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On Devastating Droughts

Raghav Gaiha[1], Kenneth Hill[2], Shantanu Mathur[3] and Vani S. Kulkarni[4]

1. **Centre for Population and Development Studies, Harvard University&Faculty of Management Studies, University of Delhi**
2. **Centre for Population and Development Studies, Harvard University**
3. **International Fund for Agricultural Development**
4. **Centre for Population and Development Studies, Harvard University**

Email id : rdg@bol.net.in

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 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-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.

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. Whether weather insurance would protect the vulnerable better than crop insurance is plausible but far from self-evident, given the limited coverage.

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 (1982), 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 (1982) and others have emphasised using an entitlements framework.

Sen (1982) 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 (1982) 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].

As part of a reexamination of Sen's (1982) rejection of FAD, an attempt will be made to demonstrate whether (i) a history of low food consumption matters, and (ii) whether *severity* of food consumption shocks in the year of the famine matters or whether even mild shocks in *combination* with a history of low food consumption trigger(s) a famine. 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

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[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).

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 (1982) 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 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 e.g. food imports, price stabilisation, cash transfers through public works, soil conservation and other longer-term development measures (e.g. 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.

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

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[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, droughts 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, drought is defined as a calendar year in which rainfall registers in the lower 10 per 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).

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]

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-have disastrous consequences. During 1978-2003, for example, 14 million hectares of land were exposed to droughts, and direct economic losses are estimated to be 0.5-3.3 per cent of agricultural value added. In Thailand alone, the drought in 2004 is 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 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

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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.

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).

7 For a detailed exposition, see Bryant (2005).

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.

An elaboration of these effects in a regional context-the Sahel - may be helpful.

- During the series of droughts in the 1960s, there was a total collapse of agriculture, and outward migration began immediately. By 1970, 3 miilion people in the west Sahel had been displaced and needed emergency food. As the drought continued in 1971, not only community groups but also national governments fell prey to the devastation.
- Outward migration of nomads led to conflicts with pastoralists over wells, dams, and other watering areas.
- Chronic malnutrition and the accompanying diseases –such as measles, cholera, smallpox, meningitis, dysentry, malaria, schistosomiastis-spread rapidly. Chronic malnutrition usually results in death, but not necessarily by starvation. Susceptibility to infection increaes while recovery becomes harder.
- As national governments were bankrupted, international response was paltry, and the transportation infrastructure was weak, food distribution even on a modest scale was not feasible. In 1973, 50 per cent of the required grain was distributed; in 1974-the seventh year of the drought-this share rose to 75 per cent.
- The environmental impact was serious too. Grasslands, overgrazed by nomads, were exposed to wind deflation. Desertification accelerated.
- But the lessons of this drought were ignored, as the 1983 drought was a repeat performance. The same national and international responses were replayed.

That much of this devastation is avoidable is illustrated by Botswana. Botswana, in 1986, 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. Some useful lessons emerge from the case studies summarised below[8].

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

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. 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. But the growth has been highly uneven. 1981-2 marked the beginning of a prolonged and severe drought which lasted until 1986-7. As argued below, it would have been accompanied by an even sharper deterioration of income and employment opportunities in the absence of vigorous public support measures. The rural economy based on livestock, crop production and derived activities suffered a predictable recession during the drought. Food crop outputs fell to negligible levels and cattle mortality increased substantially. Decline of employment opportunities further aggravated rural livelihoods.

By 1981-2, Botswana had set up an entitlement protection system, an outcome of a long process of experimentation, evaluation and learning based on 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.

- The entitlement protection that emerged relied on (i) adherence to a Relief Manual of detailed guidelines, and (ii) provision of employment to the able-bodied (for a subsistence wage paid in cash), supplemented by unconditional relief for vulnerable groups.
- 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 3) direct food distribution among selected groups.[9]
- The experience of drought relief in Botswana in 1982-7 amply demonstrates the effectiveness of a famine prevention system based 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. Reports indicate that 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.

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[9] 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).

- 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 points to the difference that public action makes[10].

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' policywas in force to facilitate procurement from surplus zones –presumably to transfer this to deficit zones[11]. Further, traditional relief measures –relief works and unconditional relief – were undertaken.
- In Bihar, the 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

[10] This draws upon Dreze (1990 a).
[11] Private trade in foodgrains across broad zones within the country was prohibited.

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.

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.[12] 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.[13]
- 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

[12] Official agencies tacitly colluded for fear of social unrest (Dreze, 1990 a).

[13] For an exposition of the link between poverty and inequality-in the context of a supply shock (e.g. drought)-see Dasgupta (1987).

greater equality in *current expenditure*; (iii) greater equality was accompanied by a considerable reduction in *average* real incomes and expenditure; and (iv) the latter resulted from 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 preserve ordinary consumption standards becomes extremely costly as widespread sales drive asset prices down[14]. 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 entitlements. 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[15]. The resilience of public works as the main income transfer mechanism ensured both a sharp concentration of resources on the needy (the targeting objective)[16] 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).

[14] 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.

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

[16] 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 Maharashtra drought (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.

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?[17] This is followed by an econometric analysis of 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 section, some key elements of a strategy of famine prevention 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[18]. The main component is EM-DAT which covers all countries over the entire 20th century[19]. 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[20]. As noted earlier, these criteria ensure greater uniformity in classifying an event as drought.

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

A recent review draws attention to the following problems/gaps in the EM-DAT[21]:

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[17] 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).

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

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

[20] 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).

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

- 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, cited on p.15). Larger discrepancies in the numbers affected are due to underreporting in DesInventar, suggesting that EM-DAT are more reliable. In any case, a general consensus is that mortality data are more robust across different data sets[22].
- The economic losses consist of direct and indirect components. The direct losses refer to the physical destruction of assets, comprising private dwellings, small business properties, industrial facilities, and government assets including infrastructure (e.g. roads, bridges, ports, telecommunications) and public facilities (e.g. hospitals, schools). The indirect losses, on the other hand, refer to disruption of economic activities, and loss of employment and livelihoods. In addition, business pessimism could dampen investment and consequently growth. So the relationship between destruction of capital and loss of income may vary a great deal[23]. 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 including insurance companies, multilateral institutions and the news media. It is thus plausible that insured losses are better covered and consequently there is significantly lower coverage of losses in developing countries (Andersen, 2005). Accordingly, the economic losses reported in EM-DAT are not analysed.

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

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

[23] 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).

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 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[24].

A brief exposition of the Poisson 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.[25] 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

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

A common formulation for λ_i is

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

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 $E\left[y_i \,/\, X_i\right] = \lambda = e^{\sum_K \beta_K X_{iK}}$. 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:

$$\text{Var}\ (y \mid \mathbf{X}) = E\ (y \mid \mathbf{X}) \qquad (3)$$

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

[24] With the logarithmic transformation of deaths, the Poisson distribution is appropriate.
[25] For an exposition of the Poisson regression, see Wooldrige (2006).

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:

$$\mathrm{Var}(y \mid \mathbf{x}) = \sigma^2 \mathrm{E}(y \mid \mathbf{x}) \qquad (4)$$

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.

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 split into 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 during 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. Ratios of droughts and deaths due to them 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[26]. 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 restrict to deaths per drought. The reduction in the deadliness of droughts in Lower Middle Income countries

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

was considerably greater than in Low Income countries, as shown in Table 2, and illustrated graphically 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 in subsequent years.

As droughts are caused by 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 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.

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

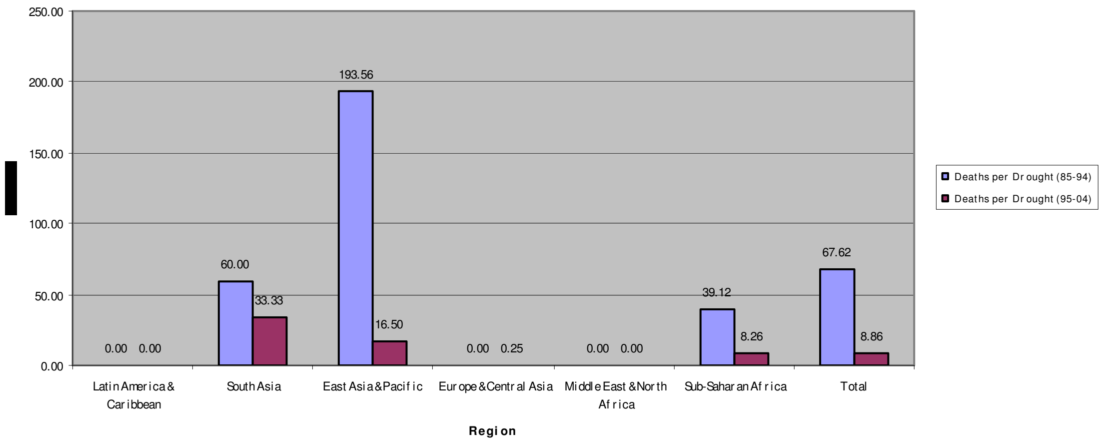


Fig. 2: Deaths per Drought by Income

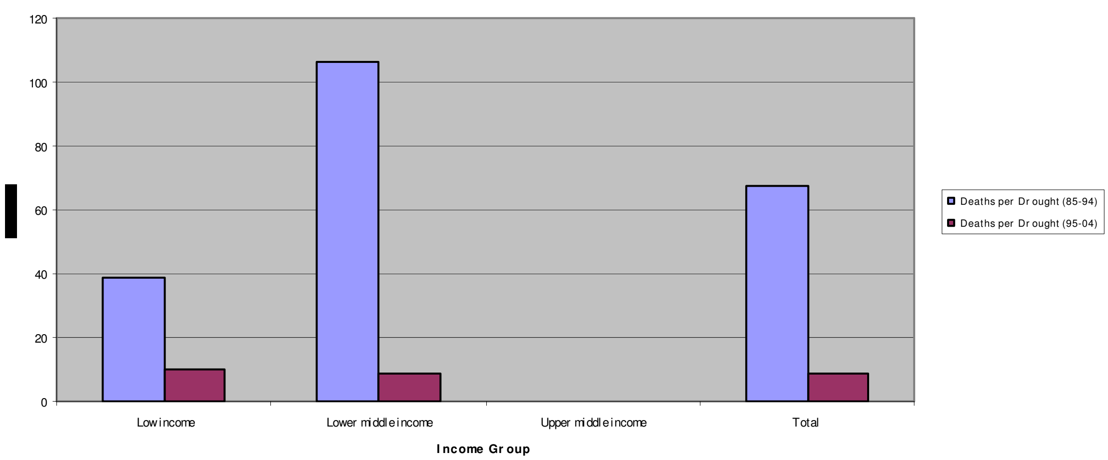


Table 3
Distribution of Droughts by Rainfall (mean mm.) during 1980-85

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

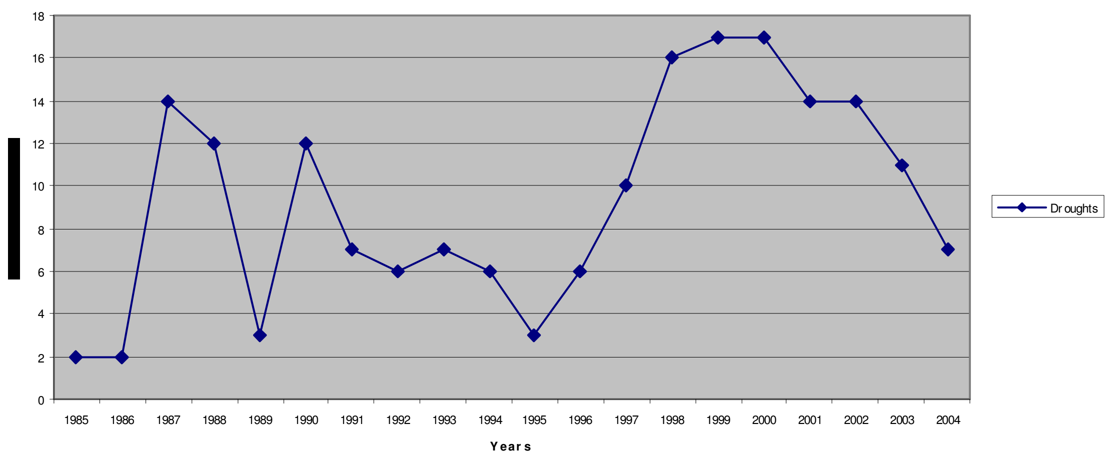
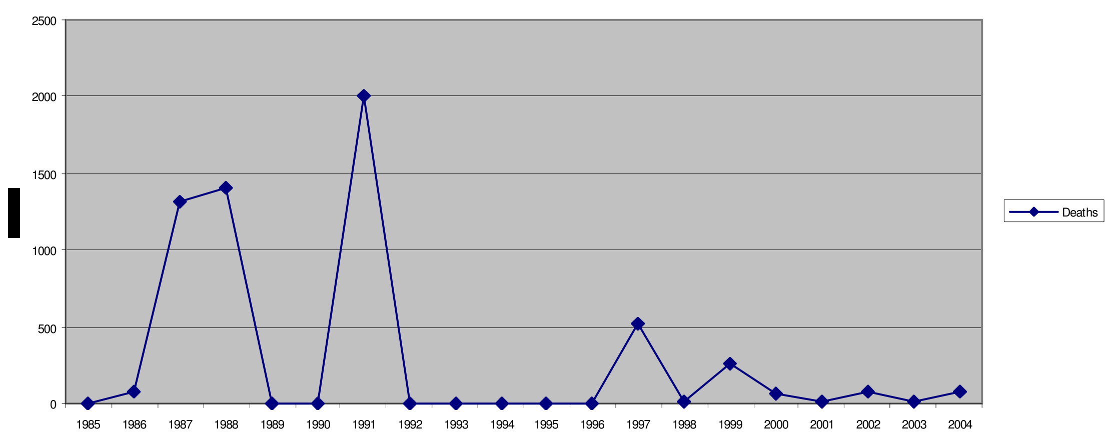


Fig: 4 Deaths Due to Droughts during 1985-2004



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 initial rainfall, annual incremental rainfall, 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-number of droughts in 1970-79 serves as a catch-all variable[27]. In addition, we experiment with country dummies. A selection of results is given below[28].

Table 5
Determinants of Droughts (1980-2004)

Poisson regression	Number of obs	=	1806
	Wald chi2(14)	=	49.17
	Prob > chi2	=	0.0000
Log pseudolikelihood = -571.7671	Pseudo R2	=	0.0379

no_dr	Coef.	Robust Std. Err.	z	P>|z|	Coef[1].	Robust Std. Err.	z
mr	-.0002845	.0004324	-0.66	0.510	-.0045592	.0018111	-2.52
_ImrXmr	5.12e-08	1.42e-07	0.36	0.719	2.12e-06	5.51e-07	3.84
gr_rain_ann	-1.232226	.417144	-2.95	0.003	-1.248085	.4092438	-3.05
al_d1	-.5514312	.2838225	-1.94	0.052	1.959348	1.882975	1.04
al_d2	-.5195879	.2042695	-2.54	0.011	.3744784	1.477694	0.25
al_d3	-.4860428	.2073243	-2.34	0.019	-.0365129	1.347134	-0.03
regd21	-.1407133	.324374	-0.43	0.664	2.450434	2.301851	1.06
regd41	-1.115804	.400146	-2.79	0.005	-9.160142	2.194482	-4.17
regd51	.063216	.2063961	0.31	0.759	4.939989	1.376346	3.59
landlock	-.1090129	.2561689	-0.43	0.670	5.712112	1.29326	4.42
elev	.0000865	.0001547	0.56	0.576	.0006759	.0005348	1.26
soilsui1	-.0153936	.0084105	-1.83	0.067	-.2658169	.038004	-6.99
distc	-.0002907	.0002152	-1.35	0.177	.0005184	.0013271	0.39
no_dr_70_79	.8603581	.2714952	3.17	0.002	11.18761	2.185885	5.12
_cons	-1.514512	.4272793	-3.54	0.000	-6.944132	3.490199	-1.99

1. These coefficients, their standard errors and z values are obtained after inserting country dummies.

Let us first consider the results in Table 5 (without the country dummies). Given the non-linearity between droughts and (initial) annual rainfall, the square of rainfall is also used as an explanatory variable. As rainfall levels change over time, a third rainfall variable measuring (annual) incremental rainfall is used[29].

- The coefficients of initial rainfall and its square are not significant. However, the coefficient of incremental rainfall is negative and significant.

[27] For a list of variables used in regressions, see Annex 1.
[28] Other diagnostic results are available on request.
[29] Log of average annual rainfall during 1980-85 is specified as initial rainfall. Incremental rainfall is accordingly measured as Δ(log rainfall$_t$ - log rainfall$_{t-1}$).

- Frequency of droughts is lower in each of the three ranges of arable land area, relative to the benchmark/default range[30].
- 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.
- Elevation and frequency of droughts are unrelated.
- As expected, droughts are less frequent in areas with greater soil suitability for rainfed crops[31].
- 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) = 54.91; Prob > chi2 = 0.0000; Pseudo R2 = 0.0391

Log pseudolikelihood = -571.05534

no_dr	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
mr	.0003026	.0003857	0.78	0.433	-.0004534	.0010586
_ImrXmr	-1.02e-07	1.31e-07	-0.78	0.436	-3.58e-07	1.54e-07
gr_rain_ann	-1.185663	.4053454	-2.93	0.003	-1.980126	-.3912009
al_d1	-.4323094	.274213	-1.58	0.115	-.9697571	.1051383
al_d2	-.5514859	.1962367	-2.81	0.005	-.9361027	-.166869
al_d3	-.5046066	.2064907	-2.44	0.015	-.909321	-.0998923
zdrytemp	-.4513967	.6245414	-0.72	0.470	-1.675475	.772682
ztropics	1.226444	.3632875	3.38	0.001	.5144131	1.938474
landlock	-.0246461	.2563623	-0.10	0.923	-.527107	.4778148
elev_d1	-.521178	.2679134	-1.95	0.052	-1.046279	.0039226
elev_d2	-.2733534	.2098133	-1.30	0.193	-.6845799	.137873
elev_d3	-.3610529	.2628926	-1.37	0.170	-.876313	.1542071
soilsui1	.0058422	.0090726	0.64	0.520	-.0119397	.0236241
distc	.0000151	.0002311	0.07	0.948	-.0004379	.0004682
no_dr_70_79	.8722035	.2688463	3.24	0.001	.3452744	1.399133
_cons	-2.348016	.3503339	-6.70	0.000	-3.034657	-1.661374

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

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

[31] For a measure of soil suitability, see the list of variables in Annex 1.

replaced by four ranges (and three dummies, with the highest range serving as the benchmark case[32]).

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. The coefficient of the dummy for the lowest arable land range is negative and significant, implying lower frequency of droughts relative to the default range. Finally, controlling for other effects, the frequency of droughts is higher with higher share of land in tropical conditions.[33]

Table 7
Determinants of Droughts

```
Poisson regression                                Number of obs   =       1806
                                                  Wald chi2(13)   =      44.89
                                                  Prob > chi2     =     0.0000
Log pseudolikelihood = -570.10544                 Pseudo R2       =     0.0407

------------------------------------------------------------------------------
             |               Robust
       no_dr |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          mr |   .0004316   .0003589     1.20   0.229    -.0002719     .001135
     _ImrXmr |  -1.33e-07   1.26e-07    -1.06   0.291    -3.80e-07    1.14e-07
 gr_rain_ann |  -1.131988   .3913523    -2.89   0.004    -1.899024    -.364951
       al_d1 |  -.2607633   .2694633    -0.97   0.333    -.7889017    .2673751
       al_d2 |  -.5498869   .2076082    -2.65   0.008    -.9567916   -.1429822
       al_d3 |  -.3444254   .2036501    -1.69   0.091    -.7435722    .0547215
     incm_d1 |   .8165234   .3344419     2.44   0.015     .1610293    1.472018
     incm_d2 |   1.091473   .3286415     3.32   0.001     .4473471    1.735598
    landlock |   .1441606   .2739283     0.53   0.599    -.3927291    .6810502
        elev |    .000022   .0001465     0.15   0.881    -.0002651    .0003091
    soilsui1 |  -.0086108   .0074837    -1.15   0.250    -.0232785    .0060569
       distc |  -.0001537    .000201    -0.76   0.444    -.0005476    .0002402
 no_dr_70_79 |   .8412335   .2672197     3.15   0.002     .3174924    1.364974
        cons |  -3.111325   .4658761    -6.68   0.000    -4.024425   -2.198225
```

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[34]. Again, most of the key relationships are corroborated-incremental rainfall reduces the frequency of droughts; it is also lower in lower ranges of arable land;

[32]
```
  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
```

[33] For details, see the note on climatic classification in Annex 1.
[34] For details of the income classification, see Annex 1.

the greater the frequency of droughts in the past, the greater was the frequency in 1980-2004.

Finally, as there are many unobserved effects in the specifications experimented with, one approach is to employ country dummies (to capture country-specific fixed effects). The results are shown in the last three columns of Table 5. Briefly, there are a few striking differences.

- The effects of initial rainfall and its square are significant- while the frequency reduces with higher rainfall, it does so at a decreasing rate. In addition, controlling for these and other effects, incremental rainfall reduces the frequency of droughts.
- The threshold effects of arable land area, however, cease to be significant.
- The lower frequency of droughts in Middle East and North Africa is corroborated. However, it is only with country dummies that Sub-Saharan Africa exhibits a higher frequency of droughts. So evidently the earlier results are vitiated by the omission of country-specific fixed effects.
- Also, not surprisingly, landlocked economies are more prone to droughts, controlling for the effects of other conditions.
- Soil suitability for rainfed crops reduces significantly the occurrence of droughts.
- Finally, countries that were prone to droughts during 1970-79 remained so during 1980-04.

As these results are based on a more complete specification and allow for unobserved effects, we will use the predicted frequency of droughts from this specification for assessing their impact in terms of deaths, impairment of agricultural productivity, loss of food output, and food entitlements through higher food prices and lower agricultural wages.

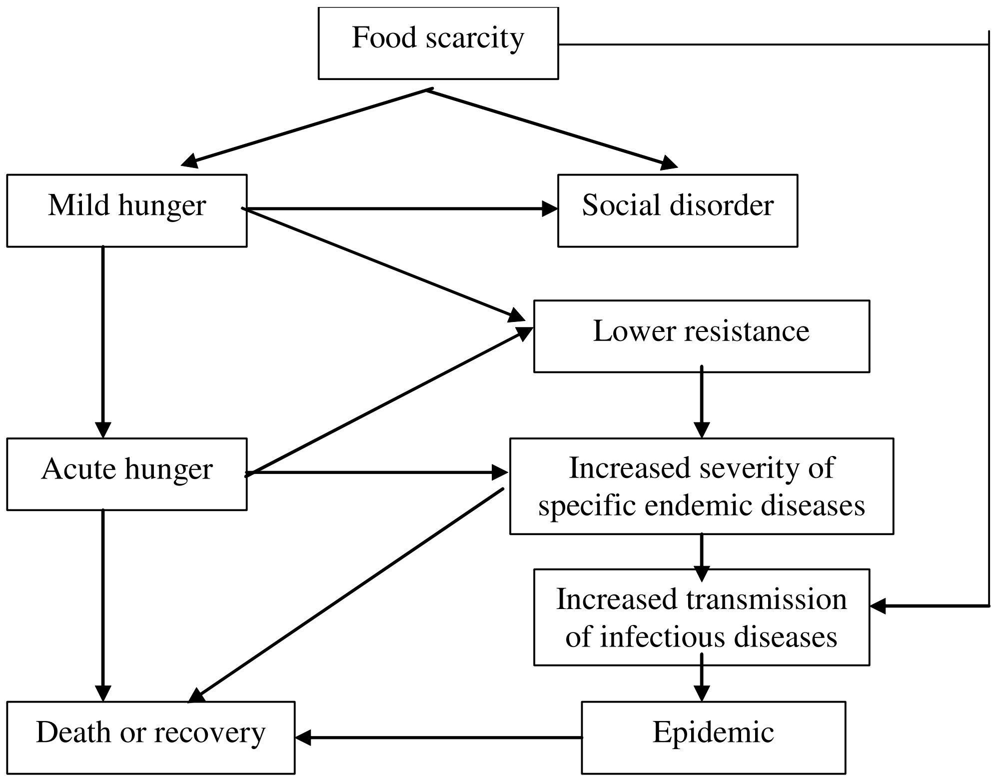
Determinants of Mortality

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[35].

Much of famine mortality is directly or indirectly attributed to malnutrition and starvation (e.g. Appleby, 1978, Sen, 1982).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

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

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 malnourished.



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[36]. 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

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

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 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[37].
- 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.

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

Here the focus is on understanding why droughts kill more in some countries than in others[38].

Table 8
Determinants of Mortality

Poisson regression — Number of obs = 1743; Wald chi2(17) = 5312.55; Prob > chi2 = 0.0000; Pseudo R2 = 0.3726

Log pseudolikelihood = -376.24676

ldeath_dr	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
pno_dr_m4	11.47207	1.615523	7.10	0.000	8.305701	14.63843
landlock	-.6393211	.5948115	-1.07	0.282	-1.80513	.526488
elev_d1	-4.149011	1.71047	-2.43	0.015	-7.50147	-.7965517
elev_d2	-.0480784	.546219	-0.09	0.930	-1.118648	1.022491
elev_d3	-1.759556	.7257272	-2.42	0.015	-3.181956	-.3371573
ethnic	1.408815	1.219164	1.16	0.248	-.9807033	3.798333
pdenpavg	-.0019699	.0019106	-1.03	0.303	-.0057145	.0017748
pdenpavg2	2.09e-06	9.27e-07	2.26	0.024	2.74e-07	3.91e-06
incm_d1	32.2341	5.088035	6.34	0.000	22.26174	42.20647
incm_d2	27.12102	4.103989	6.61	0.000	19.07735	35.16469
newstate	-.8910144	.4324705	-2.06	0.039	-1.738641	-.0433878
distc	-.0003729	.0009523	-0.39	0.695	-.0022393	.0014936
Ipolity1~1	-2.059996	.6987899	-2.95	0.003	-3.429599	-.6903932
Ipolity1~2	-2.516426	1.12221	-2.24	0.025	-4.715917	-.3169357
Ipolity1~3	-.2163299	1.146575	-0.19	0.850	-2.463576	2.030916
laff_dr_7~79	.105699	.0512132	2.06	0.039	.0053231	.206075
_Ipo3Xla	-1.461776	.1017731	-14.36	0.000	-1.661247	-1.262304
_cons	-33.00827	4.064308	-8.12	0.000	-40.97417	-25.04238

Let us first consider the results in Table 8. We have reported the results of the robust Poisson regression[39]. The main findings are:

- Predicted frequency of droughts and deaths are positively related.
- Elevation over certain ranges (i.e. the first and the third) is associated with lower mortalities.
- Ethnic fractionalization and deaths are not linked.

38

RECODE of polity1 (1 polity)	Freq.	Percent	Cum.
< -5	925	39.78	39.78
-5-0	450	19.35	59.14
0-5	375	16.13	75.27
>5	575	24.73	100.00
Total	2,325	100.00	

39 The chi-square goodness-of-fit test sometimes degenerates in a large sample. Details will be furnished on request.

- While the effect of population density is negative, it is not significant. However, its square has a significant positive effect, implying that the negative association varies with higher densities.
- 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.
- The more recent the independence of a country, the lower are the mortalities.
- As there may be non-linearities between democracy and prevention of deaths, three polity dummies are employed and the third polity dummy is interacted with log of number affected in 1970-79. This is supposed to capture learning from past experience in more democratic regimes. The results are somewhat intriguing but not implausible. At even low levels of democracy, controlling for other effects, the deaths are fewer when a drought occurs (relative to the default category). However, while the coefficient of the third polity dummy has a negative sign, it is not significant. But when it is interacted with numbers affected in the past, it has a significant negative coefficient. The higher the numbers affected in the past, the greater of course are the deaths during 1980-2004. But this effect is considerably weaker in countries with moderately democratic regimes[40]. So when the effect of democracy is assessed-taking also into account the more rapid learning from past experience- moderately democratic regimes tend to save more lives (relative to the benchmark case as well as others)[41]. This, however, leaves unanswered the question why deaths are higher in the default polity range (or the most democratic regimes). One possibility is that democracy is not such a good approximation to state capacity to prevent deaths from droughts-through, for example, speedy relief in remote areas-except perhaps over specific ranges of the former.

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 will be saved.[42] 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 Poisson regression in Table 8 are systematically related to openness[43]. Specifically, we test whether residual deaths would be fewer in a more open economy. The results are given in

[40] 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.
[41] Note that the reduction in deaths is highest as the coefficient of the interaction term multiplied by the mean of log number affected substantially reinforces the negative effect of the third polity dummy.
[42] For a more precise proposition, see Ravallion (1997).
[43] For details of the IV estimates of openness, see Gaiha and Imai (2005).

Table 9. Two points may be noted.

First, although heteroscedasticity was rejected, we prefer the robust regression results[44]. 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 9
Residual Deaths from Droughts, and Openness

```
Robust regression                                      Number of obs =     1260
                                                       F(  2,  1257) =    13.79
                                                       Prob > F      =   0.0000

------------------------------------------------------------------------------
  rldeath_dr |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
iv_tradesh~e |  -.0444745   .0102921    -4.32   0.000     -.064666    -.024283
     _IivXiv |   .0054532   .0012283     4.44   0.000     .0030435    .0078629
       _cons |    .088491   .0215229     4.11   0.000     .0462663    .1307157
```

A brief and selective discussion of simulation results based on the specification in Table 8 is given here. We consider two 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 a second scenario, the presumption is that learning constrained by limited resources for drought relief may save fewer lives. Since we have not modeled these mechanisms explicitly- the cross-country data do not permit their quantification-we rely on the following approximation. For the first scenario, we assume hypothetical reductions in the coefficient of droughts- 10 per cent, 20 per cent and 30 per cent. Clearly, there are different possibilities of learning and different ways of capturing them[45]. The second scenario is also constructed on somewhat arbitrary assumptions-specifically, the higher the per capita income level, the greater is state

44 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

Ho: Constant variance

```
chi2(1)      =   343.47
Prob > chi2  =   0.0000
```

45 Alternatively, we could have used the relationship between democracy and deaths. We have refrained from doing so as promotion of democracy is a contentious issue. Also, 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 lagged measure of severity of droughts (i.e. 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 are 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).

capacity for saving lives in a drought. This is admittedly an oversimplification as efficacy of drought relief may be linked to not just accurate identification of the needy but also transparency and accountability of relief agencies. Nevertheless, subject to these caveats, some likely effects of learning and building of state capacity could be assessed. 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 45 per cent.

Table 10
Simulations of Reduction in Deaths

Scenarios	Reduction in Deaths (%)
Learning	
10 % Reduction in Deadliness of Droughts	-11.06
20 % Reduction in Deadliness of Droughts	-20.89
30 % Reduction in Deadliness of Droughts	-29.64
Capacity Building	
10 Low Income countries move up	-45.99
20 Low Income countries move up	-70.83

Even if these results are not acceptable at face value-indeed, there are some 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[46].

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.

[46] 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.

(a) Agricultural Productivity and its Growth

Agricultural productivity is measured by agricultural value added in constant prices per hectare of arable land (avpal). As the values are large, their logarithmic values are used as the dependent variable. 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 11. We confine our discussion to robust regression results even when homoscedasticity is not rejected[47]. The subsequent specifications used

Table 11
Determinants of Agricultural Productivity

Robust regression — Number of obs = 1475; F(20, 1454) = 125.54; Prob > F = 0.0000

avpal	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
mrain_d1	-353.0432	38.93761	-9.07	0.000	-429.4231	-276.6633
mrain_d2	-356.229	39.10496	-9.11	0.000	-432.9371	-279.5208
mrain_d3	-242.8272	29.74354	-8.16	0.000	-301.1721	-184.4824
gr_rain_ann	-101.1535	44.77048	-2.26	0.024	-188.9751	-13.33183
al_d1	173.5866	32.59115	5.33	0.000	109.6558	237.5173
al_d2	425.5724	25.2781	16.84	0.000	375.987	475.1578
al_d3	271.966	26.87998	10.12	0.000	219.2383	324.6936
incm_d1	-482.1266	35.91419	-13.42	0.000	-552.5758	-411.6774
incm_d2	-166.4623	32.25345	-5.16	0.000	-229.7305	-103.194
elev_d1	-305.4365	28.34867	-10.77	0.000	-361.0451	-249.8278
elev_d2	.9490957	24.37724	0.04	0.969	-46.86921	48.7674
elev_d3	18.76604	30.07881	0.62	0.533	-40.23646	77.76854
soilsui1	2.713846	1.194355	2.27	0.023	.3710024	5.056689
distc	-.1912915	.0285548	-6.70	0.000	-.2473045	-.1352786
pno_dr_m4r	137.1735	21.17337	6.48	0.000	95.63983	178.7071
polity1d1	53.02882	30.33836	1.75	0.081	-6.482805	112.5404
polity1d2	150.7531	34.59963	4.36	0.000	82.88258	218.6236
polity1d3	-56.1137	30.73801	-1.83	0.068	-116.4093	4.181888
pdenpavg	.9186759	.0467698	19.64	0.000	.8269324	1.010419
pdenpavg2	-.0002616	.0000171	-15.32	0.000	-.0002951	-.0002281
_cons	787.7533	57.01144	13.82	0.000	675.9199	899.5868

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 11-13, most of the *key* relationships are robust to alternative specifications.

The main findings from Table 11 are as follows:

---

[47] Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 945.65
Prob > chi2 = 0.0000

- As expected, the lower ranges of initial annual rainfall are associated with significantly lower agricultural productivity, relative to the default category of rainfall[48]. However, incremental rainfall also has a negative effect on productivity. This could be due to a non-linearity between productivity and incremental rainfall with excess rainfall lowering productivity.
- Each of the arable land area dummy has a significant positive effect on agricultural productivity, implying higher productivity relative to the default case.
- 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.
- As expected, soil suitability has a significant positive effect on productivity while 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. This implies that more frequent droughts lower productivity[49]. What is important is that the negative effect of more frequent droughts 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[50]. 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.

When income level dummies are replaced by shares of land in tropical and temperate conditions, the results gain in plausibility. The rainfall effects are similar to those in Table 11, 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 elevation, relative to the default category; soil suitability ceases to 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

[48] Note that rainfall ranges used for the dummies are the same as in Table 3.
[49] The dummy takes the value 1 if the predicted frequency of droughts < 0.05, and 0 otherwise.
[50] Note that the polity index is the net democracy score. For details, see Polity IV, Centre for International Development and Conflict, University of Maryland.

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 productivity is further corroborated.

When income dummies are replaced by regional dummies, most of the key relationships remain intact, as shown in Table 13. 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.

Table 12
Determinants of Agricultural Productivity[51]

Robust regression — Number of obs = 1475; F(20, 1454) = 99.76; Prob > F = 0.0000

avpal	Coef.	Std. Err.	T	P>|t|	[95% Conf.	Interval]
mrain_d1	-297.2361	40.98153	-7.25	0.000	-377.6253	-216.8468
mrain_d2	-183.6616	42.36701	-4.34	0.000	-266.7686	-100.5546
mrain_d3	-242.2533	31.35378	-7.73	0.000	-303.7567	-180.7498
gr_rain_ann	-111.745	46.16627	-2.42	0.016	-202.3047	-21.18544
al_d1	207.9156	32.39368	6.42	0.000	144.3722	271.4589
al_d2	306.0663	27.1544	11.27	0.000	252.8003	359.3323
al_d3	235.9485	28.13524	8.39	0.000	180.7585	291.1385
zdrytemp	-574.8574	77.63683	-7.40	0.000	-727.1496	-422.5652
ztropics	-351.1797	54.18917	-6.48	0.000	-457.477	-244.8824
elev_d1	-333.707	34.32403	-9.72	0.000	-401.0369	-266.3771
elev_d2	8.559024	26.11895	0.33	0.743	-42.67582	59.79386
elev_d3	-130.8295	31.69075	-4.13	0.000	-192.994	-68.66504
soilsui1	.9438448	1.426087	0.66	0.508	-1.853564	3.741253
distc	-.3180677	.028486	-11.17	0.000	-.3739459	-.2621896
pno_dr_m4r	154.2054	20.50899	7.52	0.000	113.975	194.4357
polity1d1	-191.2841	29.09433	-6.57	0.000	-248.3554	-134.2127
polity1d2	-72.41726	32.42344	-2.23	0.026	-136.019	-8.815547
polity1d3	-195.3539	31.40837	-6.22	0.000	-256.9645	-133.7434
pdenpavg	.83891	.0472599	17.75	0.000	.7462052	.9316148
pdenpavg2	-.0002177	.0000168	-12.98	0.000	-.0002506	-.0001848
_cons	871.9239	59.53851	14.64	0.000	755.1334	988.7145

51 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 706.32
Prob > chi2 = 0.0000

.

Table 13
Determinants of Agricultural Productivity[52]

Robust regression — Number of obs = 1475; F(21, 1453) = 121.21; Prob > F = 0.0000

avpal	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
mrain_d1	-128.8354	46.07496	-2.80	0.005	-219.216	-38.45486
mrain_d2	-246.1223	38.47988	-6.40	0.000	-321.6044	-170.6403
mrain_d3	-180.6545	29.45257	-6.13	0.000	-238.4286	-122.8804
gr_rain_ann	-110.2568	43.29536	-2.55	0.011	-195.1849	-25.32868
al_d1	294.0091	30.93505	9.50	0.000	233.3269	354.6912
al_d2	300.3155	24.6543	12.18	0.000	251.9537	348.6774
al_d3	287.5077	26.13075	11.00	0.000	236.2496	338.7657
regd21	-303.5227	40.68017	-7.46	0.000	-383.3208	-223.7245
regd41	-351.7764	54.13348	-6.50	0.000	-457.9646	-245.5883
regd51	-443.7363	30.3405	-14.63	0.000	-503.2522	-384.2204
elev_d1	-374.6859	27.32092	-13.71	0.000	-428.2786	-321.0932
elev_d2	-76.08474	24.50416	-3.10	0.002	-124.152	-28.01743
elev_d3	-41.36765	28.56716	-1.45	0.148	-97.40493	14.66962
soilsui1	-1.596899	1.261322	-1.27	0.206	-4.071106	.8773091
distc	-.2996691	.0319441	-9.38	0.000	-.3623306	-.2370076
pno_dr_m4r	167.2737	19.86725	8.42	0.000	128.3022	206.2453
polity1d1	2.001338	33.02603	0.06	0.952	-62.78246	66.78513
polity1d2	75.55158	32.38167	2.33	0.020	12.03176	139.0714
polity1d3	-223.3167	30.69005	-7.28	0.000	-283.5182	-163.1152
pdenpavg	.8927697	.0459801	19.42	0.000	.8025753	.9829641
pdenpavg2	-.000254	.0000163	-15.62	0.000	-.0002859	-.0002221
_cons	826.6611	48.74031	16.96	0.000	731.0522	922.27

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 14.

Table 14
Residuals of Agricultural Productivity, and Openness[53]

Robust regression — Number of obs = 1150; F(2, 1147) = 5.44; Prob > F = 0.0044

ravpal_dr	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
iv_tradesh~e	-2669.395	1011.667	-2.64	0.008	-4654.32	-684.4691
_IivXiv	328.0738	120.6891	2.72	0.007	91.27777	564.8699
_cons	5423.557	2116.618	2.56	0.011	1270.68	9576.435

52 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 915.83
Prob > chi2 = 0.0000

53 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 50.09
Prob > chi2 = 0.0000

These results reject that productivity is underestimated in open economies.This is not surprising as distance from a coast serves as a proxy for openness. 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, going by our preferred specification in Table 12, 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 15.

- 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.

Table 15
Determinants of Growth of Agricultural Productivity[54]

Robust regression — Number of obs = 1451; F(20, 1430) = 3.13; Prob > F = 0.0000

gr_avpal	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
mrain_d1	.0100157	.0076572	1.31	0.191	-.0050049	.0250363
mrain_d2	.008508	.0079336	1.07	0.284	-.0070548	.0240707
mrain_d3	.000095	.0058477	0.02	0.987	-.0113759	.011566
gr_rain_ann	.0299137	.0086648	3.45	0.001	.0129165	.0469108
al_d1	-.0120449	.0060876	-1.98	0.048	-.0239865	-.0001034
al_d2	-.0138846	.0050985	-2.72	0.007	-.023886	-.0038833
al_d3	-.0061996	.0052885	-1.17	0.241	-.0165736	.0041744
zdrytemp	-.0319601	.0146708	-2.18	0.030	-.0607388	-.0031814
ztropics	.0063911	.0102141	0.63	0.532	-.0136451	.0264274
elev_d1	-.0172288	.0065001	-2.65	0.008	-.0299795	-.0044781
elev_d2	-.0182814	.0049219	-3.71	0.000	-.0279362	-.0086265
elev_d3	-.0068115	.0059616	-1.14	0.253	-.0185059	.0048828
soilsui1	-.0001782	.000269	-0.66	0.508	-.0007059	.0003494
distc	-.0000162	5.41e-06	-3.00	0.003	-.0000268	-5.61e-06
pno_dr_m4r	.0070283	.0038468	1.83	0.068	-.0005177	.0145743
polity1d1	.0038064	.0054477	0.70	0.485	-.0068799	.0144928
polity1d2	-.0030903	.0060788	-0.51	0.611	-.0150147	.0088341
polity1d3	.0033955	.0058941	0.58	0.565	-.0081666	.0149576
pdenpavg	.0000112	8.83e-06	1.27	0.205	-6.12e-06	.0000285
pdenpavg2	-4.97e-09	3.13e-09	-1.59	0.113	-1.11e-08	1.18e-09
_cons	.0371641	.0111757	3.33	0.001	.0152416	.0590866

54 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 5.70
Prob > chi2 = 0.0170

- 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 frequency of droughts had higher growth rates (or, by implication, those with higher drought frequencies exhibited lower growth rates). This is important as it suggests that there is more than a direct loss of agricultural output when a drought occurs.
- None of the polity dummies has a significant coefficient.
- Nor does population density or its square have a significant effect on growth of agricultural productivity.
- The overall explanatory power of the specification used, as reflected in the F-statistic, is low but significant.

Table 16
Determinants of Growth of Agricultural Productivity[55]

Robust regression

Number of obs = 1451
F(21, 1429) = 3.24
Prob > F = 0.0000

gr_avpal	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
mrain_d1	.0108677	.0091972	1.18	0.238	-.0071737	.0289091
mrain_d2	.0084366	.007643	1.10	0.270	-.006556	.0234293
mrain_d3	.0009665	.0058349	0.17	0.868	-.0104793	.0124123
gr_rain_ann	.0298873	.0086271	3.46	0.001	.0129643	.0468104
al_d1	-.0059141	.0061699	-0.96	0.338	-.018017	.0061889
al_d2	-.0109609	.0048981	-2.24	0.025	-.020569	-.0013527
al_d3	.0000366	.0052107	0.01	0.994	-.0101848	.010258
regd21	.0125332	.0080673	1.55	0.121	-.0032918	.0283582
regd41	-.0103449	.0109284	-0.95	0.344	-.0317824	.0110926
regd51	-.0163743	.0060961	-2.69	0.007	-.0283325	-.0044161
elev_d1	-.0103131	.0054673	-1.89	0.059	-.0210379	.0004118
elev_d2	-.0146586	.0048836	-3.00	0.003	-.0242384	-.0050788
elev_d3	-.0018275	.0056881	-0.32	0.748	-.0129854	.0093303
soilsui1	-.0007105	.0002526	-2.81	0.005	-.001206	-.0002151
distc	-.0000164	6.43e-06	-2.56	0.011	-.000029	-3.83e-06
pno_dr_m4r	.0071736	.0039546	1.81	0.070	-.0005839	.014931
polity1d1	.0121163	.0066058	1.83	0.067	-.0008417	.0250744
polity1d2	.0018186	.0064556	0.28	0.778	-.0108449	.014482
polity1d3	-.0014811	.006117	-0.24	0.809	-.0134804	.0105183
pdenpavg	6.33e-06	9.11e-06	0.70	0.487	-.0000115	.0000242
pdenpavg2	-3.89e-09	3.22e-09	-1.21	0.227	-1.02e-08	2.43e-09
_cons	.0398018	.0096605	4.12	0.000	.0208516	.058752

---

55 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 14.61
Prob > chi2 = 0.0001

.

When the climatic dummies are replaced by regional dummies, some of the key relationships remain largely unchanged. For example, the inverse relationship between incremental rainfall and productivity remains intact; lower ranges of elevation exhibit lower productivity growth; productivity and distance from a coast are inversely related; and negligible or low frequency of droughts has a positive effect on growth. However, there are a few minor differences (e.g. soil suitability and growth are inversely related). Allowing for these effects, Sub-Saharan Africa exhibits a significantly lower growth rate than the default category.

In sum, although the growth regressions are less robust than the level regressions, the negative impact of droughts on both agricultural productivity and its growth is corroborated.

(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:

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

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[56]. In the next stage, first, the deviations between the actual and estimated food production index i.e. $\log \text{Food}_{i,t} - \widehat{\log} \text{ Food}_{i\,t}$ (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:

$$\text{rlfprod}_{i\,t} = \gamma + \delta_i + \lambda_1 \text{ pno\_dr\_m4}_{it} + \lambda_2 \text{pno\_dr\_m4 L1}_{i1} + u_{it} \quad (6).$$

where IV estimates of droughts in t and t-1, denoted as pno_dr_m4, and pno_dr_m4 L1, respectively, are obtained from our preferred specification, δ_i is the country-fixed effect .

The results are given in Tables 17 and 18. The latter is based on the same specification as the former but with country-fixed effects.

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

Table 17
Impact of Droughts on Food Production[57]

Robust regression

Number of obs = 1552
F(2, 1549) = 20.43
Prob > F = 0.0000

rlfprod	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
pno_dr_m4						
--.	-.2115396	.1013168	-2.09	0.037	-.4102721	-.012807
L1.	-.0879833	.1014446	-0.87	0.386	-.2869667	.111
_cons	-.0003317	.0068266	-0.05	0.961	-.0137222	.0130587

Table 18
Impact of Droughts on Food Production
(With Country -Fixed Effects)[58]

Robust regression

Number of obs = 1552
F(84, 1467) = 43.92
Prob > F = 0.0000

rlfprod	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
pno_dr_m4						
--.	-.3097087	.1042254	-2.97	0.003	-.5141554	-.105262
L1.	-.19272	.1045865	-1.84	0.066	-.3978751	.0124351
cons	.0357316	.059246	0.60	0.547	-.0804843	.1519475

* Country fixed effects are omitted.

As may be inferred from the results in Table 17, the (proportionate) food production shock of a drought in the same year is negative, and of that in the previous year is negative but not significant. With country-fixed effects, however, both have significant negative effects, and the joint effect is considerably stronger. 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, as illustrated below.

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

[57]
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
       Ho: Constant variance
       chi2(1)      =    13.40
       Prob > chi2  =   0.0003
```

[58]
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
       Ho: Constant variance
       chi2(1)      =   183.30
       Prob > chi2  =   0.0000
```

(log of) lagged food price indices, lfpriceL1, lfpriceL2,, to allow for ripple effects over time. The results of three different specifications are given in Tables 19-21.

Table 19
Impact of Droughts on Food Prices[59]

Robust regression — Number of obs = 1115; F(3, 1111) =17747.22; Prob > F = 0.0000

rlfprice	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
pno_dr_m4	.499199	.1320095	3.78	0.000	.2401829	.7582151
lfprice						
L1.	1.135945	.0246618	46.06	0.000	1.087556	1.184334
L2.	-.2856879	.0229524	-12.45	0.000	-.3307229	-.2406528
_cons	-3.420993	.0221138	-154.70	0.000	-3.464382	-3.377603

The results in Table 19 point to significant effects of lagged food price index. Controlling for these effects, there is a significant inflationary effect of droughts. However, when both current and lagged frequencies of droughts are used as explanatory variables along with lagged food price indices, it turns out that only lagged droughts are inflationary. A similar result is obtained with country-fixed effects, as shown in Table 21. The conclusion therefore is that droughts are inflationary.

Table 20
Impact of Droughts on Food Prices[60]

Robust regression — Number of obs = 1187; F(3, 1183) =19563.53; Prob > F = 0.0000

rlfprice	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
pno_dr_m4						
--.	.0008113	.2380976	0.00	0.997	-.4663294	.467952
L1.	.5673593	.2369188	2.39	0.017	.1025315	1.032187
lfprice						
L1.	.8369249	.0034577	242.05	0.000	.830141	.8437088
_cons	-3.311892	.0200225	-165.41	0.000	-3.351175	-3.272608

---

59 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 335.95
Prob > chi2 = 0.0000

60 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 1165.51
Prob > chi2 = 0.0000

Table 21
Impact of Droughts on Food Prices
(With Country Fixed Effects)[61]

Robust regression — Number of obs = 1187; F(69, 1117) = 1145.24; Prob > F = 0.0000

rlfprice	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
pno_dr_m4						
--.	.2217999	.2679943	0.83	0.408	-.3040291	.747629
L1.	.5711364	.2668089	2.14	0.033	.0476333	1.09464
lfprice						
L1.	.6296252	.0033363	188.72	0.000	.623079	.6361713
cons	-2.745261	.1299992	-21.12	0.000	-3.000331	-2.49019

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[62].

So the results given below are illustrative of certain links and of course require further validation.

Table 21
Impact of Food Price Shocks on Agricultural Wage Rates[63]

Robust regression — Number of obs = 246; F(3, 242) = 39.04; Prob > F = 0.0000

rlawage	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rlfprice						
L1.	.460329	.088681	5.19	0.000	.2856439	.6350141
incm_d1	-1.061729	.1263613	-8.40	0.000	-1.310638	-.8128211
incm_d2	-.3270064	.0811718	-4.03	0.000	-.4868997	-.167113
_cons	.2958618	.0633433	4.67	0.000	.1710872	.4206363

61
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
      Ho: Constant variance
      chi2(1)      =  1207.20
      Prob > chi2  =   0.0000
```

62 For details, see Annex 2.

63
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
      Ho: Constant variance
      chi2(1)      =   180.26
      Prob > chi2  =   0.0000
```

Let us first discuss the specification used in Table 21. Following Bliss (1985), agricultural wages adjust with a lag to food price shocks. Accordingly, the deviation in log of wages from its trend value, denoted by $rlawage_{i\ t}$, is the dependent variable, and the the deviation of the log of food price index from its trend value in t-1, denoted by rlfprice $L1_{i\ t-1}$, and two income level dummies, $incm\_d1_i$ (takes the value 1 for Low Income countries, and 0 for the rest), and $incm\_d2_i$ (takes the value 1 for Lower Middle Income countries and 0 for the rest) are the explanatory variables.

As hypothesized, lagged food price residuals translate into higher wages next year and greater wage residual. The wage residuals are lower in Low Income and Lower Middle Income countries, relative to the benchmark category of Upper Middle Income countries.

In Table 22, the income level dummies are replaced by regional dummies, with Latin America and the Caribbean as the default region. The lagged inverse relationship between wage residuals and food price residuals is corroborated. Among the regions, South Asia, East Asia and the Pacific, Europe and Central Asia display lower wage residuals, while Middle East and North Africa, and Sub Saharan Africa show higher wage residuals than the default region.

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

- Droughts in t-1 have an inflationary impact in t;
- given nominal wages, real wages decline in t;
- however, the price shock is absorbed partially in a year, and so real wages are higher in t+1;
- but,in addition, there is a direct effect of droughts in t through a loss of demand for agricultural production in t+1 (e.g. through liquidation of assets, soil erosion), independently of the food price shock, as illustrated below in Table 23.

Table 22

Impact of Food Price Shocks on Agricultural Wage Rates[64]

Robust regression — Number of obs = 246; F(6, 239) = 73.17; Prob > F = 0.0000

rlawage	Coef.	Std. Err.	T	P>|t|	[95% Conf.	Interval]
rlfprice						
L1.	.3621615	.0915724	3.95	0.000	.1817696	.5425535
regd21	-1.423482	.2062706	-6.90	0.000	-1.829822	-1.017141
regd22	-.2920996	.147886	-1.98	0.049	-.583426	-.0007731
regd31	-.396548	.0874323	-4.54	0.000	-.5687842	-.2243117
regd41	2.641731	.1659765	15.92	0.000	2.314767	2.968694
regd51	.2477671	.1258417	1.97	0.050	-.0001335	.4956677
_cons	.2184096	.0572247	3.82	0.000	.1056803	.3311388

64 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
chi2(1) = 105.41
Prob > chi2 = 0.0000

Table 23
Impact of Droughts on Agricultural Wage Rates[65]

```
Robust regression                                      Number of obs =     116
                                                       F(  4,   111) =43671.47
                                                       Prob > F      =  0.0000


   lawageppc |      Coef.   Std. Err.      T    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   pno_dr_m4 |
         --. |  -.0096042   .0882207    -0.11   0.914    -.1844194     .165211
         L1. |  -.1379482   .0844732    -1.63   0.105    -.3053374     .029441
     lfprice |
         L1. |   .0203737   .0090995     2.24   0.027     .0023424    .0384049
   lawageppc |
         L1. |   .9894462   .0024524   403.47   0.000     .9845867    .9943057
       _cons |   .0356744   .0383233     0.93   0.354    -.0402659    .1116147
```

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[66]. While generalizations are risky, these findings illustrate the severity of the impact and the coping mechanisms that the preceding analysis was not designed to capture. 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 per cent points in Chattisgarh, 12 per cent points in Jharkhand, and 16 per cent 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.

[65]
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         chi2(1)      =   563.15
         Prob > chi2  =   0.0000
```

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

- 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.
- In 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 useful 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 24**.** First**,** as the dependence on rice as a source of household income was twice as high in eastern India (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.

Table 24
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 program	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)

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 (1982) 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).
- 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. 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.[67]
- 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[68]. Recent data

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

[68] 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.

on quality of institutions point to significant improvements in several developing countries-especially those in parts of 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 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 and 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.

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[69]. Examples include public-private research partnerships, competitive research grants, and tax incentives.

[69] 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 for 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).

- 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 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.[70]

- The agricultural research intensity (i.e. ratio of agricultural research 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[71]. 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[72]. 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[73]. 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

[70] Two useful contributions are Pender (2006), and Pandey and Bhandari (2006).
[71] The total agricultural research investment in India in 1998/99 was about $430, which was lower than the total cost of the drought in the rainfed areas in the three eastern Indian states (Pandey and Bhandari, 2006).
[72] See, for example, Fan et al. (2003).
[73] See, for example, the case studies of eastern states in India (Pandey and Bhandari, 2006).

ponds is common. These small private or community –owned schemes tend to be low cost and sufficiently responsive to the local needs. Similarly 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[74].

- 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[75].

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.

Despite the high costs, crop insurance has not had positive impacts on agricultural lending, agricultural 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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[74] 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).

[75] 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[76]. 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)[77].

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 decade. By contrast, the share of Low Income countries doubled. The reduction in the

76 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.

77 See, for example, Gaiha and Nandhi (2006).

deadliness of droughts in Lower Middle Income countries was considerably greater than in Low Income countries.

Our econometric 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 –even at low levels- is negative, and, when a higher level of democracy is interacted with severity of droughts in the past, there is additional reduction in mortality. This points to greater learning from past experience among moderately democratic regimes. 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.

Our analysis also points to significant dampening effects of droughts on agricultural productivity and its growth, and on food production. Besides, as expected, food entitlements are eroded through inflationary impact of droughts and loss of employment 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 shocks-droughts, pests, famines, floods, among others-insurance also has a potentially important role in mitigating the hardships. Whether weather insurance would protect the vulnerable better than crop insurance is plausible but far from self-evident, given the limited coverage.

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 %.
200	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).

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).

Table A.1.4
List of Variables Used in Regression Analysis

Variable	Description
no_dr	Number of droughts
no_dr_70_79	Number of droughts, 1970-79
pno_dr_m4	Predicted number of droughts from preferred specification
pno_dr_m4 L1	Predicted number of droughts from preferred specification lagged by one year
pno_dr_m4 r	Dummy variable takes the value 1 if predicted frequency of drough <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
rldeath_dr	Deviations of log of deaths from the trend
avpal	Agricultural value added per hectare of arable land
gr_avpal	Log $(avpal)_t$ –log $(avpal)_{t-1}$
$liavpal_{80}$	Log of agricultural productivity in 1980
mr	Mean annual rainfall, 1980-85
Imrxmr	Square of mean annual rainfall, 1980-85
mrain_d1	Dummy takes the value 1 if rainfall<500mm, 1980-85, and 0 otherwise
mrain_d2	Dummy takes the value 1 if rainfall between 501-1000mm, 1980-85, and 0 otherwise
mrain_d3	Dummy takes the value 1 if rainfall between 1001-2000mm, 1980-85, and 0 otherwise
lrain_ann 80	Log of rainfall in 1980
gr_rain_ann	Growth of rainfall (log $(rain\_ann)_t$ –log $(rain\_ann)_{t-1}$
srain_ann~04	Standard deviation of log annual rainfall
$areakm^2$	land area (km^2)
polity 1 d1	Dummy takes the value 1 if polity score <(-) 5 and 0 otherwise
polity 1 d2	Dummy takes the value 1 if polity score between (-)5-0, and 0 otherwise
polity 1 d3	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
elev_d2	elevation dummy for range 2
elev_d3	elevation dummy for range 3
(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
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
Lfprice L2	Log of food price index lagged by two years
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
rlawage	Deviation of log of agricultural wages from the trend value
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. FAO. 1995. *The Digital Soils Map of the World, Version 3.5*. Rome:FAO

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:

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

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.

(a) By Level of Income

Table A.2.1
Trend in Food Production in Low Income Countries[78]

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[79]

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

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

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

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[80]

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

(b) By Region
(c)

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[81]

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

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

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

expected performance in recent years presumably underlies the increasing trend in food production.

Table A.2.5
Trend in Food Production in South Asia[82]

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[83]

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

Table A.2.7
Trend in Food Production in Europe and Central Asia[84]

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

82
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         chi2(1)      =    59.45
         Prob > chi2  =   0.0000
```

83
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Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         chi2(1)      =   164.17
         Prob > chi2  =   0.0000
```

84
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         chi2(1)      =    56.86
         Prob > chi2  =   0.0000
```

Table A.2.8
Trend in Food Production in Near East and North Africa[85]

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[86]

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 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

85
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
        Ho: Constant variance
        chi2(1)      =    46.70
        Prob > chi2  =   0.0000
```

86
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
        Ho: Constant variance
        chi2(1)      =   167.39
        Prob > chi2  =   0.0000
```

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[87]

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

lfprice	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[88]

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

lfprice	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

Table A.2.12
Trend in Food Prices in Upper Middle Income Countries[89]

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

lfprice	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

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

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

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

(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 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.2.13
Trend in Food Prices in Latin America and the Caribbean[90]

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

------------------------------------------------------------------------------
     lfprice |      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
```

Table A.2.14
Trend in Food Prices in South Asia[91]

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

------------------------------------------------------------------------------
     lfprice |      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
```

90
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         chi2(1)      =   349.51
         Prob > chi2  =   0.0000
```

91
```
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[92]

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

------------------------------------------------------------------------------
     lfprice |      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[93]

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

------------------------------------------------------------------------------
     lfprice |      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[94]

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

------------------------------------------------------------------------------
     lfprice |      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
```

92
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         chi2(1)      =    79.05
         Prob > chi2  =   0.0000
```

93
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         chi2(1)      =    32.29
         Prob > chi2  =   0.0000
```

94
```
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[95]

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

------------------------------------------------------------------------------
     lfprice |      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[96]

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

------------------------------------------------------------------------------
   lawageppc |      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
```

95
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
         Ho: Constant variance
         chi2(1)      =   254.68
         Prob > chi2  =   0.0000
```

96
```
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[97]

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

lawageppc	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[98]

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

lawageppc	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

(b) 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.

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

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

Table A.2.22
Trend in Agricultural Wages in Latin America and the Caribbean[99]

Robust regression

Number of obs = 96
F(1, 94) = 3.07
Prob > F = 0.0831

lawageppc	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

Table A.2.23
Trend in Agricultural Wages in South Asia[100]

Robust regression

Number of obs = 8
F(1, 6) = 9630.96
Prob > F = 0.0000

lawageppc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
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[101]

Robust regression

Number of obs = 38
F(1, 36) = 0.19
Prob > F = 0.6669

lawageppc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
t95_04	.0119996	.0276509	0.43	0.667	-.0440792	.0680783
_cons	6.20601	.1516496	40.92	0.000	5.89845	6.51357

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

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

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

Table A.2.25
Trend in Agricultural Wages in Europe and Central Asia[102]

```
Robust regression                                      Number of obs =      99
                                                       F(  1,    97) =    7.44
                                                       Prob > F      =  0.0076

------------------------------------------------------------------------------
   lawageppc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      t95_04 |   .0799726   .0293212     2.73   0.008     .0217782     .138167
       _cons |   5.555263   .1710972    32.47   0.000     5.215682    5.894844
```

Table A.2.26
Trend in Agricultural Wages in Middle East and North Africa[103]

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

------------------------------------------------------------------------------
   lawageppc |      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[104]

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

------------------------------------------------------------------------------
   lawageppc |      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
```

102
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
      Ho: Constant variance
      chi2(1)      =    13.85
      Prob > chi2  =   0.0002
```

103
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
      Ho: Constant variance
      chi2(1)      =     0.60
      Prob > chi2  =   0.4387
```

104
```
Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
      Ho: Constant variance
      chi2(1)      =     6.34
      Prob > chi2  =   0.0118
```

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