there was a positive but weakly significant trend in agricultural wages over the period 1995-2004; among Lower Middle Income countries, the coefficient of time was negative but not significant; and among Upper Middle Income countries, there was a significant positive trend in agricultural wage rates. It must, however, be borne in mind that the absence of a significant trend in a group of countries need not necessarily imply that none recorded a trend, as some experiencing a positive trend could be offset by a negative trend in others.

Table A.2.19
Trend in Agricultural Wages in Low Income Countries[106]

Robust regression — Number of obs = 48; F(1, 46) = 1.22; Prob > F = 0.2751

Log of agricultural wages	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t95_04	.0642197	.0581417	1.10	0.275	-.0528134	.1812528
_cons	5.147281	.3221927	15.98	0.000	4.498741	5.795821

105 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 254.68
Prob > chi2 = 0.0000

106 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 5.95
Prob > chi2 = 0.0147

Table A.2.20
Trend in Agricultural Wages in Lower Middle Income Countries[107]

Robust regression — Number of obs = 149; F(1, 147) = 0.80; Prob > F = 0.3712

Log of agricultural wages	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t95_04	-.0193957	.0216239	-0.90	0.371	-.0621296	.0233382
_cons	6.408642	.1227076	52.23	0.000	6.166143	6.651141

Table A.2.21
Trend in Agricultural Wages in Upper Middle Income Countries[108]

Robust regression — Number of obs = 83; F(1, 81) = 20.75; Prob > F = 0.0000

Log of agricultural wages	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t95_04	.0501888	.011018	4.56	0.000	.0282664	.0721111
_cons	6.31714	.0674874	93.60	0.000	6.182862	6.451419

(c) By Region

The regional contrast in growth of wage rates is striking too. Latin America and the Caribbean, South Asia, Europe and Central Asia, and Middle East and North Africa recorded a positive trend; in sharp contrast, East Asia and the Pacific did not show a trend; and Sub-Saharan Africa recorded a positive but weakly significant trend.

Table A.2.22
Trend in Agricultural Wages in Latin America and the Caribbean[109]

Robust regression — Number of obs = 96; F(1, 94) = 3.07; Prob > F = 0.0831

Log of agricultural wages	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t95_04	.018979	.0108357	1.75	0.083	-.0025356	.0404936
cons	6.425079	.0639428	100.48	0.000	6.298119	6.552039

107 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 14.00
Prob > chi2 = 0.0002

108 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 2.21
Prob > chi2 = 0.1372

109 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 3.89
Prob > chi2 = 0.0484

Table A.2.23
Trend in Agricultural Wages in South Asia[110]

```
Robust regression                                        Number of obs =       8
                                                         F(  1,     6) = 9630.96
                                                         Prob > F      =  0.0000
Log of agricultural           Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
wages
------------------------------------------------------------------------------------------
t95_04                     .0330115   .0003364    98.14   0.000     .0321884    .0338346
_cons                      4.992836   .0023183  2153.63   0.000     4.987163    4.998509
```

Table A.2.24
Trend in Agricultural Wages in East Asia and the Pacific[111]

```
Robust regression                                        Number of obs =      38
                                                         F(  1,    36) =    0.19
                                                         Prob > F      =  0.6669
Log of agricultural           Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
wages
------------------------------------------------------------------------------------------
t95_04                     .0119996   .0276509     0.43   0.667    -.0440792    .0680783
_cons                       6.20601   .1516496    40.92   0.000      5.89845     6.51357
```

Table A.2.25
Trend in Agricultural Wages in Europe and Central Asia[112]

```
Robust regression                                        Number of obs =      99
                                                         F(  1,    97) =    7.44
                                                         Prob > F      =  0.0076
Log of agricultural           Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
wages
------------------------------------------------------------------------------------------
t95_04                     .0799726   .0293212     2.73   0.008     .0217782     .138167
_cons                      5.555263   .1710972    32.47   0.000     5.215682    5.894844
```

110
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
      Ho: Constant variance
      chi2(1)      =     0.03
      Prob > chi2  =   0.8697
```

111
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
      Ho: Constant variance
      chi2(1)      =     2.95
      Prob > chi2  =   0.0857
```

112
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
      Ho: Constant variance
      chi2(1)      =    13.85
      Prob > chi2  =   0.0002
```

Table A.2.26
Trend in Agricultural Wages in Middle East and North Africa[113]

Robust regression — Number of obs = 13; F(1, 11) = 6.54; Prob > F = 0.0267

Log of agricultural wages	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t95_04	.1914762	.0748858	2.56	0.027	.0266536	.3562987
_cons	8.296406	.3824086	21.70	0.000	7.45473	9.138081

Table A.2.27
Trend in Agricultural Wages in Sub-Saharan Africa[114]

Robust regression — Number of obs = 26; F(1, 24) = 1.85; Prob > F = 0.1863

Log of agricultural wages	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t95_04	.0923848	.0679077	1.36	0.186	-.0477698	.2325395
_cons	6.163726	.3790311	16.26	0.000	5.381444	6.946007

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113 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 0.60
Prob > chi2 = 0.4387

114 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 6.34
Prob > chi2 = 0.0118

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