Population Studies, Vol. 58, No. 1, 2004, pp. 55–75

Routledge
Taylor & Francis Group

Mortality in China 1964–2000

Judith Banister[1] and Kenneth Hill[2]
[1]Javelin Investments, Beijing, [2]Johns Hopkins University

This paper uses data from censuses and surveys to re-estimate mortality levels and trends in China from the 1960s to 2000. We use the General Growth Balance method to evaluate the completeness of death reporting above the youngest ages in three censuses of the People's Republic of China from 1982 to 2000, concluding that reporting quality is quite high, and revisit the completeness of death recording in the 1973–75 Cancer Epidemiology Survey. Estimates of child mortality from a variety of direct and indirect sources are reviewed, and best estimates arrived at. Our estimates show a spectacular improvement in life expectancy in China: from about 60 years in the period 1964–82 to nearly 70 years in the period 1990–2000, with a further improvement to over 71 years by 2000. We discuss why survival rates continue improving in China despite reduced government involvement in and increasing privatization of health services, with little insurance coverage.

Keywords: completeness of death reporting; General Growth Balance method; China; PRC censuses; mortality trends; adjusted life tables; life expectancy; child mortality; adult mortality; survival rates

[Submitted June 2003; Final version accepted November 2003]

Background

China had a very high level of mortality early in the twentieth century, with expectation of life at birth estimated at less than 25 years (Barclay et al. 1976). But after the founding of the People's Republic of China (PRC) in 1949, the crude death rate almost halved in less than a decade, in response to the radically changed circumstances: near cessation of international invasion and civil war; the disarming of the general population; allocation of arable land to most peasants through land reform; government distribution of grain to areas with a shortage; vigorous strategies of epidemic control for the main infectious diseases; and the retraining of midwives in modern midwifery (Banister 1987, pp. 50–9, 78–85). Life expectancy of about 50 years was achieved by 1957 and, after a catastrophic famine caused by the policies of Mao Zedong's Great Leap Forward, mortality decline resumed (Coale 1984; Banister 1987, pp. 85, 116). Simple systems of cooperative health insurance that were inexpensive, together with minimally trained 'barefoot doctors' and a three-tier system of referral to health services were introduced in rural areas starting from the late 1960s.

A re-analysis of data from a nationwide health survey over the years 1973–75, the results of which were initially reported by Banister and Preston (1981), reveals an estimated coverage of death reporting of approximately 76 per cent; China's population averaged an expectation of life at birth of 60 years between 1964 and 1982, far better than would have been expected given the country's level of economic development.

By the late 1970s, the PRC had achieved impressive survival gains along with other social achievements such as reduced illiteracy, widespread attainment of basic primary education, and improvements in the status of women. But severe problems remained: the minutely planned command economy was unable to achieve rapid economic development; food supplies were inadequate and rationed; and over half the population was still in poverty (according to the international standard definition that persons in poverty are those with an income per head of less than US$1 per day, using purchasing power parity calculations). After the death of Mao Zedong in 1976, subsequent leaders launched economic and social reforms designed to achieve economic take-off and social progress, with great success. Meanwhile, the family planning programme expanded into rural areas in the 1970s and brought about greatly reduced population growth from the mid-1970s to the present. Modern censuses of 1982,

ISSN 0032-4728 print/ISSN 1477-4747 online/04/010055-21 © 2004 Population Investigation Committee
DOI: 10.1080/0032472032000183753

1990, and 2000 have documented the momentous demographic and social changes taking place, including the downward trends in mortality (China National Bureau of Statistics 1985, 1993, 2002).

China mortality and population data

Information on deaths in China is gathered from a variety of sources. Since the early 1950s, deaths have been registered at local levels and, together with population numbers, are aggregated annually from localities up to provincial and then national levels. China's official annual death rates were derived from this system until the National Bureau of Statistics (NBS) instituted a new annual population survey in the 1980s. However, because the compilation of registered deaths is not reported by age, sex, or cause of death, the only mortality statistic available from this public security registration system has been the crude death rate.

The PRC Ministry of Health (MOH) has carried out periodic mortality surveys. The most useful of these was an almost nationwide mortality survey (the Cancer Epidemiology Survey) in the 1970s that attempted to record all the deaths in nearly all of China's counties and city districts for the 3-year period 1973–75. For each death, the age and sex of the person and the cause of death were recorded. The population age–sex structure was also recorded for each of the 3 years. This survey documented 18.4 million deaths over 3 years in a population of 842 million. It was by far the largest mortality survey in human history (see Banister and Preston 1981). The survey provides baseline age–sex–cause-specific mortality rates for the period 1973–75, just before the beginning of the post-Mao economic reform period. Demographers can use this baseline to analyse changes in mortality conditions as the economic reforms unfolded, though it is difficult for scholars to get access to these data.

In the 1990s, the MOH introduced a mortality surveillance system in selected counties and cities, the data from which can be used to derive annual urban, rural, and all-China life tables. In addition, the NBS has carried out an annual survey of population change since the early 1980s, and in recent years annual life tables have been reported from this survey. While both sets of life tables are useful for monitoring possible short-term mortality changes in China, reported mortality is implausibly low in these MOH and NBS life tables.

Since 1989, the Chinese Academy of Preventive Medicine of the MOH has conducted a nationally representative annual survey at 145 surveillance points, recording urban, rural, and national mortality by age group, sex, and cause of death as ascertained by verbal autopsy. While this survey also suffers from serious underreporting of deaths, it is important because it is the only current system for monitoring changes in China's cause-of-death pattern.

The most complete mortality data for China to date have been gathered from all households in the three most recent nationwide censuses of 1982, 1990, and 2000, each of which collected information about recent household deaths by single year of age and sex. The 1982 census, with a reference date of 1 July 1982, collected this information about deaths in calendar year 1981. The 1990 census, with a reference date of 1 July 1990, collected the information about deaths in calendar year 1989 and from January to June 1990. The data are published for three separate 6-month periods: January–June 1989, July–December 1989, and January–June 1990. The 2000 census, with a reference date of 1 November 2000, collected information about deaths in the 12 months before the census, i.e., the period November 1999–October 2000. The classifications of deaths in the 1990 census allow us to create groupings that are consistent both forwards and backwards: using deaths in 1989 from the 1990 census for combined analyses with the 1982 census with deaths reported for 1981; and using deaths for July 1989–June 1990 for combined analyses with the 2000 census data on deaths reported for the preceding 12 months. This consistency is useful because of the possibility that reporting of deaths may be affected by recall lapse. It may be the case, for example, that a calendar-year reference period starting 18 months before the census is associated with a level of coverage different from a reference period covering the 12 months before the census (China NBS 1985, 1993, 2002; see also Banister 1992, pp. 8, 41–2; Zhai 1993, p. 10; Jiang et al. 1994).

The evaluation of mortality data for this paper is divided into a part for ages 15 and above and a part for ages below age 5. Between the ages of 5 and 15, mortality is low and adjustments estimated for age 15 and above are assumed to apply. Above age 15, the evaluation of completeness of death reporting in all-China life tables starts with age-specific mortality rates for 5-year age groups from nationwide life tables. The sources of life tables are as follows: life tables for 1973–75 are based on the Cancer Epidemiology Survey (Rong Shoude et al. 1981, pp. 25–6); life tables for calendar year 1981 are calculated using 1982 census data; life tables for calendar year 1989 and for mid-1989 to mid-1990 are calculated using 1990 census data; and life tables for 1999–2000 are calculated using 2000 census data (China NBS 1985, 1993, 2002). The evaluation of these life tables is carried out by comparison with the age distribution of the population as recorded by the 1964, 1982, 1990, and 2000 censuses. A variety of data sources and estimation methods for mortality under age 5 are explored.

Estimating the completeness of death reporting above age 15

A number of methods have been proposed for estimating the completeness of adult death reporting relative to population counts. The early methods assumed that the underlying population was demographically stable (Brass 1975; Preston and Hill 1980; Preston et al. 1980). Such an assumption is clearly inappropriate for the Chinese population, which was affected by a short but severe reduction in growth in the late 1950s and early 1960s, followed by a period of very rapid growth until the early 1970s, and then a sharp reduction in growth that has continued to the present time. More recent methods for estimating the completeness of death recording do not assume stability, but do assume that the underlying population is essentially closed to migration and that the coverage of both deaths and population does not vary with age after childhood (Bennett and Horiuchi 1981, 1984; Hill 1987). The population of China fits these assumptions well: it is so large relative to any potential source or destination of international migrants that it is reasonable to treat the population as closed; coverage of both deaths and population is likely to vary between childhood and adulthood, but such variation will have no effect on results for adults; sharp variations in coverage within adulthood (such as may affect young adults) will affect results but will also be clearly visible in diagnostic plots of the output from these methods. Chinese censuses have routinely undercounted young children relative to the rest of the population, but such undercounts have no effect on methods for estimating the coverage of adult deaths, since these methods use data for the population aged 15 and over only.

The methods proposed by Bennett and Horiuchi and Hill are the most appropriate for use with China's population because this population is neither stable nor even quasi-stable, and because these techniques are convenient for use with census intervals that are not multiples of five (the Chinese intercensal intervals are exactly 18 years between 1964 and 1982, exactly 8 years between 1982 and 1990, and approximately 10.33 years between 1990 and 2000). The applicability and accuracy of both these methods are affected by age misreporting (Hill 2003), but age reporting in China is of very high quality (Coale 1984). The Hill method estimates the completeness of reporting of deaths by age by comparing intercensal death rates with the change in the population age distribution between two censuses. The method assumes that the completeness of reporting of deaths is constant by age (after childhood, taken here to be age 15 and over) and that the completeness of the population count of each census is constant by age after childhood but not necessarily the same for each census. The Bennett–Horiuchi method makes the additional assumption that the completeness of the count for the two censuses is the same. If the change in completeness were accurately known, it would be easy to incorporate this information into the method, but typically census coverage is not known with any accuracy. Although our estimates show that census coverage above age 15 did not change much between the 1982, 1990, and 2000 censuses (with the result that mortality estimates from the Hill and Bennett–Horiuchi methods are similar for the period 1982–2000), the analysis for the 1964–82 period suggests a substantial improvement in census coverage, indicating that the Hill method will work better than the Bennett–Horiuchi method. As a result, in this paper we present results for the Hill method only.

Hill's method, which we will here call the General Growth Balance (GGB) method, is a generalization to non-stable populations of Brass's (1975) Growth Balance method for populations that are approximately stable. In any closed population, the growth rate of the population is equal to the difference between the birth rate and the death rate. In an open-ended age segment of the population age $x+$, the growth rate $r(x+)$ is equal to the difference between the entry rate into the population $x+$, that is, the number of people reaching age x, $B(x)$, divided by the population $x+$, $N(x+)$, and the exit rate from the population $x+$, that is, deaths $D(x+)$ at age x and over divided by the population $x+$. Thus

$$r(x+) = B(x)/N(x+) - D(x+)/N(x+). \qquad (1)$$

Equation (1) can be rearranged as

$$B(x)/N(x+) - r(x+) = D(x+)/N(x+). \qquad (2)$$

Given two censuses t years apart, $B(x)$, $N(x+)$, and $r(x+)$ for the interval t can be estimated from the census age distributions. Hill shows that, if the first and second censuses have coverage, constant at all adult ages, of k_1 and k_2, respectively, and that intercensal deaths are recorded with completeness c, also constant at all adult ages, the observed entry rate x+ minus the observed growth rate x+ will be linearly related to the observed death rate x+ with an intercept determined by k_1 and k_2 and a slope determined by the value of c relative to an average of k_1 and k_2. (See the notes to Table A2 for the derivation and the approximations used to estimate $B(x)$, $N(x+)$, and $r(x+)$.) Since the method is applied for ages 15 and over only, there is no need to estimate intercensal births. Person-years lived for each age group during an intercensal interval are estimated from an average of the initial and final population of the age group. Age-specific growth rates are assumed to be constant within an intercensal period.

The GGB method uses direct mortality information in the form of intercensal deaths by age. Since we do not have intercensal deaths by age for China, we use mortality information from different sources. For the intercensal interval 1964–82, we use the age-specific death rates obtained by the Cancer Epidemiology Survey, and apply them to estimated person-years lived by age during the intercensal period to estimate intercensal deaths. (For other estimates of 1964–82 life tables, see also Coale 1984; Brass and Li 1988; Zhai 1988.) For the intercensal intervals 1982–90 and 1990–2000, we have information from the censuses on household deaths for varying time periods before the censuses—calendar year 1981 in the case of the 1982 census, the 18 months before the 1990 census, and the 12 months before the 2000 census. We used this information on deaths by age and sex to calculate age-specific mortality rates, back-dating the census population using age–sex-specific growth rates for the appropriate intercensal period. In order to maintain consistency, we calculated and averaged age-specific mortality rates for the calendar years before each census (1981 and 1989) for the 1982–90 period, and for the 1990–2000 period, we calculated and averaged age-specific mortality rates for the 12 months before each census. We then estimated age-specific deaths by applying the average mortality rates to the estimated exposure time for each age group for the intercensal period. Death rates above ages x were then calculated from cumulated intercensal deaths and exposure time. Although population data are available for age groups up to age 100 and over, the information on deaths is not always available for age groups above age 90. Again for consistency, we used an open-ended age group of 90+ as the highest age group throughout.

The results of the GGB method are most easily presented graphically. This presentation allows an easy visualization of overall patterns and of goodness of fit. Figure 1(a) and (b) shows results for the 1964–82 period, for males and females, respectively. Figure 2(a) and (b) shows results for the 1982–90 period, and Figure 3(a) and (b) shows results for the period 1990–2000. In each case, the vertical scale represents the difference between the entry rate x+ and the growth rate x+, while the horizontal scale represents the observed death rate x+. A straight line has been fitted to the points for ages 15+ to 60+ using orthogonal regression as suggested by Bhat (1990). The parameters of the fitted lines are shown in Table 1. The data for each case and illustrative calculations for one case (males 1990–2000) are shown in the Appendix.

As can be seen from the figures, the fits of the observations to a straight line are remarkably good, and improve with time, indicating that the quality of the data is extremely high and that the assumptions of the method are well met. The results for the period 1964–82 are the most erratic, particularly for age segments 5+ to 30+ (the points closest to the origin), and the points for the two oldest age segments, 80+ and 85+ (the points farthest from the origin), are also somewhat above the fitted line for males. Results for the period 1982–90 show irregularities for both males and females for age segments 25+ and 30+, and the highest points (85+) for both males and females are also somewhat above the fitted line. For the period 1990–2000, the fits are almost perfect, the only exception being that the highest point (85+) for males is very slightly above the fitted line. The irregularities for age groups under age 30 for the periods 1964–82 and 1982–90 probably result from a failure of the approximations used to estimate entries at age x to work adequately for the sharply different cohort sizes originating from the period 1955–65. Fertility dropped steeply in the period 1958–61 during the famine at the time of the Great Leap Forward, and rebounded sharply afterwards, producing unusually small birth cohorts followed by unusually large ones.

The consistency of the parameters of the fitted lines in Table 1 also suggests that the method has worked well. It is reassuring to note that, for all three periods, the intercepts are very similar for males and females; since the intercept is an indication of change in census coverage, we would expect rather similar values for males and females. For both the 1982–90 and the 1990–2000 periods, the intercepts are very close to zero, indicating highly consistent coverage. The census counts of 1982 and 1990 were almost equally complete. The census count in 1990 was about 98.5 per cent as complete as the count in 2000. If the 2000 census had a 1.81 per cent undercount (China NBS 2001), as reported from the post-enumeration survey (PES), then the 1990 census undercount was about 3.3

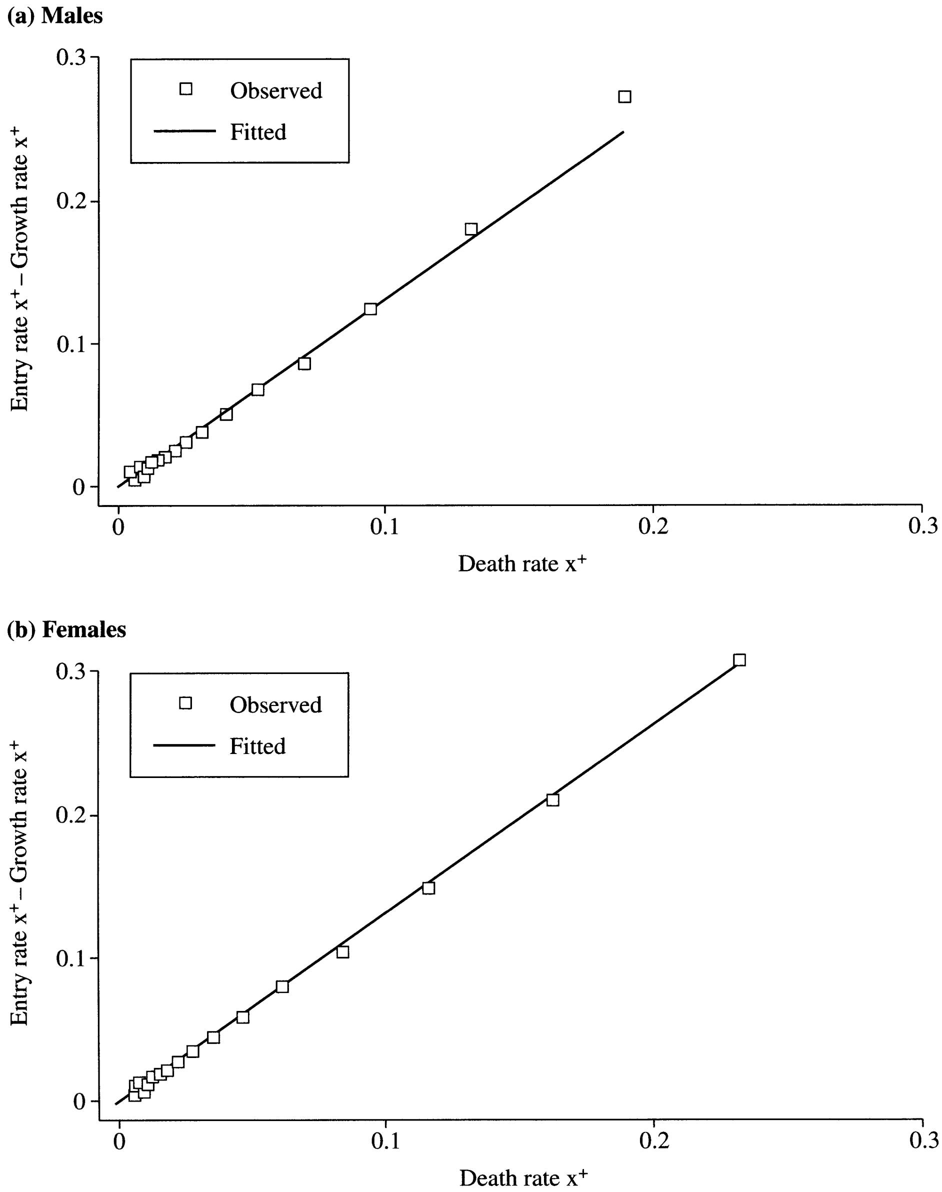

Figure 1 Plots of entry rate minus growth rate against death rate, China, 1964–82
Source: Application of GGB method to data from the 1964 and 1982 censuses of China, and from the 1973–75 Cancer Epidemiology Survey

per cent of the actual population and the 1982 census undercount was about 3.7 per cent. The intercepts for the 1964–82 period show a 2–3 per cent improvement in coverage from the 1964 census to the 1982 census. Given the 2000 census PES estimate of coverage, the analysis implies a 1964 census undercount of 5.8 per cent for females and 6.3 per cent for males.

The above results do not correspond with the results of the 1982 and 1990 census PESs or with some assumptions about the relative completeness of China's census counts. Because China's population is becoming more mobile, observers tend to assume that the 2000 census was a less complete count than the previous two censuses. But long experience of analysing data from China's censuses from 1953 to 2000 shows that there is not necessarily a strong connection between the generally assumed completeness of the counts and their actual absolute or relative completeness. In the PRC case, demographic analysis gives much more accurate information on census coverage than do prior qualitative assessments or PES estimates. The PESs from the 1982 and 1990 censuses estimated net undercounts of only 0.015 and 0.060 per cent, respectively (Yang 1984, p. 137; China NBS 1993, Vol. 4, p. 530; Yang 1994, p. 93). The idea that China's census counts were that perfect was always suspect, and the evidence of our results shows that those PES results should be discounted. For the 2000 census, it is possible that the actual completeness of the count was higher or lower than the 1.81 per cent officially

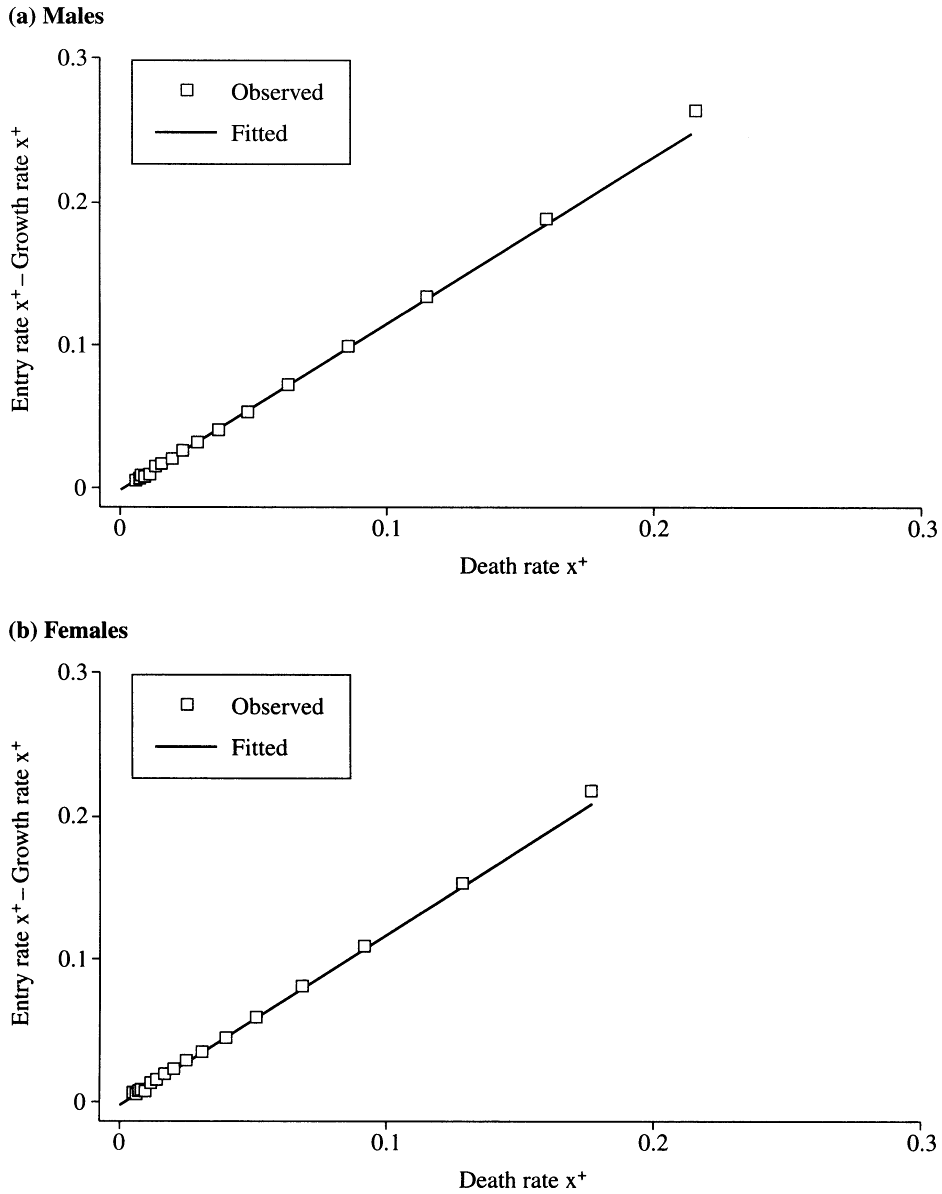

Figure 2 Plots of entry rate minus growth rate against death rate, China, 1982–90
Source: Application of GGB method to data from the 1982 and 1990 censuses of China

estimated; our estimates address only the relative completeness of successive censuses. We have confidence in the magnitude of our estimates of relative census coverage, but our estimates of absolute coverage may be in error to the extent that the estimate of completeness of the 2000 census is in error.

For the recording of deaths, the largest adjustment factors—over 1.3 for both males and females—are for the deaths recorded by the Cancer Epidemiology Survey. This finding may not mean, however, that the survey captured only 76 per cent of deaths in the period 1973–75, or that Banister and Preston's (1981) estimate of completeness in the range 80–90 per cent was incorrect. The GGB estimate is of mortality level from the survey relative to the average during the period 1964–82. Since we do not know the timing of mortality change during the period, we cannot draw conclusions about the completeness of death recording during a particular 3-year period. For the deaths reported by the censuses of 1982, 1990, and 2000, deaths of males have been slightly more completely reported than those of females. For the period 1982–90, reporting of deaths (averaged across the 1982 and 1990 censuses) of males was 87 per cent complete and of females 85 per cent complete (relative to average census coverage). For the period 1990–2000, averaged across the 1990 and 2000 censuses, death reporting of males improved to become 90 per cent complete, while for females it remained essentially constant at 85 per cent.

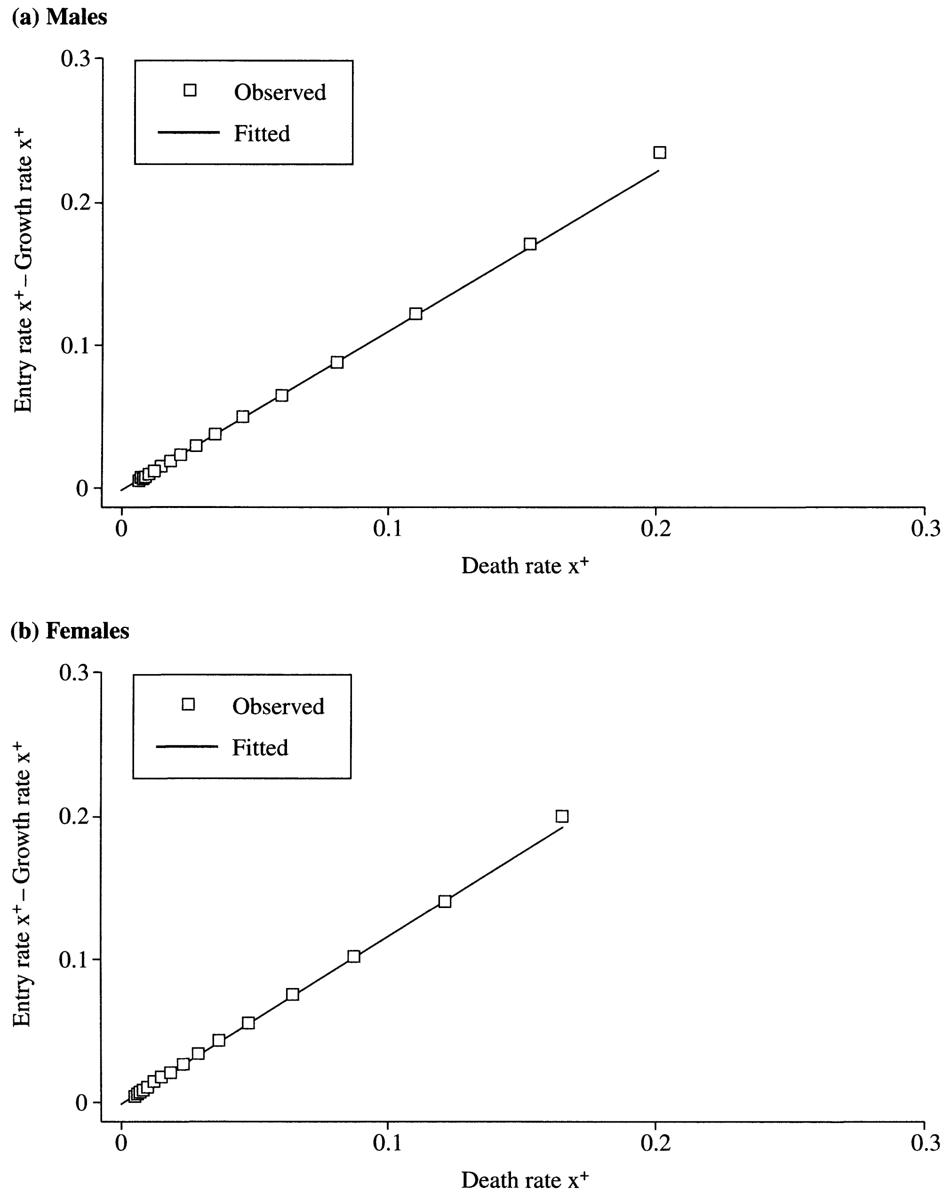

Figure 3 Plots of entry rate minus growth rate against death rate, China, 1990–2000
Source: Application of GGB method to data from the 1990 and 2000 censuses of China

Using the adjustment factors in Table 1, we have adjusted the average intercensal age-specific mortality rates and calculated the adjusted life tables that are presented in the Appendix. Although the adjustment factors are based on experience above age 15, we have applied the same adjustments to death rates between the ages of 5 and 15 also. We have extracted two summary measures of post-childhood mortality from the life tables—expectation of life at age 10, and the probability of dying between the ages of 15 and 60, ${}_{45}q_{15}$. These summary indicators are shown in Table 1.

Between the mostly pre-reform period 1964–82 and the first decade of economic reforms, 1982–90, mortality continued to decline in China, with life expectancy at age 10 of males increasing by 2.6 years and of females by 3.6 years, and the probability of dying between the ages of 15 and 60 falling by 22 per cent for men and 28 per cent for women. During the reform period, from 1982–90 to 1990–2000, mortality continued to decline but more slowly. Life expectancy for males at age 10 improved by 1.5 years and for females by 1.9 years. The probability of dying between 15 and 60 fell by 12 per cent for men and 20 per cent for women. The results show an increasing advantage to females in post-childhood mortality as measured by life expectancy at age 10, rising from a 2.3-year advantage during 1964–82 to 3.2 years during 1982–90 and to 3.6 years during 1990–2000.

Table 1 Estimates of census and death coverage and summary mortality indicators by intercensal period, using the General Growth Balance (GBB) method, China, 1964–2000

Sex	Parameter	1964–82	1982–90	1990–2000
Males	Slope (adjustment factor for deaths)	1.312	1.145	1.113
	Intercept	–0.0015	–0.0005	–0.0013
	Census 1 coverage: Census 2 coverage	0.973	0.996	0.987
	Expectation of life at age 10, e_{10}	56.8	59.4	60.9
	Probability of dying between ages 15 and 60	0.254	0.199	0.176
Females	Slope (adjustment factor for deaths)	1.324	1.183	1.181
	Intercept	–0.0012	–0.0005	–0.0015
	Census 1 coverage: Census 2 coverage	0.978	0.996	0.984
	Expectation of life at age 10, e_{10}	59.0	62.6	64.5
	Probability of dying between ages 15 and 60	0.218	0.157	0.126

Source: Application of the GGB method to data from the 1964, 1982, 1990, and 2000 censuses of China and from the 1973–75 Cancer Epidemiology Survey, with summary mortality measures from the adjusted life tables in Tables A3–A5.

Mortality under age 5

The results of the GGB technique used above to adjust adult deaths cannot be applied automatically to deaths for the youngest ages because the assumption of invariant coverage by age may not hold for the deaths or the population of young children. It has long been understood that infant mortality is always, or almost always, significantly underreported in China (Banister 1987, pp. 98–110; Zhou et al. 1989; Zhai 1993, p. 11; Tu and Liang 1994; Poston 1996). Mortality from age 1 to age 4 is also usually underreported. We therefore explore alternative sources of information about infant and child mortality.

The 1982, 1990, and 2000 censuses all included questions for women about children ever born and children surviving. Indirect estimates of the under-5 mortality rate (U5MR) are also available from data on children ever born and children surviving from the 1982 1 per cent fertility survey, the 1987 1 per cent population survey, and the 1995 intercensal survey. Indirect estimates of probabilities of dying by age 5 (U5MR) have been obtained from the proportions dead of children ever born using standard methods and the Coale–Demeny (1966) 'West' family of model life tables (UN 1983). Direct estimates, based on reported child deaths before the enumeration, are available from the censuses and from fertility surveys conducted in 1988 and 1992.

A new source of information became available from 1991 to the present. In order to get more complete reporting of U5MRs, China's MOH in concert with the United Nations Children's Fund (UNICEF) designed a nationally representative survey—the Child Mortality Surveillance System (CMSS)—to investigate intensively and record infant mortality rate (IMR) and U5MR for China. Results of the survey have not been reported by sex of the children, perhaps because the IMRs of females and their U5MRs are abnormally high compared with the rates of males. Based on this survey, China's U5MR was reported to have dropped rapidly from 61.0 deaths per 1,000 births in 1991 to 44.5 in 1995, with a further slow decline to 39.7 in 2000.

Figure 4 shows these various estimates of U5MR plotted against reference date. We have also added to this figure the estimates obtained by assuming that the adjustment factors estimated by the GGB method for post-childhood deaths are applicable to deaths in all childhood age groups.

The figure shows clearly the problems inherent in arriving at firm estimates of U5MR for China. The reported or indirectly estimated U5MRs from recent censuses and household surveys appear unrealistically low and are mutually inconsistent. For example, indirect estimates from the 1990 census, the 1995 intercensal survey, and the 2000 census are implausible, producing U5MRs below 20 for two time points from the 2000 census. The consistency between data-sets of these estimates cannot be meaningfully improved by using model life table systems different from the Coale–Demeny 'West' model used here to obtain the indirect estimates. The poor-quality data sources for the mortality of young children include direct reports of infant and under-5 mortality from China's 1990 census, 1995 1 per cent survey, 2000 census, and the Disease Surveillance System, as well as data from these same sources on children ever born and children surviving.

More satisfactory data sources for U5MR and

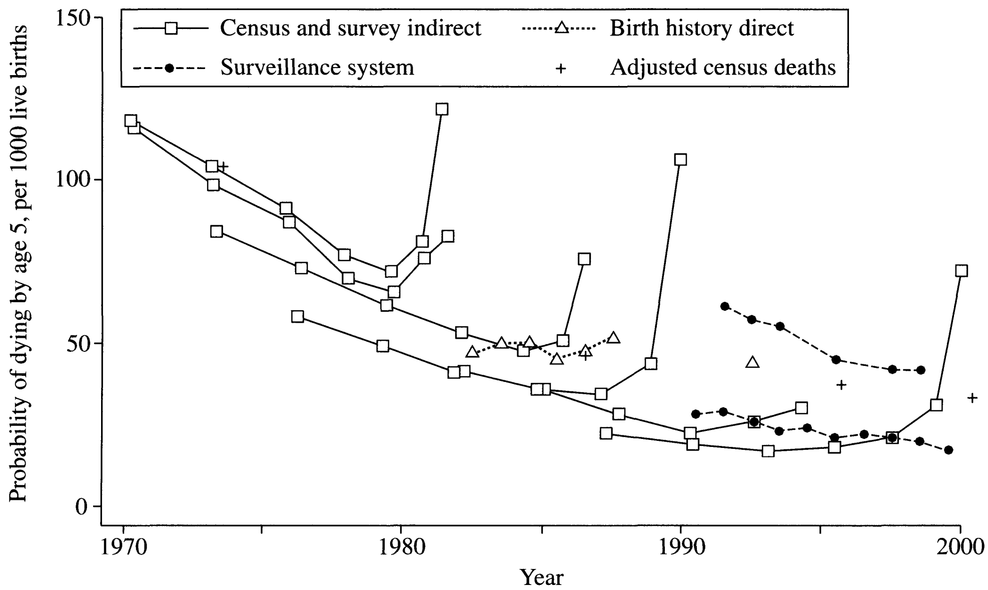

Figure 4 Estimates of under-5 mortality in China, 1970–2000
Sources: Indirect estimates of U5MR using data from the 1982, 1990, and 2000 censuses of China, the 1982 Female Fertility in China survey, and the 1987 China 1 per cent Population Sample Survey, and direct estimates from the 1988 National Survey on Fertility and Birth Control, 1992 Fertility Sampling Survey, the Child Mortality Surveillance System, the Disease Surveillance system, and adjusted household deaths from the 1982, 1990, and 2000 censuses

IMR are as follows. The indirect estimates from the 1982 census and 1982 fertility survey are reasonably consistent with one another, and show U5MR declining from about 120 per 1,000 live births in 1970 to about 70 in 1980. Indirect estimates from the 1987 intercensal survey are somewhat lower (for comparable time periods) and show a slower decline. The direct estimates from the 1988 and 1992 fertility surveys suggest U5MRs of about 50 for the mid-1980s and late 1980s and around 45 for the early 1990s. The U5MR estimates from the CMSS are much higher than other available estimates—close to 60—for 1991, 1992, and 1993, but then drop sharply to the low 40s for the rest of the 1990s.

The U5MR estimates for the period 1964–82 obtained by adjusting age-specific mortality rates from the Cancer Epidemiology Survey, using results of the GGB technique, correspond almost exactly with the series of indirect estimates from the 1982 census. The GGB estimates for the mid-1980s also correspond almost exactly with the directly reported U5MR from the 1988 fertility survey. The GGB estimates for the mid-1990s are also consistent with the directly reported U5MR from the 1992 survey, but slightly lower than CMSS estimates for the mid-1990s to 2000. Since the GGB-adjusted census deaths give child mortality estimates close to what appear to be the best available estimates from other sources, the child mortality component of the adjusted life tables we present is obtained in exactly the same way as the post-childhood estimate—by adjusting infant deaths and deaths for ages 1–4 for coverage, using the same factors as estimated for adults using the GGB.

This procedure results in good agreement for the period before 1990 between our life table estimates and the estimates in Figure 4 that we regard as satisfactory. For the period 1990–2000, our adjusted U5MR for both sexes combined is 37.7 deaths per 1,000 live births (assuming an average sex ratio at birth of 113 males per 100 females for the decade). Averaging the years of reported data for 1995 and 1997–2000 from the CMSS yields a U5MR of 42.0. Our estimates for U5MR for 1990–2000 are thus lower than CMSS estimates, but we believe the very high estimates from the CMSS for the early 1990s suggest the possibility that the system is actually overestimating U5MR at the national level. We therefore base our recent estimates of U5MR on adjusted census deaths, while securing the additional advantage of maintaining a consistent adjustment procedure for all periods from 1964–82 to 1999–2000, thus facilitating analysis of the resulting long-term trends in under-5 mortality in China.

Mortality trends in China, 1964–82 to 1999–2000

In this discussion, we use life tables adjusted for incomplete death reporting for the periods 1964–82, 1982–90, 1990–2000, and from the 2000 census for the period 1999-2000 (see Tables A3–A6). We adjust

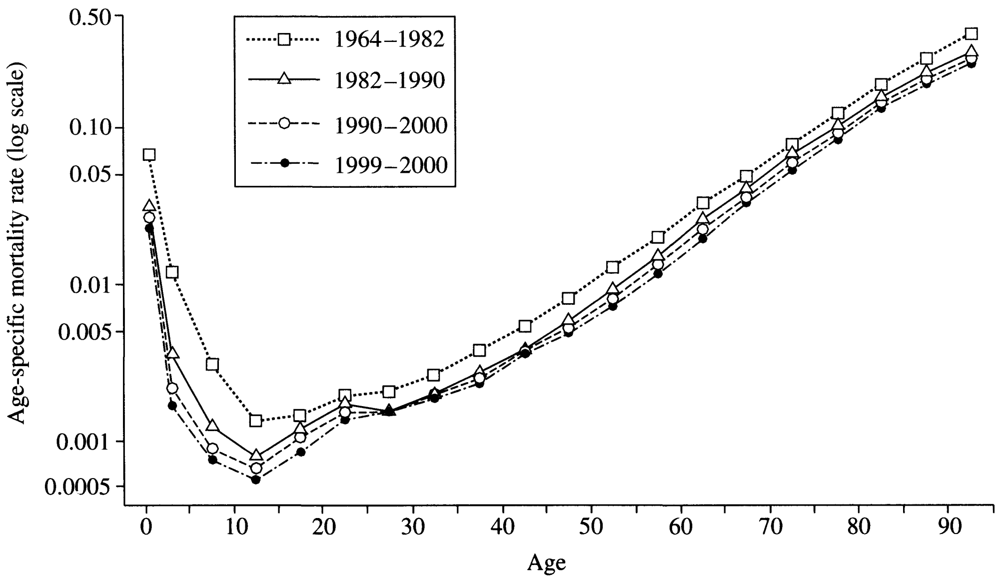

Figure 5 Age-specific mortality rates, males, China, 1964–82, 1982–90, 1990–2000, and 1999–2000
Source: Adjusted life tables in Tables A3–A6

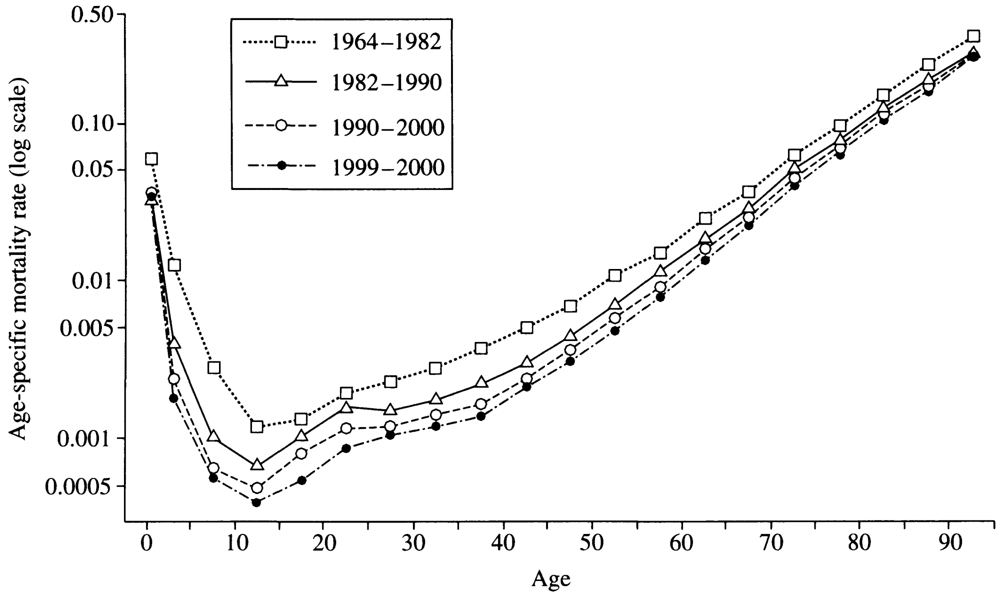

Figure 6 Age-specific mortality rates, females, China, 1964–82, 1982–90, 1990–2000, and 1999–2000
Source: Adjusted life tables in Tables A3–A6

the 2000 census life tables assuming the same completeness of death reporting for 1999–2000 by sex as we derived for the 1990–2000 period, on the ground that the adjustment factors for the time periods 1982–90 and 1990–2000 are very similar, for both males and females, suggesting that the individual censuses performed very similarly. These life tables show that expectation of life at birth for China's population has risen from 60 years for the period 1964–82 to 71 years for the period 1999–2000. Males have gained 10.8 years in life expectancy, rising from 59.0 to 69.7 years. Females have gained 11.4 years, increasing from 61.4 to 72.8 years. The increase in life expectancy averaged 0.40 of a year per year for males and 0.42 of a year per year for females.

Figures 5 and 6 show adjusted mortality rates by age group for the periods 1964–82, 1982–90, 1990–2000, and 1999–2000 for males and females, respectively. It is clear that mortality continued to decline for both sexes during the most recent quarter of a century of rapid economic, social, and demographic transformation in the PRC. Average annual rates of change from the first to the second periods, and from the second to the third, are shown in Figure 7 for both males and females.

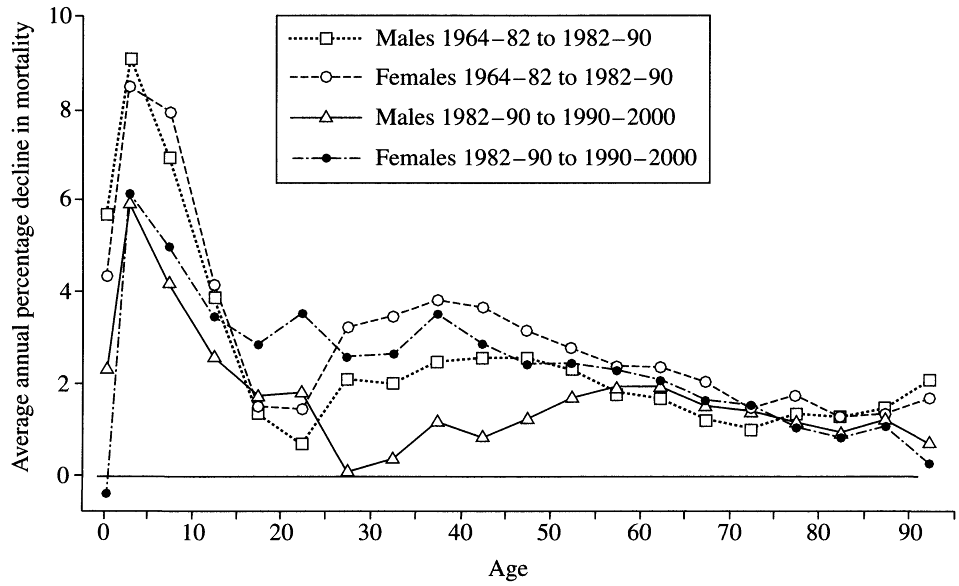

Figure 7 Average annual rates of change in mortality by age and sex, China, 1964–82 to 1982–90, and 1982–90 to 1990–2000
Source: Adjusted life tables in Tables A3–A5

Trends in child mortality

The most spectacular gains in survival have been in childhood. The most rapid declines in mortality rates occurred between the ages of 1 and 10, with annual rates of decline for both males and females and for both time periods ranging from 4 to 9 per cent. Declines were clearly faster between the two earlier periods (1964–82 to 1982–90) than between the two later periods (1982–90 to 1990–2000); Figure 4 suggests that declines in U5MR were particularly rapid in the period before 1980. Declines in infant mortality were somewhat slower than declines between ages 1 and 10, and were slower for females than males; indeed, the mortality of females under age 1 apparently increased slightly from 1982–90 to 1990–2000. Both the pre-reform period and the reform period appear to have been good for the survival of children, with the exception of infant girls. Why?

For the pre-reform period, there is little reason to doubt that public health campaigns in combination with wide access to some level of health service at minimal cost played an important role in the rapid reductions in mortality observed in China. In the reform period, however, socialized health services were replaced by free market services, and the benefits of public health campaigns had already largely been realized. Yet infant and child mortality continued to fall (except for the infant mortality of females). One important reason for the continuing declines in child mortality has been that China's economy has been booming for the last quarter of a century. From 1978 to 2001, China's real gross domestic product (GDP) per head has risen a remarkable 7.8 per cent per year on average (documented in Banister and Zhang 2003, p. 5 and Figure 1). Large increases in household consumption per head were experienced by rural as well as urban, and by interior as well as coastal populations. More income has meant better housing and clothing. The abandonment of collective agriculture brought a huge expansion in the quantity, quality, and variety of food on the tables of rural farm households and urban families. China's total agricultural output increased by 118 per cent at constant prices from 1978 to 1986 (USDA 1988, p. 4). The food supply has continued to improve since then. As a result, hunger, malnutrition, and nutrient deficiencies have greatly diminished (Popkin et al. 1993; Xinhua 1996), though much more improvement is needed. As recently as 1992, 20–50 per cent of children below 6 years of age were stunted and 10–35 per cent were underweight for their age in most provinces (Ge et al. 1996).

Poverty has declined dramatically. Using a very low poverty line (below any international standard), the PRC government reported that the proportion of China's rural population in 'absolute poverty' declined steeply, from 33 per cent in 1978 to 12 per cent in 1985, largely because of the agricultural transformation. The proportion in absolute poverty declined more gradually after 1985, falling to 6 per cent of the rural population in 1997 (Fan et al. 2002, pp. 11–2; Banister and Zhang 2003, p. 20). Using the standard of daily income per head below an internationally comparable purchasing power parity of US$1, the World Bank estimated that, in 1993, China still had 350 million people in poverty, constituting 30 per cent of the total population—down from half the population when reforms began in 1978 (World Bank 1996; 1997, p. 36).

A second reason for declining mortality is that China's government has aggressively and successfully promoted child vaccinations for the major diseases of childhood as well as improved sanitation and water supplies in rural and urban areas. For instance, the government reported that, by 1991, water treatment projects had improved the quality and safety of the water supply for 666 million of China's 880 million rural population (Wang 1991, p. 1). By 1999, safe water supply had been provided to 92 per cent of the rural population, and over 90 per cent of children in China had been vaccinated against tuberculosis, polio, measles, diphtheria, pertussis, and tetanus (China National Working Committee on Children and Women 2001, p. 14). Third, basic primary and secondary education has expanded and illiteracy has declined to low levels—a factor especially beneficial for child survival. Fourth, increased numbers of medical personnel and health facilities, and a greater variety of pharmaceuticals have also reduced the mortality of children (Banister and Zhang 2003).

Infant mortality has declined much more for boys than for girls since the 1964–82 period. At least since the 1980s, the IMR for females has been higher than for males (Jiang et al. 1994, pp. 730–1; Li and Sun 2003, p. 31). This unnatural situation is a result of the Chinese culture of son preference combined with low fertility and the one-child policy (Banister 2003). Excess infant mortality for girls can ensue when parents are determined to have a son but instead bear a daughter. If the total number of children for the couple is tightly constrained by government policy or their own preference, they may have limited tolerance for unwanted daughters.

Trends in adult mortality in China

In the adult groups of working age, between ages 15 and 65, both men and women at all ages have benefited from declining mortality rates in each recent time period (see Figures 5 and 6). As is normal, death rates among males are at all times higher than those among females in each age group. The striking difference between men and women, however, is the strength of the trend in the last quarter of a century. Survival gains for adult males have been real but modest or even small in the young adult age groups. Mortality rates for men in their late 20s and early 30s have almost stabilized since the 1980s. But for women, improvements in adult survival have been strong and continuous at all adult ages: an average annual decline of over 2 per cent per annum since the mid-1970s. From age 50 to 64, rates of mortality decline have been very similar by age, sex, and period, declining by about 2 per cent per annum. An obvious reason for the stronger mortality decline of females in the reproductive ages of 15–49 is the great reductions in rates of pregnancy and childbearing associated with China's family planning programme and with economic and social development. In particular, the spontaneous and mandated rise in age at marriage and the steep decline in fertility at third and higher parities have concentrated childbearing in the safest ages for mother and baby. Their health has also benefited from the extension of spacing between births. The near-universal adoption of relatively safe and effective modern methods of birth control has reduced the number of pregnancies each woman has, as well as the number of births. On the other hand, rules imposed under China's family planning programme may also have negative effects on the health and survival of women and babies, particularly when the desired or actual birth is not approved by authorities. The results may include lack of prenatal care, births in less safe surroundings, or compulsory abortions in the second or third trimester of pregnancy (Hardee-Cleaveland and Banister 1988, pp. 256–9; Greenhalgh 1994, p. 23). Nevertheless, the net effect of China's fertility transition on women of childbearing ages has been to reduce maternal mortality, which is now at a comparatively low level for a less developed country (China MOH 2000; China National Working Committee on Children and Women 2001, pp. 28–9).

Adult mortality should have been reduced to a similar extent for both men and women by the booming economy, rising income and consumption, greater literacy, a healthier living environment, and more medical personnel and medications. So why, in addition to the fall in their mortality associated with reduced fertility, have women made greater survival gains than men at adult ages 15–64? The answer is probably that men are experiencing excess mortality owing to occupational and lifestyle factors. Death rates from cancer (especially lung cancer) and from injuries (especially transport accidents) are much higher for men than women, as also are death rates from cardiovascular disease and chronic respiratory disease (Chinese Academy of Preventive Medicine annual). Dangerous jobs are taken more by men than by women—mining and heavy construction are clear examples. Men also work with vehicles more than women, drive more, and consume alcohol much more heavily. They also smoke more. In a country where cigarette production has nearly doubled since 1982 and which produces nearly one-third of the world's cigarettes, 63 per cent of men smoke cigarettes while only 4 per cent of women do so (Chinese Academy of Preventive Medicine 1997, p. 7; O'Neill 2002, p. 3). In order to reduce the excess adult mortality of men in China, action will be required to reduce the numbers of them who smoke tobacco and the numbers of cigarettes they consume, to improve occupational safety and control occupational diseases, to introduce modern transport safety features, and to persuade men to adopt healthier lifestyles.

Trends in mortality among the elderly

Declines in age-specific mortality above age 65 have been remarkably similar across sex and time period. Declines have even been very similar across age groups, although the rate of decline does seem to trend downwards slowly as age increases (Figures 5 and 6). Since the 1964–82 period, mortality rates for people in their 80s seem to have been falling by about 1.5 per cent per year, far faster than declines observed in the now low-mortality countries at comparable levels of overall mortality. Zeng and Vaupel (2003), examining unadjusted death rates from the 1990 census, note that reported Chinese death rates above age 97 were similar to those of Sweden and Japan, and suggest that this very low mortality in the very old may be due mainly to mortality selection in the heterogeneous Chinese population. If adequate adjustments were made for underreporting of deaths, however, death rates among the oldest old might be higher in China than in developed countries.

How can we explain these impressive mortality declines among the elderly in China? The rising living standards, increasing consumption, and poverty decline of the reform decades mean that today's elderly dependents are surely better provided for than were their predecessors of the pre-reform period. Prosperity has risen, and the proportion of the population at ages 65+ is still only 7.1 per cent (China NBS 2002, Vol. 1, pp. 570–2). Very high proportions of China's elderly live with their children, and today their children are in general economically better off than were the caregivers of a quarter of a century ago (Zeng and George 2002). In addition, studies in other countries have shown that the elderly who are literate and educated have lower mortality rates than those of lower educational level. Today, 48 per cent of China's elderly at ages 65+ are still illiterate, but this proportion is much lower than it was in the 1970s (China NBS 2002, Vol. 1, p. 634). Finally, even though today most of China's elderly lack health insurance, their increased economic well-being has enhanced their ability to pay for medical care and medications, and the quantity and quality of medical personnel, clinic and hospital facilities, and medications have greatly improved in the reform era.

China's health care system and mortality

By 1975, coverage of medical insurance provided by the rural cooperative medical system, government, and state enterprises had reached close to 90 per cent of the population—almost all the urban population and 85 per cent of the rural (World Bank 1997, p. 1). In these systems, medical costs were highly subsidized. But the rural collective health insurance system collapsed in the early 1980s at the time that collective agriculture was abandoned. The rural cooperative health system and basic rural health insurance were abandoned at the same time. Since then, throughout the 1980s and 1990s and up to the present, China's national government has stepped back further from providing free or subsidized health benefits to China's people. The national government has decentralized public health responsibilities down to provincial level, and many provinces have in turn decentralized responsibility for health matters further down to the counties and municipalities. These local levels may choose not to subsidize health costs or may believe that they cannot afford to do so. By 1998, according to the Health Services Survey conducted by China's MOH, 87 per cent of the rural population and 44 per cent of the urban population had no health benefits and had to pay all medical costs themselves (China MOH 1999, p. 18).

In practice, for most ailments, most of China's people can get access to a basic level of care at clinics or at the outpatient departments of hospitals because the cost is low and they have enough resources to pay for the care out of current income, savings, or by borrowing (Hsiao 1987; Henderson et al. 1992, p. 13). But for catastrophic or chronic medical needs for which treatment is costly, poorer people often cannot afford medications or hospital fees. High user fees are charged even for emergency services in publicly run hospitals and clinics (World Bank 1997, p. 47). In consequence, when an individual gets very sick, his or her family may not be able to pay for needed medications or hospital care and the patient may have to go without the required treatment. A 1992–93 survey found that, of those who had been referred to a hospital for care, 41 per cent did not seek hospitalization, citing as reasons the excessive cost and their inability to pay (Zhao and Wang 1995; World Bank 1997, p. 25). Thus, the shift towards a fee-for-service system may mean that ill health is left untreated or that sometimes death is allowed to occur at an earlier age than would be the case if treatment could be obtained. It is difficult to quantify the effects on mortality of the lack of health insurance in China and of the disarray and cutbacks in the health system, but we assume that survival gains would have been even greater if the public health and medical system had been functioning adequately. For instance, in a sample made up of 23 provinces, a fall in the proportion of provincial budgets devoted to health and education tended to cause life expectancy to decline by half a year from 1981 to 1995, though this effect was offset by factors that tended to raise expectation of life by much more (Banister and Zhang 2003). The slowdown in the decline of infant and child mortality evident for the 1990s may be the result of changes in the health system over the last 15 years.

During the Maoist decades and the reform period as well, China's public health and medical systems have been geared toward combating infectious and endemic diseases that have been historically widespread. Owing to the great success of the interventions, only a small proportion of deaths are now caused by these diseases. However, China's medical personnel and facilities are still poor at accurately diagnosing and successfully treating non-communicable diseases, which have been the main causes of death and of the disease burden since before the 1970s. Future reductions in mortality and morbidity may require an emphasis on preventing, controlling, and curing chronic diseases, injuries, and certain communicable diseases that still pose problems, primarily tuberculosis, malaria, HIV/AIDS, and, most recently, severe acute respiratory syndrome or SARS (Jamison et al. 1984; World Bank 1990). It is surprising that mortality declines among the elderly appear to have been steady and (by historical standards) rapid, even though it is at these advanced ages that the burden of chronic disease would be expected to be highest. Further analysis of mortality declines by cause of death is needed for a more thorough understanding of the momentous changes in Chinese mortality that have occurred during the most recent three decades.

Conclusions

We have adjusted incomplete mortality data from the PRC for the period 1964–2000 in order to establish the true levels and changes in mortality for the world's most populous country, the people of which comprise over one-fifth of the world's population. Hill's GGB method is the best technique to use for this purpose, because China's population is neither stable nor quasi-stable, age reporting is excellent, data of adequate quality are available from four successive censuses, the censuses are separated by odd numbers of years, and completeness of the census counts has varied over time.

Our analysis indicates that the quality of data from the Chinese censuses of 1964, 1982, 1990, and 2000 is generally good, though census coverage is estimated to have improved gradually from each census to the next. If correct, the official estimate of a net undercount of 1.81 per cent for the 2000 census would indicate that the net undercount has declined from 6 per cent of the total population in 1964 to 4 per cent in 1982, 3 per cent in 1990, and to 2 per cent in 2000. This information is new and counter-intuitive; it had been assumed that census coverage had been getting worse, not better. Questions in the 1982, 1990, and 2000 censuses about recent deaths in the household produced data of reasonable quality, though requiring some upward adjustment of observed rates.

Our analysis has produced further new results. Reported data from the huge 3-year Cancer Epidemiology Survey of 1973–75 had indicated that Maoist China had achieved a life expectancy of 65 years (males 64 and females 66 years). Based on this and other data-sets, observers had concluded that the PRC had reached relatively advanced mortality conditions during the pre-reform Maoist decades, using its unique, cheap, simple, and egalitarian public health model. Scholars who tried to adjust the mortality data of the 1970s for underreporting were hampered by the piecemeal release of partial data and by inadequate demographic methods. Now, with enough reported data and the Hill GGB method, we have been able to show that average life expectancy in the 1964–82 intercensal period was 60 years (males 59 and females 61 years), which is still impressive for a poor less developed country though not as impressive as previously supposed.

Infant mortality in China dropped rapidly in the 1970s, before the economic reform period, for both boys and girls. Since the mid-1980s, the IMR for boys has declined slowly but for girls has risen. Child mortality dropped spectacularly for both sexes from before the economic reform to the 1980s, and has continued declining for both boys and girls at ages 1–4, 5–9, and 10–14. Slowdowns in mortality reduction among children and especially infants may be due to greatly reduced coverage of medical care subsidies and insurance. But, despite the weakened health system, child mortality declines have continued because of the much improved quantity and quality of available food, declining poverty, rising incomes and household consumption, reduced illiteracy and expanded education, child vaccination programmes, improved water supplies, and more medications.

In adulthood, mortality decline has continued for both sexes in all age groups. But gains for men have been much more modest than for women in recent decades. Women have benefited from a steep decline in fertility, concentration of childbearing at the healthiest ages, longer spacing between births, and the use of modern methods of birth control. Declines in mortality for men, meanwhile, have been slowed by occupational and lifestyle factors. A large proportion of Chinese men but few women smoke tobacco. Men drink alcohol more heavily than women, and men are involved in far more traffic accidents and work-related diseases and deaths than women.

Another new finding from this research is that mortality rates of the aged declined continually from 1964–82 to 1999–2000. Unadjusted mortality data for China had suggested that mortality decline was negligible or small for most elderly age–sex groups between the 1970s and the 1990s. However, after proper adjustments for changing completeness of death reporting, an intriguing result has emerged. It is now clear that elderly men and women in China have gained steadily in survival chances from 1964–82 to 1999–2000 in all the age groups from 60–64 to 90 and above.

Mortality has fallen rapidly in China over the past four decades, with life expectancy increasing from an average of about 60 years between 1964 and 1982 to 71 years in 1999–2000. The fall in mortality has occurred at all ages, except that the mortality risks of girls in infancy increased from 1982–90 to 1990–2000. These mortality declines have taken place against a backdrop of rapid economic growth, a strict fertility control policy, and a major shift in the health system away from state subsidy to fee for service. The potentially negative effects of the changes in the health system appear to have been more than counteracted by overall increases in the standard of living and educational levels of the Chinese population.

Appendix

Table A1 Unadjusted mortality data for China, 1973–75 to 1999–2000 (age-specific central death rates m_x)

	1973–75[1]		1982–89		1990–2000		1999–2000	
Age groups	Male	Female	Male	Female	Male	Female	Male	Female
Under 1	0.05096	0.04435	0.02800	0.02827	0.02332	0.02935	0.02036	0.02837
1–4	0.00906	0.00928	0.00318	0.00344	0.00191	0.00199	0.00151	0.00152
5–9	0.00231	0.00211	0.00108	0.00084	0.00076	0.00054	0.00067	0.00046
10–14	0.00101	0.00085	0.00070	0.00056	0.00057	0.00041	0.00050	0.00033
15–19	0.00110	0.00096	0.00105	0.00088	0.00092	0.00068	0.00076	0.00047
20–24	0.00148	0.00146	0.00155	0.00136	0.00135	0.00099	0.00121	0.00072
25–29	0.00157	0.00171	0.00137	0.00125	0.00140	0.00100	0.00141	0.00087
30–34	0.00200	0.00209	0.00177	0.00149	0.00175	0.00118	0.00167	0.00099
35–39	0.00286	0.00280	0.00237	0.00191	0.00219	0.00139	0.00207	0.00114
40–44	0.00411	0.00374	0.00337	0.00260	0.00321	0.00202	0.00316	0.00176
45–49	0.00622	0.00512	0.00511	0.00380	0.00470	0.00306	0.00433	0.00259
50–54	0.00985	0.00776	0.00836	0.00604	0.00737	0.00486	0.00656	0.00410
55–59	0.01539	0.01153	0.01390	0.00946	0.01198	0.00769	0.01053	0.00660
60–64	0.02532	0.01916	0.02332	0.01576	0.02014	0.01306	0.01776	0.01139
65–69	0.03763	0.02886	0.03675	0.02473	0.03289	0.02140	0.02942	0.01896
70–74	0.06064	0.04627	0.06076	0.04254	0.05475	0.03702	0.04923	0.03316
75–79	0.09478	0.07258	0.09089	0.06487	0.08392	0.05921	0.07627	0.05397
80–84	0.14575	0.11275	0.14188	0.10694	0.13402	0.09902	0.12291	0.09109
85–89	0.21589	0.17121	0.20498	0.16137	0.18860	0.14655	0.17210	0.13424
90+	0.30688	0.26307	0.26813	0.23560	0.25735	0.22922	0.23417	0.21817

[1] Mortality data reported from the 1973–75 Cancer Epidemiology Survey are used as a basis for deriving adjusted life tables for China's 1964–82 intercensal period.
Sources: 1973–75 survey (Rong Shoude et al. 1981) and censuses of China, 1982, 1990, 2000.

Table A2 Illustrative calculations using the General Growth Balance (GGB) method for the male population of China, 1990–2000

Age group	Total census male population 1-Jul-1990 (1)	1-Nov-2000 (2)	ASMR 1989–90 (3)	ASMR 1999–2000 (4)	Average ASMRs 1990–2000 (5)	Average annual deaths 1990–2000 (6)	$N1^0(a+)$ (7)	$N2^0(a+)$ (8)	$D^0(a+)$ (9)
0	12,254,905	7,460,206	0.026274	0.020358	0.023316	222,940	584,916,014	642,639,157	4,010,046
1–4	48,794,225	30,188,488	0.002308	0.001510	0.001909	73,260	572,661,109	635,178,951	3,787,106
5–9	51,630,875	48,303,208	0.000844	0.000674	0.000759	37,908	523,866,884	604,990,463	3,713,846
10–14	50,183,593	65,344,739	0.000638	0.000499	0.000568	32,542	472,236,009	556,687,255	3,675,938
15–19	62,354,152	53,686,859	0.001090	0.000756	0.000923	53,405	422,052,416	491,342,516	3,643,396
20–24	65,745,940	48,659,026	0.001487	0.001212	0.001349	76,323	359,698,264	437,655,657	3,589,990
25–29	53,870,163	60,657,818	0.001390	0.001406	0.001398	79,902	293,952,324	388,996,631	3,513,667
30–34	43,889,574	65,539,595	0.001837	0.001669	0.001753	94,033	240,082,161	328,338,813	3,433,765
35–39	44,681,679	56,271,164	0.002305	0.002074	0.002189	109,769	196,192,587	262,799,218	3,339,732
40–44	33,386,447	42,288,791	0.003260	0.003159	0.003209	120,597	151,510,908	206,528,054	3,229,963
45–49	25,892,513	43,967,965	0.005056	0.004334	0.004695	158,415	118,124,461	164,239,263	3,109,366
50–54	24,149,339	32,818,233	0.008180	0.006563	0.007371	207,516	92,231,948	120,271,298	2,950,951
55–59	21,877,803	24,068,942	0.013430	0.010530	0.011980	274,907	68,082,609	87,453,065	2,743,435
60–64	17,507,680	21,676,235	0.022531	0.017758	0.020144	392,424	46,204,806	63,384,123	2,468,528
65–69	12,940,423	17,549,348	0.036368	0.029420	0.032894	495,704	28,697,126	41,707,888	2,076,104
70–74	8,357,275	12,436,154	0.060278	0.049229	0.054754	558,197	15,756,703	24,158,540	1,580,400
75–79	4,689,104	7,175,811	0.091566	0.076274	0.083920	486,795	7,399,428	11,722,386	1,022,202
80–84	1,993,954	3,203,868	0.145128	0.122913	0.134020	338,740	2,710,324	4,546,575	535,407
85–89	605,746	1,056,941	0.205105	0.172103	0.188604	150,911	716,370	1,342,707	196,667
90+	110,624	285,766	0.280522	0.234173	0.257347	45,756	110,624	285,766	45,756
Total	584,916,014	642,639,157				4,010,046			

Age group	$N^0(a)$ (10)	$N^0(a+)$ (11)	Entry rate $a+$ (12)	$r^0(a+)$ (13)	X (14)	Y (15)	Observed ASMR (16)	GGB-adjusted ASMR (17)	Observed $_5q_a$ (18)	GGB-adjusted $_5q_a$ (19)
0		613,098,633	0	0.00910	0.00654		0.02332	0.02594		
1–4		603,110,506	0	0.01002	0.00628		0.00191	0.00212		
5–9	10,860,698	562,969,332	0.01929	0.01393	0.00660	0.00537	0.00076	0.00084	0.00379	0.00421
10–14	11,616,895	512,725,821	0.02266	0.01591	0.00717	0.00674	0.00057	0.00063	0.00284	0.00316
15–19	10,381,136	455,381,484	0.02280	0.01470	0.00800	0.00809	0.00092	0.00103	0.00460	0.00512
20–24	11,016,519	396,766,909	0.02777	0.01898	0.00905	0.00879	0.00135	0.00150	0.00672	0.00748
25–29	12,630,131	338,151,540	0.03735	0.02710	0.01039	0.01025	0.00140	0.00156	0.00696	0.00775
30–34	11,883,819	280,763,765	0.04233	0.03028	0.01223	0.01204	0.00175	0.00195	0.00873	0.00971
35–39	9,939,250	227,066,639	0.04377	0.02827	0.01471	0.01550	0.00219	0.00244	0.01089	0.01210
40–44	8,693,755	176,893,338	0.04915	0.02996	0.01826	0.01918	0.00321	0.00357	0.01592	0.01770
45–49	7,662,726	139,286,304	0.05501	0.03188	0.02232	0.02313	0.00470	0.00522	0.02320	0.02578
50–54	5,830,082	105,322,629	0.05535	0.02568	0.02802	0.02968	0.00737	0.00820	0.03619	0.04018
55–59	4,821,821	77,162,380	0.06249	0.02422	0.03555	0.03827	0.01198	0.01333	0.05816	0.06449
60–64	4,355,357	54,117,013	0.08048	0.03058	0.04561	0.04990	0.02014	0.02241	0.09589	0.10611
65–69	3,505,700	34,596,192	0.10133	0.03617	0.06001	0.06517	0.03289	0.03660	0.15197	0.16764
70–74	2,537,157	19,510,483	0.13004	0.04134	0.08100	0.08870	0.05475	0.06091	0.24081	0.26432
75–79	1,548,809	9,313,375	0.16630	0.04450	0.10976	0.12179	0.08392	0.09336	0.34683	0.37847
80–84	775,197	3,510,369	0.22083	0.05004	0.15252	0.17079	0.13402	0.14910	0.50193	0.54307
85–89	290,344	980,752	0.29604	0.06077	0.20053	0.23527	0.18860	0.20982	0.64085	0.68815
90+		177,799		0.09180	0.25735		0.25735	0.28630	0.78299	0.83433

Table A2 (Continued)

Sources:
1. The GGB method is described in Kenneth Hill (1987).
2. Columns (1) and (3) are derived from China's 1990 census.
3. Columns (2) and (4) are derived from China's 2000 census.

Notes:
1. Column (5) is calculated from columns (3) and (4).
2. Column (6) is calculated from columns (1), (2), and (5).
3. Columns (7), (8), and (9) are cumulated from columns (1), (2), and (6), respectively.
4. The $N^0(a)$ values in column (10) are calculated as: $N^0(a) = 1/5\{N1^0[a-5, a]N2^0[a, a+5]\}^{1/2}$.
5. The $N^0(a+)$ values in column (11) are calculated as: $N^0(a+) = \{N1^0(a+)*N2^0(a+)\}^{1/2}$.
6. The $r^0(a+)$ values in column (13) are calculated as: $r^0(a+) = \log\{N2^0(a+)/N1^0(a+)\}/t$.
7. The estimation equation is $\{N^0(a)/N^0(a+)\} - r^0(a+) = \log(k_1/k_2)/t + \{((k_1/k_2)^{1/2})/k_3\}\{D^0(a+)/N^0(a+)\}$.

This has the form $Y = A + BX$, where $Y = \{N^0(a)/N^0(a+)\} - r^0(a+)$, $X = D^0(a+)/N^0(a+)$, $A = \log(k_1/k_2)/t$, and $B = ((k_1/k_2)^{1/2})/k_3$. The values of X and Y are given in columns (14) and (15), respectively. The least square line fitted to these (X, Y) values has intercept $A = -0.0013$ and slope $B = 1.1125$. From this we deduce (a) that $k_1/k_2 = 0.9865$, indicating that males were 1.35 per cent more completely enumerated in the 2000 census than they were in the 1990 census; and (b) that putting $k_1 = 1$, gives $k_3 = 0.9050$, indicating a completeness of death registration, relative to the 1990 census, of 90.5 per cent.

Table A3 Adjusted life tables, People's Republic of China, 1964–82

		Males			Females		
Age, x	n	$_nM_x$	l_x	e_x	$_nM_x$	l_x	e_x
0	1	0.06686	100,000	58.95	0.05873	100,000	61.39
1	4	0.01189	93,643	61.93	0.01229	94,385	64.03
5	5	0.00303	89,322	60.86	0.00279	89,887	63.16
10	5	0.00133	87,978	56.75	0.00113	88,640	59.02
15	5	0.00144	87,397	52.11	0.00127	88,143	54.33
20	5	0.00194	86,769	47.47	0.00193	87,585	49.67
25	5	0.00206	85,931	42.91	0.00226	86,742	45.12
30	5	0.00262	85,050	38.33	0.00277	85,765	40.61
35	5	0.00375	83,941	33.80	0.00371	84,587	36.14
40	5	0.00539	82,381	29.39	0.00495	83,033	31.77
45	5	0.00816	80,190	25.13	0.00678	81,002	27.50
50	5	0.01292	76,983	21.07	0.01028	78,302	23.37
55	5	0.02019	72,165	17.31	0.01527	74,380	19.47
60	5	0.03322	65,229	13.88	0.02537	68,910	15.81
65	5	0.04937	55,226	10.95	0.03822	60,690	12.62
70	5	0.07956	43,091	8.32	0.06127	50,105	9.75
75	5	0.12435	28,794	6.21	0.09611	36,794	7.38
80	5	0.19122	15,137	4.57	0.14930	22,538	5.46
85	5	0.28324	5,345	3.35	0.22671	10,286	3.98
90+		0.40262	913	2.48	0.34835	2,844	2.87

Table A4 Adjusted life tables, People's Republic of China, 1982–90

		Males			Females		
Age, x	n	${}_nM_x$	l_x	e_x	${}_nM_x$	l_x	e_x
0	1	0.03205	100,000	65.92	0.03380	100,000	68.81
1	4	0.00365	96,882	67.04	0.00386	96,749	70.12
5	5	0.00123	95,481	64.00	0.00098	95,190	67.24
10	5	0.00080	94,894	59.38	0.00067	94,716	62.57
15	5	0.00120	94,514	54.61	0.00104	94,405	57.77
20	5	0.00177	93,947	49.92	0.00145	93,913	53.06
25	5	0.00157	93,117	45.34	0.00151	93,164	48.46
30	5	0.00202	92,388	40.68	0.00173	92,475	43.80
35	5	0.00272	91,458	36.07	0.00219	91,663	39.17
40	5	0.00386	90,224	31.53	0.00302	90,634	34.59
45	5	0.00585	88,498	27.10	0.00448	89,249	30.08
50	5	0.00957	85,945	22.83	0.00704	87,265	25.71
55	5	0.01591	81,929	18.82	0.01089	84,200	21.56
60	5	0.02670	75,662	15.18	0.01833	79,617	17.65
65	5	0.04207	66,193	11.99	0.02924	72,525	14.14
70	5	0.06956	53,594	9.22	0.04984	62,641	10.97
75	5	0.10405	37,716	7.05	0.07651	48,641	8.41
80	5	0.16242	22,144	5.25	0.12820	32,982	6.22
85	5	0.23465	9,354	4.00	0.18595	17,133	4.65
90+		0.30695	2,437	3.26	0.29997	6,064	3.59

Table A5 Adjusted life tables, People's Republic of China, 1990–2000

		Males			Females		
Age, x	n	${}_nM_x$	l_x	e_x	${}_nM_x$	l_x	e_x
0	1	0.02594	100,000	68.25	0.03465	100,000	71.14
1	4	0.00212	97,464	69.02	0.00235	96,634	72.61
5	5	0.00084	96,641	65.60	0.00064	95,732	69.28
10	5	0.00063	96,233	60.87	0.00048	95,427	64.49
15	5	0.00103	95,930	56.05	0.00081	95,198	59.64
20	5	0.00150	95,438	51.33	0.00117	94,814	54.88
25	5	0.00156	94,725	46.69	0.00118	94,262	50.18
30	5	0.00195	93,991	42.04	0.00139	93,708	45.46
35	5	0.00244	93,079	37.43	0.00164	93,059	40.76
40	5	0.00357	91,952	32.85	0.00238	92,298	36.08
45	5	0.00522	90,325	28.40	0.00361	91,206	31.48
50	5	0.00820	87,997	24.09	0.00574	89,575	27.01
55	5	0.01333	84,461	19.99	0.00908	87,040	22.72
60	5	0.02241	79,014	16.20	0.01542	83,177	18.66
65	5	0.03660	70,630	12.82	0.02526	77,003	14.96
70	5	0.06091	58,790	9.90	0.04371	67,854	11.64
75	5	0.09336	43,250	7.56	0.06991	54,485	8.88
80	5	0.14910	26,881	5.64	0.11691	38,273	6.58
85	5	0.20982	12,283	4.37	0.17303	20,961	4.95
90+		0.28630	3,830	3.49	0.27064	8,302	3.69

Table A6 Adjusted life tables, People's Republic of China, 1999–2000

		Males			Females		
Age, *x*	*n*	$_nM_x$	l_x	e_x	$_nM_x$	l_x	e_x
0	1	0.02266	100,000	69.70	0.03351	100,000	72.76
1	4	0.00168	97,779	70.28	0.00180	96,743	74.21
5	5	0.00075	97,125	66.74	0.00055	96,049	70.73
10	5	0.00055	96,761	61.98	0.00039	95,787	65.92
15	5	0.00084	96,493	57.15	0.00055	95,601	61.04
20	5	0.00135	96,088	52.38	0.00086	95,337	56.20
25	5	0.00156	95,442	47.71	0.00103	94,930	51.43
30	5	0.00186	94,698	43.07	0.00117	94,444	46.69
35	5	0.00231	93,823	38.45	0.00135	93,894	41.94
40	5	0.00352	92,746	33.87	0.00208	93,263	37.21
45	5	0.00482	91,130	29.42	0.00305	92,298	32.57
50	5	0.00730	88,958	25.08	0.00484	90,899	28.04
55	5	0.01172	85,767	20.92	0.00779	88,726	23.66
60	5	0.01976	80,884	17.03	0.01345	85,336	19.50
65	5	0.03274	73,267	13.54	0.02239	79,784	15.69
70	5	0.05479	62,179	10.51	0.03916	71,324	12.25
75	5	0.08489	47,197	8.05	0.06374	58,604	9.37
80	5	0.13680	30,671	6.05	0.10758	42,493	6.97
85	5	0.19155	15,038	4.73	0.15853	24,481	5.26
90+		0.26063	5,299	3.84	0.25766	10,584	3.88

Notes

1 Judith Banister is at Javelin Investments, Beijing. E-mail: Judith_Banister@yahoo.com. Kenneth Hill is at the Hopkins Population Center, Bloomberg School of Public Health, Johns Hopkins University, Baltimore. E-mail: khill@jhsph.edu

2 The names of the authors are listed alphabetically and senior authorship is not assigned. The work of Judith Banister on this paper has been supported by the Research Grants Council of the Hong Kong Special Administrative Region, China (Project No. HKUST6048/98H). The work of Kenneth Hill on this paper was supported by National Institute on Aging grant 1-PO1-AG17625 as part of the *Adult Mortality in Developing Countries* project.

References

Banister, Judith and Samuel Preston. 1981. Mortality in China, *Population and Development Review* 7(1): 98–110.

Banister, Judith. 1987. *China's Changing Population*. Stanford, CA: Stanford University Press.

Banister, Judith. 1992. China: recent mortality levels and trends. Paper presented at the annual meeting of the Population Association of America, Denver, May 1992.

Banister, Judith. 2003. Shortage of girls in China today. Manuscript.

Banister, Judith and Zhang Xiaobo. 2003. China: economic development and mortality decline. Paper presented at the annual meeting of the Population Association of America, Minneapolis, May 2003.

Barclay, George W., Ansley J. Coale, Michael A. Stoto, and T. James Trussell. 1976. A reassessment of the demography of traditional rural China, *Population Index* 42(4): cover and 605–635.

Bennett, Neil and Shiro Horiuchi. 1981. Estimating the completeness of death registration in a closed population, *Population Studies* 47(2): 207–222.

Bennett, Neil and Shiro Horiuchi. 1984. Mortality estimation from registered deaths in less developed countries, *Demography* 21(2): 217–234.

Bhat, P. N. Mari. 1990. Estimating transition probabilities of age misstatement, *Demography* 27(1): 149–163.

Brass, William. 1975. *Methods for Estimating Fertility and Mortality from Limited and Defective Data*, POPLAB Occasional Publication. Chapel Hill, NC: University of North Carolina, International Program of Laboratories for Population Statistics (POPLAB).

Brass, William and Li Bohua. 1988. Levels, trends, and patterns of adult mortality in China over twenty-five years. Paper presented at the Seminar on Mortality Transition in South and East Asia, Beijing, August–September 1988.

China, Ministry of Health. 1999. *Research on National Health Services—An Analysis Report of the Second National Health Services Survey in 1998*, 2 volumes. Beijing: Ministry of Health (in Chinese).

China, Ministry of Health. 2000. *Chinese Health Statistical Digest 2000*. Beijing: Ministry of Health.

China, National Bureau of Statistics. *China's Censuses*. China: Population Census Office under the State Council and Department of Population Statistics, National Bureau of Statistics. 1953, 1964, 1982 censuses. 1985. *The 1982 Census of China (Major Figures)*. Hong Kong: Economic Information & Agency; 1990 census. 1993. *Tabulation on the 1990 Population Census of the People's Republic of China*, 4 volumes. Beijing: China Statistics Press; 2000 census. 2002. *Tabulation on the 2000 Population Census of the People's Republic of China*, 3 volumes. Beijing: China Statistics Press.

China, National Bureau of Statistics. 2001. Communique on major figures of the 2000 population census, released 28 March.

China National Working Committee on Children and Women. 2001. *Report of the People's Republic of China on the Development of Children in the 1990s—National Report on the Follow-up to the World Summit for Children*. Beijing: China National Working Committee on Children and Women.

Chinese Academy of Preventive Medicine. 1997. *Smoking and Health in China: 1996 National Prevalence Survey of Smoking Pattern*. Beijing: China Science and Technology Press.

Chinese Academy of Preventive Medicine. Annual. *Report on Chinese Disease Surveillance*. Beijing: Beijing Medical University Press (in Chinese). Available: http://www.chinadsps.com/yufang/en_news/news_list_view.asp (in English); http://www.chinadsps.com/yufang/baogao_index.asp (in Chinese).

Coale, Ansley J. and P. Demeny. 1966. *Regional Model Life Tables and Stable Populations*. Princeton, NJ: Princeton University Press.

Coale, Ansley J. 1984. *Rapid Population Change in China, 1952–1982*, Committee on Population and Demography Report No. 27. Washington, DC: National Academy of Sciences Press.

Fan Shenggen, Linxiu Zhang, and Xiaobo Zhang. 2002. *Growth, Inequality, and Poverty in Rural China: The Role of Public Investments*, Research Report 125. Washington, DC: International Food Policy Research Institute.

Ge Keyou, Zhai Fengying, and Yan Huaicheng. 1996. The third national nutrition survey, *Weisheng yanjiu* (*Journal of Hygiene Research*) 25 (Supplement, December): 3–15 (in Chinese).

Greenhalgh, Susan. 1994. Controlling births and bodies in village China, *American Ethnologist* 21: 3–30.

Hardee-Cleaveland, Karen and Judith Banister. 1988. Fertility policy and implementation in China, 1986–88, *Population and Development Review* 14(2): 245–286.

Henderson, Gail, et al. 1992. Equity and the utilization of health services: report of an eight-province survey in China. Presented at the annual meeting of the Association of Asian Studies, Washington, DC, April 1992.

Hill, Kenneth. 1987. Estimating census and death registration completeness, *Asian and Pacific Population Forum* 1(3): 8–13, 23–24.

Hill, Kenneth. 2003. Adult mortality in the developing world: what we know and how we know it. Prepared for United Nations Training Workshop on Adult Mortality and HIV/AIDS, New York, 14–18 July 2003.

Hsiao, William C. 1987. The incomplete revolution: China's health care system under market socialism. Paper presented at the annual meeting of the Association for Asian Studies, Boston, April 1987.

Jamison, Dean T., et al. 1984. *China, the Health Sector*. Washington, DC: World Bank.

Jiang Zhenghua, Li Shuzhuo, and Sun Fubin. 1994. An estimation of the completeness of death reporting and mortality analysis in China's 1990 census, in China National Bureau of Statistics (eds.), *1990 Population Census of China—Proceedings of International Seminar*. Beijing: China Statistical Publishing House, pp. 728–738.

Li Shuzhuo and Sun Fubin. 2003. Mortality analysis of China's 2000 population census data: a preliminary examination, *The China Review* 3(2): 19–36.

O'Neill, Mark. 2002. Tobacco: WTO means industry needs to close ranks, *South China Morning Post* (Hong Kong) 3 June 2002, p. 3.

Popkin, Barry M., et al. 1993. The nutrition transition in China: a cross-sectional analysis, *European Journal of Clinical Nutrition* 47: 333–346.

Poston, Dudley L., Jr. 1996. Patterns of infant mortality, in Alice Goldstein and Wang Feng (eds.), *China, the Many Facets of Demographic Change*. Boulder, CO and Oxford: Westview, pp. 47–65.

Preston, Samuel H. and Kenneth Hill. 1980. Estimating the completeness of death registration, *Population Studies* 34(2): 349–366.

Preston, Samuel H., Ansley J. Coale, James Trussell, and Maxine Weinstein. 1980. Estimating the completeness of reporting of adult death in populations that are approximately stable, *Population Index* 46(2): 179–202.

Rong Shoude et al. 1981. Analysis of life expectancy in China, *Renkou yu jingji* [*Population and Economy*] 1981(1): 24–30, 17 (in Chinese).

Tu Ping and Liang Zhiwu. 1994. An evaluation of the quality of enumeration of infant deaths and births in China's 1990 census, in China National Bureau of Statistics (eds.), *1990 Population Census of China—*

Proceedings of International Seminar. Beijing: China Statistical Publishing House, pp. 281–288.

United Nations. 1983. *Manual 10: Indirect Techniques for Demographic Estimation*. New York: United Nations, Department of International Economic and Social Affairs, Population Division.

USDA. 1988. United States Department of Agriculture, Economic Research Service. *China, Agriculture and Trade Report, Situation and Outlook Series*. Washington, DC: US Government Printing Office.

Wang Wenli. 1991. Pure water supplied to more rural residents, *China Daily* 6 December 1991, p. 1.

World Bank. 1990. *China: Long-term Issues and Options in the Health Transition*, Report No. 7965-CHA, 2 volumes. Washington, DC: World Bank.

World Bank. 1996. *Poverty Reduction and the World Bank: Progress and Challenges in the 1990s*. Washington, DC: World Bank.

World Bank. 1997. *China 2020; Financing Health Care*. Washington, DC: World Bank.

Xinhua. 1996. China: Xinhua cites 'accomplished goals' in children's health, *Foreign Broadcast Information Service Report—Environment and World Health*, FBIS-TEN-96-001, 10 January 1996.

Yang Rizhang. 1984. How was the sampling check on the quality of the enumeration work in the 1982 population census of China carried out?, in China National Bureau of Statistics (eds.), *A Census of One Billion People*. Beijing: China National Bureau of Statistics, pp. 132–139.

Yang Rizhang. 1994. Improvement of the post-enumeration survey and quality control of China's 1990 population census, in China National Bureau of Statistics (eds.), *1990 Population Census of China—Proceedings of International Seminar*. Beijing: China Statistical Publishing House, pp. 90–99.

Zeng Yi and Linda George. 2002. Extremely rapid aging and the living arrangement of elderly persons: the case of China, in *Living Arrangements of Older Persons, Population Bulletin of the United Nations, Special Issue No. 42/43*. New York: United Nations.

Zeng Yi and James W. Vaupel. 2003. Oldest-old mortality in China, *Demographic Research* 8(7): 215–244.

Zhai Zhenwu. 1988. Estimation on indexes of China's life tables: 1953–1964 and 1964–1982, *Renkou yanjiu* [*Population Research*] 5(2): 40–48, 39.

Zhai Zhenwu. 1993. An adjustment of 1990s IMR and an estimation of life table, *Renkou yanjiu* [*Population Research*] 1993(2): 9–16 (in Chinese).

Zhao Zhuyan and Lusheng Wang. 1995. Present ways to raise funds for health care in the countryside of China. Paper presented at Beijing Health Economics Institute Health Care Seminar, Beijing, May 1995.

Zhou, Y., et al. 1989. An analysis of infant mortality rates in China, *Zhongguo renkou kexue* [*Chinese Journal of Population Science*] 1989(3): 35–46 (in Chinese).