Famines in Historical Perspective

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Mortality crises are thought to have been a regular feature of the experience of past societies. Periodically, it has been said, war, epidemic, or famine would ravish a population, leaving marks on its size and demographic composition and, presumably, on the structures of society. Although the demographic consequences of famine and other crises are usually unmeasured, they are in principle measurable. The social consequences of calamity, such as the creation of what has been called "landscapes of fear," are not readily quantifiable, but surely do not vary at random with demographic catastrophes.

Mortality crises play an essential role in what may be termed the "boom and bust" model for explaining the slow long-term growth of populations in the past. Under this model, the underlying or "normal" rates of mortality and fertility yield relatively high rates of population growth; then a mortality crisis occurs, cutting the population back. There is a second model, however, in which such vast fluctuations in mortality are not the rule. Rather, fertility and mortality vary much less dramatically and yield a small but persistently positive growth rate.

It is the first of these models that represents the usual thinking on the role of mortality crises in the past. Famines are of particular interest as a mechanism that could produce the boom and bust scenario. Malthus considered famines a telling measure of the degree to which populations are ultimately capable of maintaining a balance between people and resources. The logic of the First Essay is both clear and brutal:

> Famine seems to be the last, the most dreadful resource of nature. The power of population is so superior to the power in the earth to produce subsistence for man, that premature death must in some shape or other visit the human race. The vices of mankind are active and able ministers of depopulation. They are the precursors in the great army of destruction; and often finish the dreadful

> work themselves. But should they fail in this war of extermination, sickly seasons, epidemics, pestilence, and plague, advance in terrific array, and sweep off their thousands and ten thousands. Should success be still incomplete, gigantic inevitable famine stalks in the rear, and with one mighty blow, levels the population with the food of the world. [Malthus, 1798 (1965), p. 140]

The population will be reduced in size by the crisis, but then, released from restraint, it will proceed to grow until the next, and inevitable, disaster. Although Malthus's pessimism was relieved in subsequent essays that explored the powers of preventive checks such as delayed marriage, Malthusian logic makes famine a court of last resort for a population that has exceeded its resource base. The Malthusian paradigm has been used to explain periods of population stability in the past (Le Roy Ladurie, 1974; Goubert, 1960) and to account for modern population growth once subsistence crises were no longer a threat (Helleiner, 1965; Flinn et al., 1977; Flinn, 1981).

The Malthusian view has been challenged by some who doubt that famines were a consequence of overpopulation relative to available resources (Sen, 1981; Alamgir, 1980; Appleby, 1978; Bois, 1984). For example, Sen found that in several recent famines, per capita food availability did not decrease significantly: what changed was the distribution of entitlements to food. Appleby locates the cause of widespread hunger and elevated death rates in Tudor-Stuart England primarily in transportation difficulties, and Bois offers fiscal relations between lord and peasant as the explanation for population stagnation in medieval Normandy. Others have questioned the accepted correlation between food availability and mortality rates. Records of Jesuits in an Italian order in the mid-sixteenth century show that the death rate among this select and presumably well-fed group was so high that the members could not have been much better off than the ordinary population, and the mortality levels of the British aristocracy closely match those of the total population before the mid-eighteenth century (Livi-Bacci, 1983). In addition, data from contemporary developing countries do not permit a confident allocation of deaths to food scarcity (Watkins and van de Walle, 1983).

In this paper we will consider the role Malthus assigned to famine from another perspective, that of its demographic consequences. Were famines large enough and frequent enough to have been, as they have been called, "cruel correctives" to population growth? If so, how long could the respite they provided last? Critical to an assessment of the demographic importance of famine is an appreciation of the time it can take a population to recover: the shorter the time to achieve prefamine population size, the more frequent famines would have to be to serve as a check to population growth. Unless there was a relatively close correspondence between the time to recovery and the frequency with which famines occurred, they may have been of less importance than Malthusian logic leads us to expect in explaining past stagnation or in understanding modern growth.

We begin by reviewing what is known about the magnitude and duration of changes in mortality and fertility during famines and the frequency of famines in past societies; where the historical record is weakest, we amplify it by drawing on information from contemporary populations. Then we use this evaluation to provide reasonable alternative values with which to simulate the sequence of demographic changes that could be expected to have accompanied and followed famines in the past.

In the simulations we will, for two reasons, restrict our attention to a range of assumptions that is consistent with the demographic characteristics of premodern Asian populations. The effect of famines in providing respite from population pressure has seemed particularly important to historians of these relatively densely populated societies; in addition, the demographic regimes of Northwestern Europe may be quite different because of the potential for adjustment of population and resources through nuptiality.[1] By taking stylized premodern Asian populations as a model and by using estimates of the magnitude and duration of famine that are, in the context of the historical record both for European and Asian populations, extremely high, our simulations should provide upper bounds for the effects of famine. That is, the effects may have been less severe than in our simulations, but they are unlikely to have been greater. The simulations permit us to compare the estimated frequency of famine compatible with various rates of population growth over long periods of time with the recorded frequency. Lastly, we discuss the conditions under which the findings are generalizable to other mortality crises of the past or to contemporary famines.

The demography of past and present famines

The marks left by famine are usually only dimly visible. When no more than series of deaths (or burials) survive to trace mortality in the past, even the identification of a famine may be problematic, and often depends on supporting information such as a concomitant sharp rise in the prices of staples or comments in surviving documents. Shocking famines were unlikely to escape the attention of chroniclers, but less drastic crises of subsistence may have been difficult to detect, or less interesting to record. Crises of subsistence have also been identified through the combination of high mortality at a time of high prices, but if most of the population was not dependent on the market for food, or if there was a decline in purchasing power (or, more generally, exchange entitlement, in Sen's term), prices need not reflect availability.

Identification of famine through recorded causes of death is also not certain. By no means all famine victims succumb to frank starvation. Rather, famine seems to be associated with an increase in deaths from a number of infectious diseases. In some years of the Madras famine of the 1870s, approximately 40 percent of the total deaths were due to cholera and smallpox (Lardinois, 1985, Table 5). In Matlab thana, Bangladesh, which experienced two famines in the early and mid–1970s, the cause of death was rarely listed as starvation, but rather infectious disease (Chen and Chowdhury, 1977). Some of the increase in infectious disease may be due to increased susceptibility that is thought to accompany malnutrition and some may be due to the peculiar conditions that accompany scarcity, for example, a breakdown of systems of water supply and waste disposal, an increase in the number of vagrants, or the crowding and dismal conditions of refugee camps. All deaths associated with a famine, whether from starvation or disease, ought to be included in any assessment of the demographic impact of famine.

The magnitude of famine mortality

It is rare to find quantitative estimates of the magnitude of famine mortality before the early modern period. In the oldest records, there are references to times when ''famine scoured the hills,'' or to a ''heavy-timed hunger that severely oppressed the earth.'' Mortality is measured by ''a great number of inhabitants carried off,'' or by ''endless multitudes,'' or ''vast numbers who died'' (Walford, 1878). As late as mid-nineteenth century Ireland, where censuses bracket the years of the Great Famine, doubts about the quality of recording, the numbers of emigrants, and normal mortality rates result in estimates of excess mortality that range from 860,000 to 1.5 million (Cousens, 1960; Aykroyd, 1975, p. 31). Even when the numbers are given, there is rarely a scale against which to compare them: 200,000 are said to have died of famine in India in 1833 (Walford, 1878), but how many died in India in other years, and how many lived in India then?

Establishing a scale for famine mortality introduces yet another difficulty: what is the appropriate population of the living? The Chinese famine of 1877–78, which has been called ''one of the worst drought famines of modern times,'' affected four provinces of Northern China [Henan, Shanxi, Shaanxi, and Hebei, and neighboring Shandung (Ho, 1959, p. 231)]. The Foreign Relief Committee estimated that between 9 and 13 million died (Peking United International Famine Relief Committee, 1922, p. 9). The interpretation of the magnitude of the famine depends, however, on the base population. If the 13 million is compared to the total population of China, estimated to have been about 430 million in 1850 (Ho, 1959, pp. 232–233), the famine raises the crude death rate by less than 50 percent.[2] Thirteen million is a substantially larger proportion of the affected five provinces, which had a population of about 108 million (Rozman, 1982, pp. 12–13). Some areas of these provinces apparently suffered extreme devastation: in 1877, according to local gazeteers, the population of Wei-shan county in Shanxi was about 140,000, while in 1880 it was 45,000, a loss in these three years of some two-thirds of the county population (Rozman, 1982, p. 92). If these estimates are even close to the truth, and if the missing are deaths rather than migrants, it means that famine mortality of stunning harshness in some areas may appear as a moderate fluctuation in death rates when the population base is expanded.

Some famines were widespread, such as that of 1313–1317, which affected lands from the Pyrenees to Russia and from Scotland to Italy (Lucas, 1930). They were usually local, however, rarely affecting entire populations. For example, a list of disasters in the Chinese province of Hubei between 1644 and 1911, based on local histories, shows that only once were half of the 71 counties affected, and the maximum in the remaining years was 6 counties (Ho, 1959, p. 229 and pp. 292–300). In the provinces most affected by the 1920–22 famine in North China, only 97 of the 160 counties were affected: "Or, la famine apparaît souvent comme un phenomène ponctuel, frappant un village et épargnant un autre toute proche" (Bergère, 1973). Even in modern China there were extreme regional differentials in the effects of the recent food crisis. The Chinese famine of 1958–61 is estimated to have led to a minimum of 16 million deaths (Coale, 1981) or as many as 27 million excess deaths (Coale, 1984) or as many as 30 million premature deaths (Ashton et al., 1984; for other estimates, see Aird, 1982; Banister, 1984). Data are not yet available to permit a thorough analysis, but Shanghai county appears to have suffered little, while Anhui and Henan were affected far more seriously (Ashton et al., 1984).

When crude death rates during a famine for a population of substantial size can be calculated, generally the numbers are largest when the supporting evidence is skimpiest. Two-thirds of the population of Italy are said to have died in the famine of 1376, a quarter or perhaps a third of the Finns are said to have died during the great famine of 1696, and a third of the population of Bengal in the famine of 1770 (Keys et al., 1950, pp. 1248–1252; Jutikkala, 1955; Walford, 1878). The death of two-thirds of a population is equivalent to a crude death rate of 667 per thousand population per year. Since death rates in preindustrial populations were normally on the order of 50 per thousand per year or less, this is more than a 500 percent increase for Finland and Hindustan, and more than a 1000 percent increase for Italy.

When the data are better, the death rates are usually lower and the percentage increase less. Appleby's analysis of 382 English parishes in 1597, a year of widespread scarcity, shows that burials increased by 52 percent over the five preceding years (Appleby, 1978, p. 137). In Bangladesh, in the two famines in the 1970s, the crude death rate rose by 39 percent during the famine of 1971–72, and by 58 percent during the famine of 1974–75.[3] In China, for the period 1958–61, Ashton et al. estimate that there were nearly 30 million premature deaths, representing an increase of 72 percent over the number expected in the absence of famine. Over a shorter period, the increase was greater: Coale (1984), correcting for underreporting of deaths, estimates a death rate of 38.8 for 1960, which is 104 percent higher than the lowest prefamine rate, 19.0 for 1957. These increases are so large proportionately in part because normal death rates were so low.

It is not only the case, of course, that the data are better for Tudor-Stuart England, and for recent famines in Bangladesh and China, but also that the persons affected may have benefited from more developed economies and relief programs than, say, the population of fourteenth century Italy or of nineteenth century India. Nonetheless, when the reports are less impressionistic than those of early chroniclers and the numbers of deaths double, triple, or quadruple, the population in question is usually a relatively small one.

When the data come from small populations, population losses are likely to be exaggerated by the migration that accompanies disaster, since the smaller the population the less likely it is to be closed to migration, and records rarely permit distinguishing between losses due to migration and losses due to death. The *compoix,* detailed lists of the extent, nature, and value of land, examined by Le Roy Ladurie for Languedoc from 1500 to the beginning of the eighteenth century, show that 5000 out of 10,000 Albigeois disappeared from the lists between 1342 and 1357 (Le Roy Ladurie, 1974, pp. 13–14). Some of these surely died, but others may have left the area to seek a valley free from plague or a bountiful harvest elsewhere. In mid–seventeenth century Salerno, the loss of 50 percent of the population in a plague year was found to be the result almost equally of death and emigration (Corsini and DeLille, 1979). Most of the fuller discussions of famine, such as the report of the Peking United International Famine Relief Committee on the North China famine of 1920–21, mention extensive migration: ''Many workers remark the absence of younger men in the villages. They have all gone away to find work in new places or perhaps even to beg in the large cities. One worker in the Tsinan District speaks of 'whole villages entirely deserted. . . . [F]rom Shang Kwong in the same district, all the younger people had gone, both men and women' '' (Peking United International Famine Relief Committee, 1922, p. 14). The general point is well made by Caldwell, who concluded that deaths during the Sahelian drought of the early 1970s had been exaggerated. ''What conclusions can one draw about the extra mortality arising from the drought of the early 1970s? Primarily that no one knows; the figures in the newspaper headlines were figments of the imagination and many apparently serious reports were little better'' (Caldwell, 1975, p. 26).

Duration and frequency of food crises

The intensity of a mortality crisis is given not only by the increase in death rates over normal times, but also the length of time during which death rates are elevated.[4] This too is likely to be exaggerated in early and more impressionistic accounts of famine. The longest famine in Walford's account of famines of the world, past and present, was 23 years, in thirteenth century Britain, but the more common duration in his list is two to four years (Walford, 1878). As with estimates of the magnitude of famines, however, chroniclers of the past were probably more likely to note famines of unusual length, and to pass over those of brief duration. The longest time-series of historical mortality, that constructed by Wrigley and Schofield using a sample of English parish registers between 1541 and 1871, finds crises (of all sorts) to be of much shorter duration: the median crisis was 1.7 months and the mean 2.2 months, and in only six parishes was the mean duration more than three months (Wrigley and Schofield, 1981, Appendix 10). Similarly, Dupâquier's analysis of mortality crises in Europe at several levels of aggregation, from village to nation, found that few years of crisis were accompanied by a crisis in an adjacent year (Dupâquier, 1979). The effect on the annual death rate is dampened if the crisis is of short duration. If a three-month crisis raised the monthly deaths by 50 percent, it raised the annual deaths by only 12.5 percent. Similarly, if deaths doubled for three months (a 100 percent increase), annual deaths increased by only a quarter.

How frequent were famines? The analysis by Dupâquier noted above shows, for each level of aggregation, that although mild crises occurred in one year out of five, only once in a hundred years was there a severe crisis.[5] Since Dupâquier's records included mortality crises of all sorts, crises of subsistence presumably were even rarer. Even in China, the best available data show that famines were quite infrequent. A list of disasters in the Chinese province of Hubei between 1644 and 1911, based on local histories, shows that in only 59 of those years was there a famine in at least one of the 71 counties (Ho, 1959, p. 229 and pp. 292–300). A parallel list of population counts for the period from 1850 to 1912 permits us to compare population figures and recorded disasters for a period of population stagnation and decline that included the Taiping rebellion. In 1850 the population of the province was 33.8 million; in 1891 it was 34.7 million, and in 1912 it was 27 million (Liang Fangzhong, 1980, pp. 262–267). During this time there were 4,473 county-years of observation (71 counties × 63 years); of these, there were 29 recorded county-years of famine, and 11 county-years of epidemic (Ho, 1959, pp. 298–300). Although it would be unwise to take either the population counts or the recording of disasters by type as fully accurate, periods of hunger that involved death were likely to have been reported as famines in the Hubei county histories. Thus, the best available evidence of the frequency of famine during a time of population stagnation shows that famines were, even then, relatively rare.

In principle, there are no limits to the magnitude, duration, or frequency of famines, save the obvious one that they must end when the population has disappeared. There are reasons for believing that famines were of greater magnitude and longer duration when transportation and relief arrangements were rudimentary, and that the ability to mitigate the effects of a season of drought or flood is not unrelated to the capacity to record deaths accurately: thus we might expect famines to be less harsh in Tudor-Stuart England and in Bangladesh than they were in fourteenth century Italy. There are also reasons, however, for believing that the magnitude and duration of famines is easily exaggerated—by spokesmen for international agencies, as well as by medieval monks who relied on visitors to their monastery for news of the outside world. On the basis of the historical record, it would seem that famines in which death rates doubled for two years were rare, even for small populations, and that famines of greater intensity were highly unusual if they occurred at all.

Age and sex patterns of mortality

The demographic consequences of a famine depend not only on the magnitude and duration of the crisis but also on the rapidity with which a population can recover. This depends on the gap between crude birth rates and crude death rates once the crisis ends, which may well be affected by the age and sex distribution of deaths, and by changes in fertility. If the very young or the very old die disproportionately, the demographic effect will be more fleeting than if the greatest losses are among women who have yet to complete their reproduction.

The most reliable sources of age- and sex-specific death rates during a famine come from the records of the Demographic Surveillance System in Matlab thana, Bangladesh.[6] To the degree that they reflect common biological predispositions rather than varying cultural circumstances, they provide useful information. If, however, as is likely, cultural practices favored different groups in the past, or in different parts of the world, the Matlab thana data may not accurately reflect the age and sex patterns of deaths in other famines, particularly in premodern populations.

During the Bangladesh famine of 1974–75, when crude death rates rose by nearly 60 percent, from 15.6 (1973–74) to 24.6 (1974–75), deaths did not rise equally at all ages. As can be seen in Table 1, compared to the averages for the five years prior to Independence, the greatest rises during the famine years occurred among children aged 1–11 months followed by children aged 5–9 years and persons over 45, in that order. Children 1–9 experienced even higher mortality in the year after the famine than they suffered during the crisis. Because the neonatal death rate was virtually unchanged, infant mortality rose less than in the age groups already noted. These findings are corroborated by far less detailed data from the Mysore famine of 1876–78, in which it was found that the greatest deficits in the census of 1881 occurred in numbers of children under age 10 years and, to a lesser extent, among those over 50 (Lardinois, 1985). In the modern Chinese famine, however, infants and young children were not especially affected (Coale, 1984). The increase in mortality appears concentrated among those over 40, and especially affected men. Ashton et al. (1984) believe there may have been a system of food allocation in effect that gave preference to those under 40 so that, although mortality rose, children were protected to a greater extent than the elderly or the middle-aged.

Comparison of these age patterns of mortality with premodern European populations is hindered because the major source of information, parish registers, is more adequate for measuring mortality in infancy than in the later years of life. It is interesting to note, then, that Schofield and Wrigley, examining mortality rates for three age groups (infant, child, and adult)[7] in the parish of Ludlow in a series of years that included one of apparent food scarcity, found changes that are roughly consistent with those of Bangladesh, culturally a quite different society. As in Bangladesh, infant mortality rose in Ludlow, but not as much as the death rates of children and adults (Schofield and Wrigley, 1979).

TABLE 1 Infant mortality rates (per 1000 births) and age-specific death rates (per 1000 population) in Matlab thana, Bangladesh, 1966–67 to 1975–76

	Infant mortality rate			Age-specific death rates					
Year	Total	Neo-natal (0–29 days)	Post-neonatal (30 days–11 months)	1–4	5–9	10–14	15–44	45–64	65+
1966–67	110.7	59.5	51.2	24.9	4.1	1.7	4.1	15.3	67.9
1967–68	125.4	67.8	57.6	29.4	5.0	2.1	4.4	17.9	79.3
1968–69	123.8	82.9	40.9	23.8	3.9	1.7	3.7	17.4	74.4
1969–70	127.5	87.5	40.0	23.1	3.3	1.0	3.8	17.9	71.1
1970–71	131.3	89.9	41.4	27.9	2.3	1.3	2.7	14.4	72.9
1966–71 average	123.7	77.5	46.2	25.8	3.7	1.6	3.7	16.6	73.1
1971–72	146.6	86.9	59.7	25.8	3.7	1.6	3.7	16.6	73.1
1972–73	129.2	71.9	57.3	36.9	11.4	2.2	5.1	20.0	119.1
1973–74	128.8	81.1	47.7	22.7	14.1	2.0	2.9	14.7	96.5
1974–75	167.2	74.8	92.4	29.7	6.5	1.6	4.4	23.8	109.3
1975–76	150.4	71.0	79.4	32.7	12.3	1.2	3.8	25.1	100.1
Change in rates from 1966–71 to 1974–75 (1975–76 for children 1–9)									
Percent	35	−4	100	27	232	3	18	43	49

SOURCE: Chen and Chowdhury (1977), p. 416.

A possible explanation is that a substantial proportion of deaths in the first year of life occur in the first month. Neonates may not be affected by sudden changes in availability of food or by varying cultural practices. In most historical populations as well as most developing countries, they are likely to take most if not all of their nourishment from breast milk. Although the evidence is incomplete, it may be that the quantity and quality of breast milk are sufficient for the very young until the mother is nearly starved, so that they will be protected long after their elders are affected (*Population Reports*, 1981). The data from Bangladesh shown in Table 1 add partial support for this statement. Neonatal mortality was hardly affected during or after the famine: postneonatal mortality increased by only 30 percent after the 1971 war but nearly doubled after the 1974–75 famine. Mortality still rose much less for infants than for older children.[8]

The ability of a population to recuperate from a famine may depend on the sex composition of deaths as well as the ages at which deaths occurred. Are women of reproductive age more or less likely to die? Again, the best evidence comes from contemporary countries rather than from historical populations. Most life tables for Western societies, in the past as well as the present, show that mortality rates in normal times are higher for men than for women at all ages, although the differences are smaller when expectation of life at birth is low (Preston, 1976, p. 122). Where death rates for women are higher at some ages, there is reason to believe either that particular diseases that affect females selectively are widespread (such as tuberculosis at some ages) or that cultural customs favor males over females. During a famine, the advantage of females may be maintained or even increased in those countries where such advantage predated the famine, and may be achieved by women where it did not. During the Dutch Hunger Winter of 1944–45, mortality rose for all ages combined by 73 percent for females, but 169 percent for males (Dols and van Arken, 1946); in Greece, the scarcity of food during World War II also affected men more than women, especially over age 20 (Valaoras, 1946). In the famines of 1876–78 in Madras and Bombay, women appear to have been less susceptible than men (McAlpin, 1983, pp. 63–64). In Bangladesh, where death rates for females are normally higher than those for males at nearly all ages, the disadvantage of young females (under age 10 years) appears to have been exaggerated during the 1974–75 famine, but disaster diminished or even reversed the disadvantage of older women in most age groups by raising male death rates more than female death rates. In 1975 mortality was higher for men than for women from age 25 on (Ruzicka and Chowdhury, 1978b).[9] In China, male mortality apparently was higher than female mortality, at least at ages over 40 (Coale, 1984; Ashton et al., 1984). Death registration is too incomplete to determine which sex, if either, enjoyed a mortality advantage at younger ages (Ashton et al., 1984). In most situations where reasonable data are available, the sex and age differentials in excess mortality appear to favor women and young adults, so that the capacity for reproduction is preserved.

Fertility change

During a famine, declines in fertility are the rule. Researchers have found evidence of a decline in fertility in times of high grain prices in European parishes, in the European cities blockaded during World Wars I and II, in the Spanish Civil War, in concentration camps, and during the Bangladesh famines (Keys et al., 1950; Stein et al., 1975; Meuvret, 1946). Some part of the change is probably due to the postponement of marriages that would have otherwise occurred or to the separation of spouses: the woman may be sent home to her family in a more prosperous part of the country, or the man may seek work or food elsewhere. Increased stillbirths or fetal losses could contribute to a reduction in fertility. The evidence on stillbirth rates is contradictory: increases during periods of scarcity have been found by some researchers (Antonov, 1947; Smith, 1947) but not by others (Stein et al., 1975; Chen and Chowdhury, 1977). Another part of the decline is probably due to physiological and behavioral effects of malnutrition, hardship conditions, and stress, including famine amenorrhea and loss of libido.

In Bangladesh, the total fertility rate declined by about 33 percent between 1974 and 1975 (Ruzicka and Chowdhury, 1978b; Chowdhury and Curlin, 1978). Fertility rates, which are shown in Table 2, fell by nearly the same proportion in all age groups, so that there was no shift in the age pattern of fertility as there had been in the age pattern of mortality. The decline in fertility in Bangladesh was not due to an increase in contraceptive use, since only 2.4 percent of married women used contraception in a survey conducted

TABLE 2 Age-specific fertility rates (per 1000 women) in Matlab thana, Bangladesh, 1974 and 1975

Age	1974	1975	Percentage decline from 1974 to 1975
10–14	5.6	3.7	34
15–19	161.3	116.4	28
20–24	311.8	223.3	28
25–29	323.3	200.3	38
30–34	253.8	179.4	29
35–39	163.4	95.0	42
40–44	55.8	36.3	35
45–49	16.3	7.1	56

SOURCE: Ruzicka and Chowdhury (1978b).

in October 1975 (Chowdhury and Curlin, 1978). Neither was it due to delayed marriage; in 1974 only 2.7 percent of those aged 20–24 were still single (Ruzicka and Chowdhury, 1978c). Thus, the most likely explanations for fertility decline in Bangladesh are the effect of severe food deprivation on reproductive physiology, both male and female, and the effect of decreased coital frequency, whether induced biologically or resulting from increased stress or separation.

Age-specific fertility rates for young women are available for the 1958–61 Chinese famine and have been estimated for older women (Coale, 1984). They also show fertility declining at all ages, but somewhat more for women in their teens or early twenties as compared to the middle and later twenties. Coale (1984) suggests that fertility decline also increased with age for women over 35. Overall, declines in the crude birth rate were of the same order of magnitude as in Bangladesh: at its lowest, the annual birth rate in China was about 45 percent below prefamine level (Coale, 1981; Ashton et al., 1984), but over the four crisis years, we calculate the decline averaged 28 to 31 percent.

Sometimes there is evidence of a rise in fertility following a famine or other crisis, a rebound after the disaster. Two sources of such a rise may be the increase in nuptiality due to marriages delayed during the famine and the remarriages of those whose spouses had died. Other explanations are primarily physiological. The death of a nursling that interrupts lactation or a stillbirth during a crisis shortens postpartum amenorrhea, and women who fail to conceive are not pregnant when the crisis is over. Either would leave a larger proportion of the female population of reproductive age at risk of another pregnancy. Given these potential sources of post-crisis fertility rebound, it is important to note that there was no such rebound in Bangladesh, where total fertility was virtually the same in 1976 as it had been before the famine (Ruzicka and Chowdhury, 1978c). After the famine in China, however, fertility rose, perhaps by as much as 25 percent for the first post-crisis fiscal year (1962–63) and then declined again (Ashton et al., 1984).[10] Registered births in Madras rose for several years after the famine of 1876–78 (Lardinois, 1985), but it is impossible to separate an increase in the birth rate from increases in births because many people migrated into the area.

The collage pieced together from both historical and contemporary records suggests revision of conventional views of the demography of famines. In the short run, mortality rises and fertility falls during a famine, but these changes appear to be rather circumscribed. Famines were usually local rather than widespread, and of smaller magnitude and shorter duration than impressionistic accounts have led many to believe. In addition, when long time periods are considered, severe famines appear to have been rather infrequent. It is the long-run demographic impact of famines, however, rather than their short-term characteristics, that is at the heart of Malthusian explanations of population change in the past. The question thus remains whether famines were sufficiently severe and sufficiently frequent so that they might have served as a major check to population growth in the past. The review of the literature presented above suggests that this is unlikely. By turning to computer simulation, it is possible to give more precise form to our speculations on this question.

Modeling the demographic effects of famine

The demographic consequences of famine are usefully summarized by measures of the time it takes for a population to regain its initial (prefamine) size, or by comparisons of the size, over the long run, in two initially equal populations, one that experiences a famine and one that does not. Assuming that the population is closed to migration, the information needed to simulate these consequences is the age composition of the population at the time the crisis begins, the magnitude, duration, and age pattern of changes in mortality and fertility during the crisis, and the age-specific mortality and fertility rates (and implied rates of natural increase) when the crisis is over. If the information is uncertain, it is possible to consider a wide variety of alternatives.

Only some of the many possible alternatives are reasonable and useful to explore, however, in light of what we know about the demography of traditional societies. First, knowing that they grew slowly, we confined the range of estimates of normal growth to between 0 (a stationary population), where a mortality crisis would leave the population permanently diminished, and a growth rate of 1 percent a year, which is very high for a population before the demographic transition begins. Second, we used parameters chosen to represent the demographic regime of an Asian society (high mortality, early and virtually universal marriage, and relatively moderate fertility); we chose as our model the Chinese farmers surveyed by Buck in 1929–31 and analyzed by Barclay et al. (1976), using as an estimate of normal mortality an expectation of life at birth of 27.5 years. Third, we simulated only famines of a magnitude and duration that, on the basis of our review of historical records, are extreme; we chose combinations in which death rates increased about 110 percent or about 150 percent for a duration of two or five years.[11] Fourth, as noted above, we assumed that the populations were closed to migration, and that there was no fertility rebound. Fifth, we assumed, based on the Bangladesh data, that famine affected mortality differentially by age but that fertility declined by the same proportion for all women. Finally, for simplicity, we chose initial age distributions from stable populations (i.e., populations that had had unchanging fertility and mortality rates for a long time before the famine). These assumptions can be challenged, and we will discuss below the sensitivity of our results to reasonable alternative assumptions. Most of these alternatives, however, would tend to mute the effect of famine. If one were considering populations in which it was believed that a shift to significantly earlier marriage (and thus higher fertility rates) following a famine might have taken place, the time to recovery would be more rapid, as it would be if the effects of famine on mortality were thought to be less intense than those stipulated in the simulations. Thus, our evaluation of the extent to which famines could have played a major role in keeping a population at or near stationarity over the long run is conservative in that the actual extent is likely to have been smaller. The simulations are presented in greater detail in Watkins (1985) and summarized in the appendix.

Before we present the results, we should note one other simplifying assumption, the one that may be hardest to justify. We assumed that after the famine the age-specific mortality and fertility schedules returned to prefamine levels. Some changes in age-specific rates could obtain immediately after the famine: if diseases stimulated and spread by famine conditions continued to prevail, rates could remain elevated; but if the famine had advanced the deaths of the frailest in some age groups, it could cause a subsequent decline because only the more robust remained alive once it had ended.[12] These changes could be expected to be of relatively brief duration, however. Longer-lasting effects might be expected if disaster changed the composition of the population by economic and social characteristics: if, for example, it permitted a concentration of resources in fewer hands, a larger proportion of the population might be vulnerable subsequently. On the other hand, over the long term, subsequent mortality rates might be lower if disaster, especially repeated disaster, were to stimulate protective innovation (Boserup, 1965; Simon, 1977). If, as some have argued, mortality is density dependent, one would expect mortality to be lower shortly after a famine when population density was lower and then to increase gradually as population growth once again increased density (Ward and Weiss, 1976). These expectations of long-term changes in rates are both speculative and contradictory. In addition, our understanding of levels, trends, and differentials in mortality in populations before the beginning of the sustained decline in death rates leads to the conclusion that the bulk of normal mortality was associated with geographic, social, and economic conditions that were part of the "deep structures" of the society. Since these would be transformed little if at all during a crisis, and would continue to obtain when the crisis was over, it is reasonable to assume a return to prefamine conditions.

Simulation results

Figure 1 and Table 3 illustrate the changes in size for a population that at the start has a growth rate of 0.5 percent per year, and then experiences what we will call a "severe" famine, one in which death rates rose by 110 percent and fertility declined by one-third for two years. It is evident that the effect of this famine is quite fleeting: little more than 11 years after the crisis, the population regains its original size. In other words, a famine more severe than almost any observed checks population increase only for slightly over a decade. Nor does it have much effect on population size in the long run.[13] Some 90 years after the famine, the population is nearly 50 percent larger than at the start, only 7 percent smaller than it would be had there been no famine. The long-run growth rates in the two populations would thus be quite similar: the combination of a two-year famine followed by 90 years of vital rates that would lead to a constant growth rate of 0.5 percent produces the same size population as one with no famine and a constant growth rate of 0.42 percent for 92 years. Thus, the demographic effects of such a famine would have been scarcely visible, even if accurate decadal censuses were available. Although a famine of this magnitude is at the outer boundary of plausibility, it is possible to consider

FIGURE 1 Simulated change in the size of a population over a period of 95 years subjected to a famine-induced increase in mortality during years 1 and 2 causing death rates to rise by 110 percent and birth rates to fall by a third: Initial population is a unit-size stable population growing at an annual rate of 0.5 percent

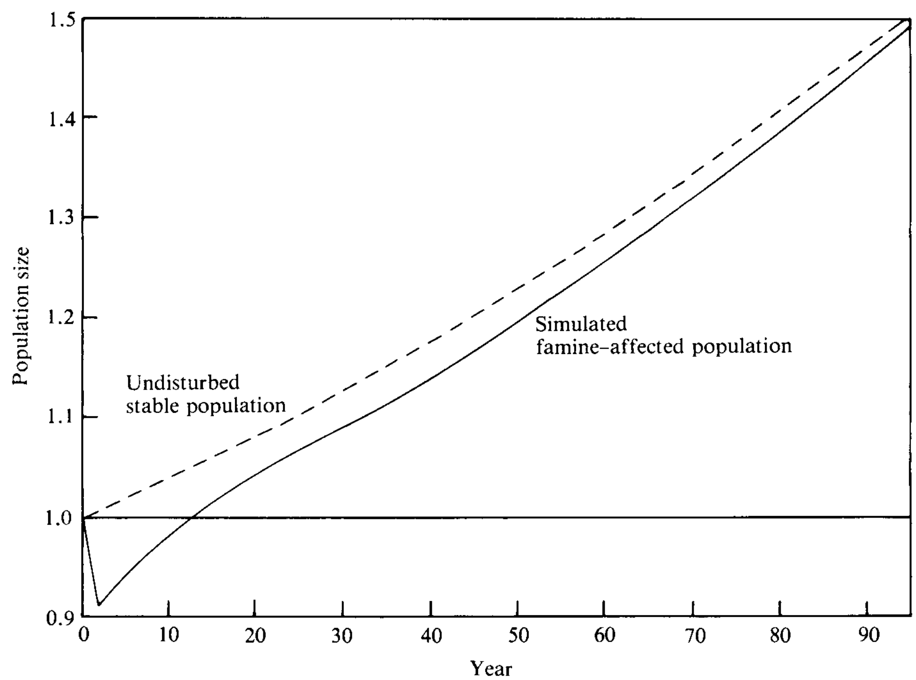


TABLE 3 Simulated effects of famine on population recovery, size, and growth rates: Initial stable growth rate = 0.5 percent

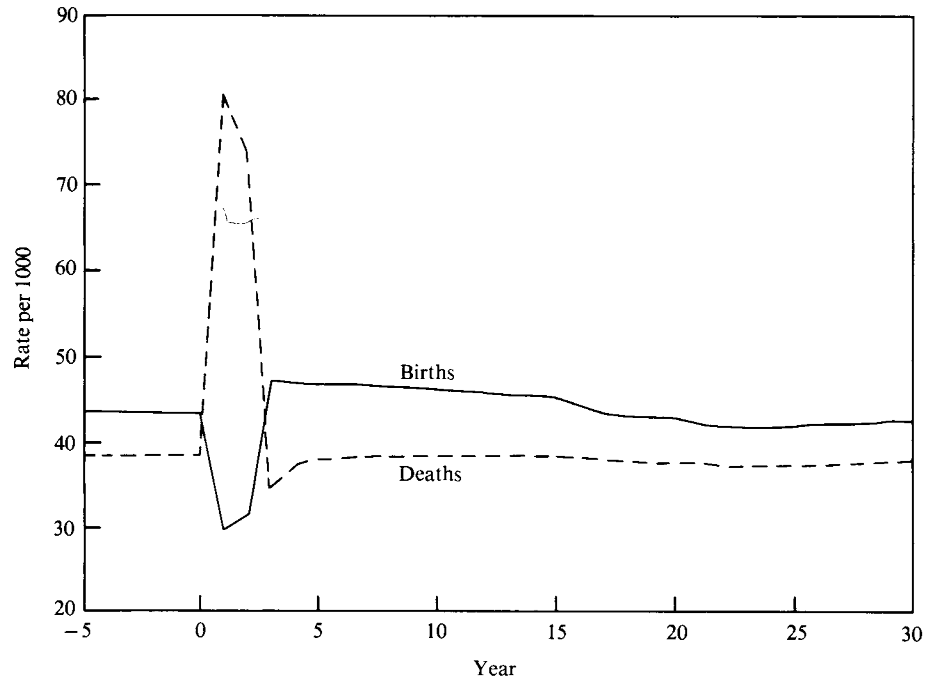
	Mortality increase due to famine			
	110 percent		150 percent	
	Duration of famine		Duration of famine	
	2 years	5 years	2 years	5 years
1 Prefamine population size (t = 0)	1000	1000	1000	1000
2 Population size at the end of the famine	910	816	886	767
3 Time to recovery (years)	11.3	14.3	27.1	50.4
4 Population size 90 years after famine	1472	1348	1407	1216
5 Average growth rate during 90-year period (percent)	0.42	0.31	0.37	0.21
6 Population size at t = 90 if there had been no famine	1584	1608	1584	1608
7 Percent reduction in population size due to famine	7.0	16.2	11.2	24.4
8 Population size 90 years after famine if famine mortality were not age selective	1427	1280	1390	1203
9 Ratio: (8) to (4)	.969	.950	.988	.989
10 Recovery time if famine mortality were not age selective (years)	18.8	24.1	40.6	53.1
11 Ratio: (10) to (3)	1.66	1.50	1.69	1.05

NOTE: Recovery is defined as the time when the population regained its initial size and stayed above that level thereafter.

ones even more extreme. If the famine had increased death rates by 150 percent for five years, it would indeed take longer (50 years) to regain initial population size, and after 92 years the famine population would be 25 percent smaller than would be the population had there been no famine.

Our next interest was to ascertain the effect of differential increases in age-specific mortality during a famine on a population's subsequent demographic course. Even though age-specific mortality and fertility schedules were assumed to have returned to normal after the famine, the sharp fluctuations in crude birth and death rates seen in Figure 2 demonstrate one effect of changes in the age composition. Crude death rates fall both because a greater proportion of the famine survivors are in the ages when mortality rates are normally low and because fewer infants (who are always subject to high mortality) are born; crude birth rates rise because a larger proportion of the female population is in the reproductive years. In both cases, these changes come about because famine tends to hit the young and the old harder than other ages, so that these

FIGURE 2 Simulated change in birth and death rates over a period of 30 years in a population subjected to a famine-induced increase in mortality during years 1 and 2 causing death rates to rise by 110 percent and birth rates to fall by a third: Initial population is a unit-size stable population growing at an annual rate of 0.5 percent



age groups constitute a smaller proportion of the population after the famine than before. But are these age compositional effects sufficiently important so that they need be taken into account? If famine were to have a negligible effect on age composition, much simpler calculations would be possible.[14]

To examine this question, we assumed that in two initially identical populations famine caused a reduction, such that the populations were still identical in size after the two famine years. In one, mortality increased by the same proportion at all ages; in the other, mortality change was age selective.[15] As expected, when people of reproductive age are affected to the same extent as younger and older people and when the birth rate remains constant, the population returns to its prefamine size less quickly. When the growth rate is 0.5 percent per year, and the famine is severe (110 percent increase, 2 years), it takes nearly 19 years for a population to recover from an age-neutral famine but less than 11 years to recover from one in which mortality is age-selective. Over the long term (90 years after the famine's end), the age-neutral famine population grows nearly as rapidly as the one with age-compositional changes. Specifically, it grows by 43, as compared to 47, percent and is only 3 percent smaller in size. Thus, as other calculations with even more extreme famines confirm, when age composition is not altered by famine, recovery time is longer and growth is slower.

While the recovery time found by assuming mortality is age-neutral overestimates the recovery time from a single age-selective famine, the effects of changes in age composition are far smaller than the effects of famine duration and magnitude and of differences in the growth rate (for which results are not shown here). Because the age-neutral famine recovery time reflects the differences in the severity of the famines adequately, we will use this measure to estimate the frequency of famines necessary to check population growth.

By not allowing for an increase in fertility (other than that due to the distorted age structure of the population), the simulations exaggerate the effect of famine: a fertility rebound of the type that occurred in China and in some European populations (Meuvret, 1965) would make recovery more rapid. In other simulations, we assumed that fertility rises by 30 percent for two years after the famine ends. The time to recovery is shortened by a small, but measurable, amount.

We were also interested in the immediate impact of the age-selective famines that were accompanied by reduced fertility. Table 4 shows the effects of 16 famines we simulated by combining four different assumptions concerning initial stable growth rates (r = 0.0, 0.25, 0.5, 1.0 percent); two durations for the rise in mortality (2 and 5 years); and two levels of increase in mortality (about 110 percent and about 150 percent above precrisis level). The impact is measured by the size of the population at the end of the famine compared to its size at the start. Although even our least severe famines (2 years, 110 percent rise in mortality) are harsher than nearly all well-documented famines, they reduce the population by only about 10 percent. Only in the

TABLE 4 Population size after an age-selective famine relative to its size at the start according to the initial population growth rate and the severity of the famine

	Mortality increase due to famine			
	110 percent		150 percent	
	Duration of famine		Duration of famine	
	2 years	5 years	2 years	5 years
Population size at the start of famine	1000	1000	1000	1000
Population size at the end of a famine when initial annual growth rate had been				
0.00 percent	899	793	880	752
0.25 percent	901	797	880	753
0.50 percent	910	816	886	767
1.00 percent	920	838	892	780

most extreme famines (5 years, 150 percent rise in mortality) does the population reduction approach a quarter.

Table 5 shows the recovery time estimated for various combinations of famine severity and growth rate of the original population. The severity is measured by the relative size of the population after the famine and the recovery time is estimated under the assumption that the famine is age-neutral. Details of the calculation are given in the appendix. The frequency with which the population would have to experience famine to prevent it from exceeding its original size can be estimated as the recovery time plus the duration of the famine.

Table 5 also permits a limited comparison of the relative effects of famine magnitude and duration, and the normal mortality and fertility implicit in a variety of growth rates. As the small number of scenarios considered here demonstrates, the results are highly sensitive to the growth rate chosen. Of course, if a population with a normal growth rate of zero sustains a famine or other mortality crisis and has no compensating subsequent increase in fertility or decrease in mortality, it never regains its original size. The recuperative ability of a stationary population is, of course, nil, while that of a population growing at 1 percent a year is considerable. By the same token, however, if rapid growth advances the time of a subsequent imbalance between population and resources, famines would have to be more frequent than in populations in which normal growth was slow. The population growing at 1 percent per year would fail to surpass its original size only if three or four extreme famines, reducing its size by over 20 percent each time, occurred every century.

If a famine restored an equilibrium between population and resources, it could, as Malthus would agree, only be a temporary solution to the problems posed by a growth in population more rapid than a growth in resources. After recovery, one would expect additional famines to occur if population size were not to exceed the initial level; over a century of relative population stagnation, then, one would expect to see about five severe famines if the famine plus

TABLE 5 Recovery time from an age-neutral famine according to the initial annual growth of the population and the reduction in population size due to the famine

	Initial annual growth rate				
	0.00	0.10	0.25	0.50	1.00
Doubling time (years)	—	693	277	139	69
Recovery time when the famine reduces the population by					
5 percent	*	51	21	10	5
10 percent	*	105	42	21	11
15 percent	*	163	65	33	16
20 percent	*	223	89	45	22
25 percent	*	288	115	58	29

* = no recovery.

recovery cycle took 20 years, or two of the more extreme if it took 50 years. Even where the recovery time is longest, when the growth rate is barely greater than zero, it would take a very extreme famine every two or three centuries to limit population size. The historical record, skimpy as it is for time series, does not support the view that famines were usually that frequent.

The simulations presented here do not exclude the possibility that successive disasters could strike the same population, as was the case in India when there was virtually no growth between 1891 and 1901, and several major famines occurred (McAlpin, 1983; Davis, 1951). They do, however, provide a corrective to facile interpretations of the role that famine played in the past: if famines are to carry some part of the burden of explanation for population stagnation or population growth, the expectations derived from simulations such as those presented here should at least be consistent with the plausible estimates of the magnitude, duration, and frequency of famines in the actual population under investigation. If they are not compatible, one would want to challenge either the assumptions used in the simulation or the accuracy of the historical record and its interpretation.

Conclusions

Famines have, we believe, appealed to modern historians seeking explanations for population stagnation in the past because they are dramatic, because they can be interpreted as endogenous to a class or political system, and because hunger has increasingly been classified as an injustice rather than a misfortune. Yet the only way famines and other mortality crises could have been a major deterrent to long-run population growth when the underlying normal mortality and fertility rates would have led to even moderate growth is if they occurred with a frequency and severity far beyond that recorded for famines in history.

It is important to note that these results speak only to the demographic impact of famines, and not to their more general social consequences. In both the short run and the long, the effects of famine or other crises may have been quite significant in other areas of life. The migration that accompanied a crisis may well have distorted not only the age composition of the population, but also the moral economy of the community. When a part of a community that is normally stable and well-integrated is removed, either by death or migration, the losses may be felt with great harshness, for the usual way of doing things must adjust to these losses. The fear of crisis, even if it did not occur frequently, and even if the demographic effects were not great, may have had a subtle but profound effect on attitudes toward life and death. In addition, there is some evidence that a crisis may have long-lasting effects on economic arrangements and social structures. For example, the migration associated with a Chinese famine of the mid–1930s was thought to have had serious effects on the rural economy: not only was there a drain of able-bodied young men, but also "With the general flight of the resident landlords and other well-to-do people from the villages, money has become increasingly scarce in the countryside,'' leading to greater usury (Hu Nai-tsui, 1939). Ownership of productive resources sometimes appears to have become more concentrated, as seems to have been the case in early modern Languedoc and recent Bangladesh (Le Roy Ladurie, 1974; Alamgir, 1980).

Family life may also have been disrupted by the flight and death that accompanied a crisis. Families would have been fractured if wives went back to their parental families in an untouched area, or husbands sought work and food elsewhere. Describing the effects of a famine in 1935 in a Chinese village that initially had 530 inhabitants living in 76 families, an eyewitness wrote: ''In the winter of 1935, 25 entire families left the village, and from each of 39 families one to three persons left, leaving only 12 families intact'' (Hao P'un-sui, 1939). After the crisis, widows, widowers, and orphans would have a difficult time coping in an economy in which the family was the central productive unit; remarriages can recreate the family economy, but may not have reconstituted the bonds of affection and loyalty that nourished it. Orphans old enough to fend for themselves may well have left most easily, and it is reasonable to suppose that their migration was more likely to be permanent.[16]

With proper caution, our results are generalizable to the mortality crises brought on by war or disease in the past, and to early modern European as well as Asian populations. Compared to what appears to be less flexibility in marriage age in traditional Chinese societies, the patterns of marriage and household formation in historical European populations would seem in principle able to enhance their recovery from the demographic effects of a famine by permitting a rebound in fertility once the famine was over. Simulations discussed earlier indicate, however, that the effect of a subsequent rebound that increased fertility by a third over its prefamine level was small.

In these simulations, the age distribution of crisis deaths was first chosen to be representative of a famine. As noted earlier, compared to a situation without age selectivity, there was a somewhat more rapid recovery to precrisis population size, but little difference in long-run population growth. Some epidemic diseases have rather different age patterns of death: if a particular disease were more likely to attack adults than children or the elderly, recovery would be less rapid than in these simulations. Mortality crises of all sorts were, of course, more frequent than those attributable to famine, but were also usually local, and of rather modest intensity. Thus, the results of our simulations lead us to be skeptical about the role that crises in general as well as famines in particular played in accounting for long-run population stability.

What this analysis strongly suggests is that the far more plausible explanation for the long-term slow growth of large populations in the past is the low rate of natural increase set by normal levels of mortality and fertility. Although it is true that, for aggregates of substantial size, levels of normal mortality would have reflected small, short, and local famines, mortality was high even in areas that rarely experienced a crisis. It would thus appear that the control of normal mortality, the day-to-day causes of death, rather than the elimination of the one-time or extremely rare large-scale killer, is far more responsible for the onset of modern population growth.

On the other hand, the effects of famine on other aspects of social life may have been more far-reaching than those of a war or an epidemic. The scarcity of food is likely to affect livestock (Davis, 1951, p. 41) and thus to have an effect on the restoration of a normal economy. In addition, it is likely that a potential famine was signaled well in advance of its arrival, while a plague or epidemic would have been less predictable. Indeed, the late nineteenth-century Famine Code of India noted that the sale of land was to be taken as an early warning signal of a coming crisis of subsistence (Aykroyd, 1975; Bongaarts and Cain, 1981). It was not, however, only land that was jettisoned in an attempt to stave off starvation. Francis Nichols, who at the turn of the century traveled through Shensi, wrote of his observation of famine:

> In order to buy food the farmers sold first their scanty stock of furniture and farming tools, then the roofs of their houses, and, lastly, their children. . . . Only at rare intervals was a house with a roof visible anywhere. The thatch of which the roofs of Chinese houses are made always finds a ready market in the towns as fuel, and as a last resort before abandoning all hope the starving villagers had sold the shelter of their homes. (Nichols, 1902, p. 232 and p. 242)

Similarly, Alamgir writes that the people of Bangladesh in 1974 not only sold or mortgaged land, but also sold cattle and agricultural implements, cooking pots, plates, mugs, spoons, and even toilet jugs (Alamgir, 1980, p. 135). For most of the past, food could be purchased at some price; in epidemics, there was no cure for disease available in the market at any price. Except to finance flight, there was little incentive to give up property. Although it is often said that the removal of a part of the population by death vacated niches for those who would otherwise not have had access to them, it is less often noted that following a famine, at least, it may have been difficult to furnish that niche with the basic necessities of life.

Social and economic conditions can make recovery from a crisis more or less rapid. Gutmann (1980) concludes that in the early modern Low Countries the keys to rural recovery from incessant warfare were access to land and the perception that there were opportunities to survive and prosper. When patterns of landholding changed, when family life was distorted, when vacated niches were barren of the simplest necessities of life, recuperation may have been delayed, and delayed well beyond the time measured simply by demographic simulations.

How generalizable are the results presented above to less developed countries of today? For the past, we argued that in general famines were sufficiently local and brief that their impact on the demographic statistics of larger aggregates was usually modest, and that even comparatively low (by modern standards) rates of natural increase would erase their traces rather quickly. Recent famines have also usually been circumscribed in scope and duration. Moreover, as Bongaarts and Cain (1981) conclude, in many contemporary populations, growth rates are so high that demographic effects of famine would be even more fleeting than those described by the simulations presented above. The modern Chinese famine of 1958–61 had relatively little effect on population growth, which had been proceeding at nearly 3 percent per annum. Between 1958 and 1964, the average growth rate was reduced to 1.2 percent, so that the population in the latter year was only 5 percent less than it would have been if it had continued to have a 3 percent growth rate throughout that time. Writing of the effects of drought on the Sahelian savannah, Caldwell observes that droughts there no longer have a Malthusian impact:

> It became increasingly apparent that, in spite of the appalling conditions being experienced over most of the West African savannah, population growth had not been halted in the region as a whole and, except in the completely nomadic areas, natural increase may not have been greatly checked. True Malthusian conditions do not easily set in and are usually not permitted to persist in the modern world for long or over great areas. (Caldwell, 1975, p. 2)

The modest effect on subsequent population growth in the Sahel was in part due to the modest magnitude of the crisis and in part to the relatively large gap between normal birth rates and death rates. In the present as in the past, it is often the social rather than the demographic consequences of famine that are most notable.

Local food shortages are likely to occur in the future. They may be exacerbated or alleviated by high levels of coordination and control characteristic of the centralized governments of modern states: exacerbated because national policies permit errors of national scope, alleviated because national governments command national resources (Levy, 1966; Black et al., 1975). The post-Revolutionary Chinese government developed the ability to implement national policies effectively, making the Great Leap Forward a national rather than a local disaster; the consequences of the widespread subsistence crisis were yet more extreme because of the government's continued insistence on exporting rice (Ashton et al., 1984). By the same logic, however, the dominance of the nation over the region also permits the whole community to assume responsibility for each of its parts. The national communications, roads, and transport systems that have reduced local autarky have extended the territory from which assistance can come, and expanded the number of people who care. In 1984 in Bangladesh, despite destruction of much of the rice crop by abnormal monsoon flooding, famine was averted by effective government action to obtain and distribute substitute grains. Indeed, that there were 400 relief agencies in Africa in 1980 (Jaynes, 1980) and that the *New York Times* continues to chart the progress of the Sahelian drought symbolize the extension of the relevant community well beyond national boundaries.

The combination of the historical record and the calculations presented here suggest that famines may not have played a major role in accounting for long-run population stability in the past. As to the future, although high rates of natural increase would, of themselves, predict more frequent pressure of population on resources, the paths of escape from the Malthusian trap are well charted. Unless famine intensities exceed those upon which our calculations were based, there is little likelihood that famines will be a major determinant of population growth in the future, any more than they appear to have been in the past.

Appendix: Method of simulation

To estimate the effect of famine on birth rates, death rates, and the age structure of a population through a simulation exercise, the initial population was assumed to have a stable age distribution, resulting from a long period of unchanging age-specific mortality and fertility rates and absence of migration. Such a population has a crude birth rate, crude death rate, crude rate of natural increase, and age distribution that are constant from year to year (Coale, 1972). The effect of famine was simulated by increasing mortality rates and decreasing fertility rates for the stipulated duration of the famine. After the famine's end, mortality was assumed to return immediately to its prefamine level. In most instances, no fertility rebound effect was simulated; in some runs, however, fertility was assumed to rise above normal levels by a third for two years after the famine, thereafter returning to the initial pattern.

The initial populations

The initial population chosen for all the simulations corresponded in its expectation of life to the Chinese farmers surveyed by Buck in 1929–31 and analyzed by Barclay et al. (1976). They estimated that the life expectancy at birth of the Chinese farmers (North Region) was between 26.5 and 28.1 years. Rates by single years of age are needed for the simulation; these are available for the West model life tables calculated by Coale and Demeny (1966). The West model life table corresponding in life expectancy most closely to the Chinese farmers is Level 4, which has an expectation of life at birth of 27.5 years for females and of 25.3 years for males.

To obtain the age-specific fertility rates, the age pattern of fertility was assumed to follow schedules developed by Coale and Trussell (1974) for natural fertility when the mean age at marriage equals that estimated for the Chinese farmers. The total fertility rate needed to produce a stationary population was found, by trial and error, to be 4.7.

We also wanted to simulate the effects of a famine on populations that were growing. Three assumptions about growth rates were used: one moderately low ($r = 0.25$ percent), one moderate ($r = 0.5$ percent), and one relatively rapid ($r = 1.0$ percent). In these populations, mortality rates were kept at the level used in the stationary population, but age-specific fertility rates were increased by the same proportion at all ages. Through trial and error, the level of fertility was adjusted until the proportion that produced the required rate of growth was located. The total fertility rates needed to produce the stipulated growth rates were 5.1, 5.5, and 6.3.

Famine changes in mortality and fertility rates

Two assumptions were used concerning the magnitude of famine-generated increases in death rates: about 110 percent and about 150 percent. The assumed age and sex distribution of the increase in mortality matched that recorded in Bangladesh during the famine of 1974. Again, it required some trial and error to find the new death rates that increased the crude death rate in the first year of the famine by about 110 percent and 150 percent. These famine death rates were kept in effect for two years in some simulations; in others they were in effect for five years. Age-specific fertility rates were lowered for all ages for the duration of the famine in accord with the level of change shown in the Bangladesh famine: by about a third. After the famine period ended, mortality and fertility schedules were assumed to revert to their prefamine levels. The populations were projected for a total of 95 years, so that there were 93 post-famine years in the two-year famine and 90 years in the five-year famine case.

In some simulations, a fertility rebound was assumed: age-specific rates were made to rise above their normal levels by a third for the first two post-famine years and then resumed their original levels.

Projecting the population

The actual projection program uses quite simple relations. The number dying at age a in year t, $D(a,t)$, is obtained by multiplying the age-specific death rate for that year, $M(a,t)$, by the number of persons of that single year of age, $P(a,t)$.

$$D(a,t) = M(a,t)\ P(a,t). \qquad (1)$$

The crude death rate is simply $\Sigma\ D(a,t)/\Sigma\ P(a,t)$. The births to women aged a, $B(a,t)$, are given by the age-specific fertility rate, $F(a,t)$, multiplied by the population at that age:

$$B(a,t) = F(a,t)\ P(a,t). \qquad (2)$$

The crude birth rate is given by $\Sigma\ B(a,t)/\Sigma\ P(a,t)$. Finally, the population aged $a+1$ in year $t+1$ is found by subtracting the deaths aged a in year t from the population, i.e.,

$$P(a+1,\ t+1) = P(a,t) - D(a,t). \qquad (3)$$

It need only be noted that $P(0,t) = \Sigma\ B(a,t)$.

Projecting the population when the growth rate is constant

In our basic simulations of the demographic effects of famine, we have assumed that mortality changes are age-selective and ferti declines. This implies that the age distribut of the population changes during the fami for example, because fewer children are b and people of certain ages, notably child and older people, have greater increases mortality than others. Those who were m protected against famine mortality then c stitute a somewhat larger portion of the p ulation and this effect will last for some ti before the stable age distribution is regaine

If, however, the age distribution is u changed during and after the famine, the p ulation immediately returns to growing at pre-famine rate. Then population can be p jected very simply:

$$P(*,t+1) = P(*,t)\ (1+r)$$

where r is the growth rate expressed as a p portion (for example, $r = .005 = 5/1000$/yea and the symbol $*$ indicates the entire popu tion. In this case, the population n years la is given by

$$P(*,t+n) = P(*,t)\ (1+r)^n \qquad ($$

which is approximated by

$$P(*,t+n) = P(*,t)\ e^{rn} \qquad ($$

The population size obtained in this way c be compared to that found when the a specific mortality is assumed to chan selectively.

The recovery time, RT, can be estimat from the population at the start of the famir $P(0)$, and at the end, $P(*)$, and the grow rate, r:

$$RT = ln[P(*)/P(0)]/r.$$

Notes

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1 The separation of marriage from menarche that underlies the Western European marriage pattern provided these populations with what in principle is a sensitive mechanism of response to improvements in the economic environment: the age of marriage or the proportions never marrying could fall after a crisis and spur regeneration. In Asia, where the timing of marriage appears normally to have been closer to the timing of menarche, and where marriage was nearly universal, this mechanism may not have been as effective (Watkins, 1984; Watkins and Naquin, 1985).

2 This maximum figure was calculated under the assumptions that the usual death rate was about 40 per thousand population, 13 million deaths occurred in the affected region, and all deaths occurred in a single year.

3 The rise in the crude death rate was calculated on the basis of rates adjusted to take into account the provision of health services by the Cholera Research Laboratory (Chen and Chowdhury, 1977, Table 1).

4 There is an extensive discussion of this point by Hollingsworth (1979) and others in Charbonneau and LaRose (1979).

5 Dupâquier developed an index of mortality crises that is based on the difference between the number of deaths in a given year and in the preceding ten years and takes into account the variability in deaths over that ten-year period and the size of the population. The index ranges from 1 to 6, or from least to most severe. A loss of 20 percent of a small population (1,500 inhabitants) implies a crisis of magnitude 5; for a larger population (500,000), the loss of 10 percent of the population is considered a crisis of magnitude 5. For the ten regions of France between 1750 and 1792 and eight countries of Europe between 1750 and 1799, a crisis of some magnitude occurred approximately one year out of five. More severe crises were rare: a crisis of magnitude 4 occurred five times, of magnitude 5 once, and there were no crises in these areas of magnitude 6 (Dupâquier, 1979).

6 The Demographic Surveillance System is sponsored by the International Centre for Diarrhoeal Disease Research, Bangladesh, previously the Cholera Research Laboratory. It began recording demographic information in 1966 in a population of about 260,000 in Matlab thana. A staff of approximately 300 village workers visits each family at least bi-weekly and collects information about births, deaths, migration, marriages, marital dissolutions, miscarriages, and stillbirths. A fuller description is given in a report by the Cholera Research Laboratory (1978). The area experienced famines both in 1971 and in 1974–75; because the first was associated with the War of Independence from Pakistan, and the effects of famine are difficult to disentangle from war, we will use primarily data from 1974–75.

7 The category "children" is not clear from the records, and may include adult unmarried offspring. Wrigley and Schofield (1981) believe that most of those buried as children were under age 10 years.

8 We believe the age-specific mortality rates for 1971–72 beyond age 1 may be incorrect because they are exactly equal to our averages of the previous five years for every age group. We report these figures as they appear in Chen and Chowdhury (1977).

9 The effect of male losses on fertility will depend on the marriage patterns. If women cannot subsequently find husbands to replace those they lost, the effect will be greater than if they can. Thus, polygynous societies may be advantaged in this respect, unless a widow taboo is observed.

10 The rebound in China is difficult to estimate because fertility had been declining before the famine. This estimate is relative to the lowest fertility observed before the famine (1955–56). When calendar years are considered, the fertility rebound lasted at least two years and increased the birth rate by about 15 percent (Coale, 1984).

11 The increase in the crude death rate was about 110 percent or about 150 percent in the first year of the famine. Because mortality was assumed to increase disproportionately by age and sex, a combination that produced approximately the selected overall change was found by trial and error.

12 Alternatively, one might hypothesize that survivors are weakened by the crisis, and therefore have higher mortality.

13 A similar conclusion was reached by Bongaarts and Cain (1981), who also considered more rapidly growing populations.

14 If there were no fertility decline and no difference in the age pattern, if the proportion of each age group that survived to the next age were reduced by the same amount by the famine, then the age structure of the population would remain unchanged (Coale, 1973). Population growth would then resume its original level as soon as the famine ended and be unaffected by the changes in age structure due to disproportionate famine deaths and lower birth rates.

15 In response to an earlier draft of this paper, David Weir calculated the expected frequency of famines under the assumption of no age compositional effects and for a wider range of growth rates. His results led us to the calculations of population growth when mortality is not age-selective.

16 We could find little other than the sheerest speculation that would permit even rough estimates of the probability that migrants would return. Lardinois says that in the 1881 census, a few years after the end of the Madras famine, 95–98 percent of the counted population resided in their district of birth (Lardinois, 1985). The famine affected only some parts of India, however, while the census results to which he refers are presumably for the whole country. Speaking of the migrations during the North China famine of 1920–21, the Relief Committee writes, ". . . of the few that managed to reach a haven of safety, hardly any can have returned to their desolate homes" (Peking United International Famine Relief Committee, 1922).

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