DECOMPOSING CHANGES IN LIFE EXPECTANCY AT BIRTH BY AGE, SEX, AND RESIDENCE FROM 1929 TO 2000 IN CHINA*

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Abstract: Life expectancy at birth (LEAB) in China has doubled in the twentieth century from below 35 years to over 70 years. To capture the contribution of types of mortality change to the increase in LEAB, we decompose the changes in LEAB by age, sex, and residence in six periods between 1929 and 2000. Based on available life tables, we perform the decomposition using Arriaga's discrete method. The results show dramatic increases in LEAB in the 1930s, 1940s, and 1950s. Overall, mortality decline among young ages contributed more to the increase in LEAB. Mortality decline during adulthood and the elder years has contributed to an increasing share of advance in LEAB since 1980. We discuss possible causal pathways between changes in LEAB and historical events and social disruptions such as wars, famine, regime change, women's movement, the Cultural Revolution, economic reform and epidemiological transition in different periods.

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INTRODUCTION

Life expectancy at birth (LEAB) increased substantially in the 20th century, and such a trend is likely to continue in the 21st century (Oeppen and Vaupel 2002). Demographers tend to agree that reductions in mortality early in life resulted in most of the gain in LEAB before the first half of the 20th century, and the improvement in mortality among the elderly has and will continue to contribute to advances in LEAB (Wilmoth 2002; Cheung and Robine 2005). In decomposing the change in LEAB, various methods have been developed over time, especially in recent decades (see Vaupel and Canudas 2003). There are two main approaches to decompose the difference in life expectancies: a continuous approach (Pollard 1982) and a discrete approach (Arriaga 1984). These two approaches are formally identical but Arriaga's formula is easier to apply to a life table where the majority of the data is given in discrete time (Preston, Heuveline, and Guillot 2001). Many previous studies have applied Arriaga's technique for decomposition (e.g., Velkova, Wolleswinkel-van den Bosch, and Mackenbach 1997; Zhao and Kinfu 2005).

Like most other countries around the world, LEAB in China has increased substantially in the 20th century. LEAB was estimated around 33-35 years in the early 1930s (Banister and Preston 1981; Campbell 2001; Seifert 1935; Zhao 1994), and it doubled to over 70 years at the turn of the 21st century (National Bureau of Statistics of China, NBSC 2003). Factors contributing to this achievement consist of the cessation of civil war, the changes of political regime, implementation of economic reform since the late 1970s, and various nationwide intervention programs that focus on healthcare promotion and poverty reduction (Banister 1987; Guo 1997), health promotion--especially implementations of programs in reproductive health, and poverty alleviation. The combination of these efforts and endogenous social, cultural and historical factors has resulted in a large reduction of mortality at all ages, with particularly sizable declines among the young age groups (Campbell 2001). For example, from the establishment of the People's Republic of China in 1949 to 1990s, infant mortality declined from 200‰ to below 30‰; maternal mortality declined from 1500/100,000 to less than 60/100,000 (Gao 1997).

Banister and Hill (2004) provided a relatively detailed qualitative discussion about the factors contributing to life expectancy increase (or mortality decline) in the different periods from 1964-2000 in China. One study on the decomposition of changes in LEAB in China from the latest three census (1982, 1990, and 2000) estimates that the decline in children's mortality contributes to the increased life expectancy by 35-40% from 1981 to 2000 (Ren, Zheng, and Cao 2005). It further finds that the gender difference in the gain in LEAB is mainly due to improvement of reproductive health for women (Ren et al. 2005:8).

However, no study systematically decomposes changes in life expectancy to include the periods of 1930s, 1940s, and 1950s, during which China witnessed the anti-Japanese War and civil wars, social structural changes, political movements, and famines. In addition, considering different socioeconomic development and healthcare systems in urban and rural areas, one would expect to see different patterns of contribution of age-specific mortality rates to the gained LEAB. It is also worthwhile to see how these factors are reflected in the gained LEAB. This study attempts to decompose changes in LEAB into six periods from 1929/31 to 1999/2000 using available life tables.

DATA SOURCE AND METHODS

Data

This study uses secondary data that are mainly from sex-specific abridged Chinese life tables for the years of 1929/31, 1936/41, 1956/58, 1973/75, 1981/82, 1989/90, and 1999/2000. The life table for the year of 1929/1931 comes from a study by Seifert (1935), while the life tables for years of 1946/41 and 1956/58 are from the United Nations internal database. We use the life table for the year of 1973/75 from Rong and his colleagues (1981). Data for the last three years (i.e., 1981/1982, 1989/1990, and 1999/2000) comes from the three most recent censuses, which are from Huang and Liu (1995) and the National Bureau of Statistics of China (2003). Most researchers have reached a consensus that the death rates are underreported, especially for the infant and childhood years (Banister and Hill 2004; Huang 2004). This pattern implies that the estimated death rates might be artificially low. Therefore, we estimated another set of LEAB for the last four periods based on adjusted mortality rates from Hill's General Growth Balance (Hill 1987). After comparing the two sets of results, we find that the patterns of the gained LEAB based on the unadjusted method are similar, although the absolute numbers in the gained LEAB between these two methods are different. The adjusted results are not presented in the text due to space limitations but are available upon request from the authors.

Methods

Changes in LEAB are the aggregate of changes in the mortality rates across ages. Changes in the mortality rate between ages x and $x+n$ will not only affect the number of person years lived between age x to $x+n$, but also affect all person years lived above age $x+n$ because the change in number of survivors at age $x+n$ will increase or decrease the number of survivors reaching each age above $x+n$ (Preston, Heuveline, and Guillot 2001). Therefore, the effect of mortality change between ages x and $x+n$ on LEAB from time one to time two is equal to the sum (total effect) of a direct effect, an indirect effect and an interaction effect. The direct effect captures a change in the number of years lived within ages x and $x+n$ added to LEAB. The number of years could be negative if mortality after age x increases. The indirect and interaction effect account for the addition of the person years to be added at and after age $x+n$, respectively. Again, the person years could be negative due to increases in mortality after age x.

Given that the risk of dying is age-dependent, decomposing changes in life expectancy could provide a clear picture of the age patterns in mortality change. Vaupel and Canudas (2003) extended

Keyfitz's approach by making formulas more elegant and exact and more easily to incorporate covariates and cause-specific analyses. However, Vaupel and Canudas' method yields results almost identical to those based on Arriaga's method. Therefore, we use Arriaga's method in this study to decompose the change in LEAB.

The formulas below describe the decomposition of life expectancy at age a in Arriaga's method (1984)[1]. ${}_nTE_x$ denotes the total contribution of mortality changes to life expectancy for the age interval $[x, x+n)$ to age a between time t and time $t+k$. ${}_nDE_x$ denotes the direct contribution, ${}_nIE_x$ the indirect contribution, and ${}_nI_x$ the interaction contribution.

$$ {}_nTE_x = {}_nDE_x + {}_nIE_x + {}_nI_x $$

Where,

$$ {}_nDE_x = \frac{l_x^t}{l_a^t} \cdot \left(\frac{T_x^{t+k} - T_{x+n}^{t+k}}{l_x^{t+k}} - \frac{T_x^t - T_{x+n}^t}{l_x^t} \right), \quad (a \le x) $$

$$ {}_nIE_x = \frac{T_{x+n}^t}{l_a^t} \cdot \left(\frac{l_x^t \cdot l_{x+n}^{t+k}}{l_{x+n}^t \cdot l_x^{t+k}} - 1 \right), \quad (a \le x) $$

$$ {}_nI_x = \frac{T_{x+n}^{t+k}}{l_a^t} \cdot \left(\frac{l_x^t}{l_x^{t+k}} - \frac{l_{x+n}^t}{l_{x+n}^{t+k}} \right) - \frac{T_{x+n}^t}{l_a^t} \cdot \left(\frac{l_x^t \cdot l_{x+n}^{t+k}}{l_{x+n}^t \cdot l_x^{t+k}} - 1 \right), \quad (a \le x) $$

l_x^t and T_x^t are the general terms in life table. The former refers to number of persons reached at age x at time t, whereas the latter refers to total person-years lived from age x and above.

For the open end age interval (i.e., the last age-group), there is only a direct effect:

$$ DE = \frac{l^t}{l_a^t} \cdot \left(\frac{T^{t+k}}{l^{t+k}} - \frac{T^t}{l^t} \right), \ (a \le x) $$

RESULTS

General trend of the LEAB

The upper part of Table 1 provides LEAB at different years by sex. LEAB improved substantially in the 1940s and the 1950s as compared to the 1930s, with females gaining more than their male counterparts. The improvement continued in the last three decades of the 20th century, but the pace tended to slow down. The annual increase in LEAB was around 1 year per year in the 1930s, 1940s, and 1950s. However, the recent annual increase has been only about 2-3 years per decade. LEAB in 1999/2000 reached more than 70 years, which is much higher than the average of countries around the world with the similar GDP per capita (Eggleston, Wang, and Rao 2005; Zhao and Kinfu 2005). Except the years of 1929/31, the sex difference in LEAB was around 3-4 years across different periods. The low part of Table 1 also presents LEAB by sex and residence for available years. The urban/rural difference for both males and females is notable and increased from the 1980s to 2000. The urban/rural gap increased from less than 2.5 years in 1981/82 to around 6.0 years in 1999/2000 for both males and females. Rural residents only gained 0.14 year per year in the 1990s, which is much smaller than that for urban residents in the same decade and smaller than rural residents' gain in the 1980s.

Figure 1 provides life expectancy at each age for 1929/1931- 1999/2000 by sex. Life expectancy at young ages improved greatly in the 1930s, the 1940s and the 1950s. The improvements in life expectancy at each age from the late 1950s on are rather smooth. Figure 1 also reveals that improvements in life expectancies at old ages were quite small with almost no improvement at oldest-old ages.

--- Table 1 and Figure 1 about here---

Age and gender patterns of contribution to the gained LEAB

Figure 2 summarizes the gained years to LEAB for different age groups by sex across periods in terms of direct, indirect, interaction and total contributions. Several distinct features are noteworthy. First, for both sexes and for all periods, the direct and interaction contributions to the change in LEAB was due to improvement of mortality between age x and $x+n$ is much smaller as compared to its indirect contribution for almost all ages.

Second, in general, with few exceptions (in 1956/58-1973/75 and in the 1990s), the total gained LEAB mainly resulted from the decline in infant mortality rate (IMR) and under-5 child mortality (U5MR) for both sexes. Indeed, as shown in Table 2, more than 50% of the total increased LEAB in each period was attributed to the improvement of infant and child mortality. This figure reached 80% in the 1930s and in the 1970s. However, the differentials in age patterns of contribution across periods are still notable. In other words, different ages contributed different shares to LEAB over time. The increase in LEAB in the 1930s was mainly due to the improvement in survivorship of children aged 1-4 but not the improvement of the infant mortality. On the other hand, the decline of the infant mortality rate in the 1940s and the early 1950s contributed substantially to the change in LEAB. The contribution of the improvement in adulthood mortality to LEAB in the 1940s and the early 1950s were also more remarkable than in the 1930s and other periods. Furthermore, both the direct and indirect contributions for ages 25 and beyond are all negative in the 1930s, but are generally positive in other periods for the same ages. From 1956/58 to 1973/75 and from 1989/1990 to 1999/2000, the improvement of survivorship at adulthood or elderhood dominated the contributions to LEAB. The infant mortality rate and childhood mortality worsened in the late 1950s and the 1960s for males. In addition, the female infant mortality rate also worsened in the 1990s.

-- Figure 2 and Table 2 about here---

Third, the sex pattern in the gained LEAB was more or less similar across different periods, as indicated in Table 2. However, the contribution of the infant mortality rate to LEAB was higher for males than for females in the last two decades of the 20^{th} century, and the contribution of the female IMR in 1990s even changed from positive to negative. On the other hand, the change in LEAB resulting from decreased mortality for adulthood ages 15-59 was greater among females than among males, especially in the last quarter of the 20^{th} century.

Finally, the magnitude of the shared contribution to LEAB by older ages (ages 60+) tended to grow in the 1980s and the 1990s, from less than 30% in the period of 1980-1989 to more than 45% in 1990-2000 (see Table 2). In the period of 1956/58-1973/75, the contribution of old ages was also large, which is a special case as we will discuss below.

Urban/rural difference

Figure 3 separates the age-sex-specific shared percentages to the change in LEAB by residence. As above, we focus on the total contribution of each age group to LEAB, given that the direct and the interaction contributions are relatively small. First, the shared percentages for older ages increased for both urban and rural residents from 1981 to 2000 regardless of sex. However, the shared percentages of older ages were always higher among urban residents than among rural residents across ages and sexes. On the other hand, the shared percentages for infants and children declined. For urban males, the percentage decreased from 45-50% in the 1980s to 20% in the 1990s, while it declined from 30% in the 1980s to 15% in the 1990s for urban females. For rural residents, the IMR increased from 1990 to 2000, especially for females, leading to a negative contribution. Overall, the shared percentages by young ages decreased over time.

--- Figure 3 and Table 3 about here---

Second, the shared percentage of contribution to LEAB for children was higher for rural residents in the 1980s while it was higher for urban residents in the 1990s. The female IMR witnessed a worsening trend in rural areas in the last two decades of the 20^{th} century, especially in the 1990s, which contributed negatively to LEAB.

Third, for females, the effects of the declined mortality rates at reproductive prime ages (25-39) to the gained LEAB were larger in rural areas than in urban areas, and larger in the 1990s than in the 1980s for both urban and rural areas (see Table 3). There is almost no contribution to LEAB from this prime age group among males for both urban and rural areas except for urban areas in the 1990s.

DISCUSSION

Our study finds that the shares to the males' LEAB for ages 35 and over from 1929/31 to 1936/41 were negative, suggesting that the Anti-Japanese War and civil wars caused numerous deaths among male adults. However, the survivorship for children in this period was largely improved, resulting in a net yearly increase of 0.8 year in LEAB. Furthermore, for females, each age contributed positively to LEAB in spite of the wars, indicating the adverse impact of wars on survival was smaller in women than in men. The increase of LEAB in women was somewhat related to the advancement of women's movement in the 1930s in China. The May Fourth Movement in 1919 heralded the modern Chinese women's movement. As a result, educational opportunities for women increased in 1930s as compared to earlier decades (Curtin 1975). Colleges and universities admitted women students and co-education became an accepted social norm in this period (Lucas 1965). The Anti-Japanese War, which began in 1937, also undoubtedly enhanced women's participation in social activities. The promotion of modern medicine, establishment modern hospital in urban areas, and subsequent initiatives of national health policy in rural areas were also critical factors for the decline in infant and child mortality in this period (see Campbell 1997; Lucas 1982), which is also another important factor for increasing LEAB.

From 1936/41 to 1956/58, China incurred a series of major political events with the cessation of Anti-Japanese War and the civil war between the Communist Party and the Guomindang, followed by the establishment of the People's of Republic of China. As a result of these events, land reform, and health campaign, the social institutional system changed drastically. After the foundation of the People's Republic of China in 1949, the government launched "patriotic public health campaign" to emphasize the importance of environmental sanitation, and started vaccination programs to tackle contagious diseases. Another major emphasis in public health programs of the 1950s was setting up maternal and child health stations and retraining midwives to reduce high infant and maternal mortality. The Chinese government's most important effort was a health insurance program consisting of a government insurance scheme (GIS) and a labor insurance scheme (LIS) in the middle of 1950s. These two schemes covered 100% of treatment and prescription drug expenses for almost all urban employees and 50% of the costs for all dependents of beneficiaries before the urban system was reformed in the 1980s (Dong 2003). These campaigns and programs greatly improved health conditions and reduced the disease prevalence and incidence, and thus increased LEAB.

The change in LEAB in this period was closely related to the fundamental change and substantial improvement of women's status through legislation. The 1949 Communist Revolution ushered in broad changes in women's status in all parts of China (Yang 1965). The new Communist government empowered women with more opportunities to obtain political power, economic advantages and educational improvement. The law guaranteed equity between men and women (Croll 1983). Women could "hold up half the sky" and earned the same money as men. They enjoyed unprecedented social liberation. Gender differences diminished to a great extent in public institutions and ideology (Min 1999). For example, 20% of all elected representatives nationwide were female in (insert year here), in just (insert number of years here) years after the country shifted from a semi-feudal and semi-colonial system (Wang 2004). Large-scale involvement of women in the labor force outside the family since the establishment of the new regime in 1949 permits women to escape from patriarchal authority by replacing the family as a dominant and independent unit of economic production. If women work and have earnings, sons are no longer perceived as the only source of providing family support, which often forms one of the bases of son preference (Muhuri and Preston 1991).

The adult illiteracy eradication movement and its achievement in the 1950s played a crucial role in prolonging LEAB in this period. It was estimated that the rise of 10% in literacy rate could decrease infant mortality by 6% and prolong LEAB by 1.2 years (Furukawa 2005). Since the prevalence of son preference is related to women's lower status, education of mothers has been assumed to leave its mark on sex mortality differentials (Muhuri and Preston 1991).

During the period of 1957/58 -1973/75, China witnessed the three-year famine (1961-63) and the Cultural Revolution (1966-1976). Although the negative impact of famine may have already been diminished at the year of 1973/75, the malnutrition suffered in the infant and early childhood during the famine caused the increase in mortality rates for children ages 5-14 in this period, and thus the contribution to LEAB turned to negative among these ages. The adverse impacts of infants or fetal disadvantage on later survival in childhood and adulthood are well-documented (Barker 1992; Marmot and Wadsworth 1997). Further, the nationwide movement of the Cultural Revolution caused economic stagnation. Dankert and van Gineken (1991) reported that the neonatal mortality (as a proportion of infant mortality) increased in all three provinces surveyed (Shaanxi, Heibei, and Shanghai) during the period of the Cultural Revolution.

However, LEAB continued to rise. This improvement was largely attributed to the health promotion and the establishment of healthcare system in rural areas and the health insurance program in urban areas. In this period, the cooperative medical system (CMS) under an organized three-tiered healthcare delivery system in terms of village healthcare point, township/town healthcare center, and county hospitals began in rural areas in the late 1960s (Campbell 2001; Feng et al. 1995; Tomlinson 1997; Wang et al. 2005). It was reported that before the economic reform in the late 1970s, 90% of Chinese rural residents are covered by the CMS in 1975 (Tomlinson 1997; Wang et al. 2005). The number of rural township hospitals doubled from 1960 to 1976, tripling their personnel and increasing their number of beds by twenty times (Liu, Xu, and Huang 1996). For the first time, the vast majority of China's rural people had access to medical care. In urban areas, the GIS and LIS continued to benefit residents. With nearly twenty-year's implementation, these systems greatly improved health and survivorship at adulthood and elderhood. There is no doubt that the barefoot doctors (i.e., informal rural doctors, or doctors in rural without formal training) and the CMS system in rural and the GIS and the LIS insurance systems in urban in this period played a crucial role in improving survivorship for adults and elders, offsetting the increased mortality at young ages and leading to the net increase in LEAB. The adult illiteracy eradication movement in the 1950s and 1960s also created a beneficial effect on the prolonged LEAB.

From 1973/75 to 1981/82, China launched an economic reform following the end of the Cultural Revolution. The Soviet model established in the 1950s in China had built-in defects. It was conceded that out of twenty-four years from 1957-1980, seventeen were wasted and harmful. It was increasingly clear that systemic reforms are needed to cure the economic system. Although the coverage of the rural health care system declined in 1981/82 as compared to that in 1975 due to the reform, the rapid economic growth offset the negative impact of the health care system. Thus, LEAB still reached an annual increase of 0.40 year. The gained LEAB in this period can be largely attributed to the improvement in survivorship at young ages. This age pattern was related to the Chinese government's efforts and commitment to the promotion of child vaccinations, improvement of sanitation, and improvement in water supplies in both urban and rural areas. For example, 60% of rural population had access to a clean water supply in 1987 and 90% of children had been vaccinated against TB, polio, measles, diphtheria, pertussis, and tetanus (Banister and Hill 2004). In addition, infant mortality declined much more for boys than girls in this period. According to Rao and Chen (1993), the increase in LEAB from 1973-1981 was mainly due to the decrease of mortality from respiratory (particularly pneumonia among lower age groups) and infectious disease. This finding implies that improvement in LEAB is not independent of economic progress. However, due to the government's priority of a large population coupled with inadequate resources, health care facilities, in both town and countryside failed to keep pace with the population growth and with the changing pattern of diseases (Hill and Zheng 1994). Indeed, the problems regarding inadequate skills of the medical personnel, inequity of the system, and insufficient funds emerged in 1975. The economic reform exacerbated these difficulties. The rural CMS virtually ceased in many rural areas in the late 1970s. Therefore, the contribution of adulthood mortality to LEAB largely declined in the period. Finally, adverse environmental conditions, such as intentional or unintentional deprivation of necessary food, neglect of care and inadequate health care for female children might also contribute to the slowing improvement in survivorship for females (Chen, Huq, and D'Souza 1981).

After nearly a decade of economic reform, China's economy in the 1980s grew rapidly with an annual increase rate of 8-9% from 1981-1990. Furthermore, in 1990, the per capita GDP exceeded $400. Economic growth is likely to create better living conditions, which leads to increased nutrition. Economic growth also played an important role in health improvement (Frank and Evans 1994), another mechanism through which the economy contributed to the increase in LEAB. Moreover, the continued implementation of the family planning program nationwide strengthened and increased maternal children care (MCH) services, breast feeding, and other reproductive health services throughout the country. These efforts led to a profound decline in women's mortality at reproductive ages. However, the excess female infant mortality increased noticeably, especially in rural areas. In rural areas, there was also excess female under-5 child mortality. Female infanticide and abandonment, and unequal treatment of male and female infants and children may also account for the low contribution of changes to the younger ages to the LEAB among females compared to males, and among rural compared to urban areas (Xu et al. 1994). In addition, the rural reform enhanced the cultural propensity for sons, which may have caused direct infanticide or indirect infanticide through unfavorable allocation of scarce resources, inferior health care (Chen, Huq, and D'Souza 1981;

Banister 2003), or discriminatory feeding practice against females (Arnold 1991). In this period, the contribution of improved IMR and U5MR to LEAB in urban areas was smaller than in rural areas. However, because substantial effort would be necessary to bring the already low level of the IMR in urban further down, less effort is needed to decline a much higher level of the IMR in rural areas (Gao et al. 2002).

Another noteworthy pattern of the 1980s is that the larger shared of LEAB associated with adult ages for women might be related with the family planning reproductive health programs and maternal and child health care. The lower contribution for the men is due to the excess mortality resulting from occupational (dangerous jobs) and lifestyle factors (smoking and drinking) (Banister and Hill 2004).

Some researchers have examined cause-specific death rates in this period. During 1981-1990 the drop of mortality caused by cerebrovascular diseases (CVD) and respiratory diseases (particularly chronic bronchitis among the middle-aged and elderly population) were the primary causes of increased LEAB in urban areas. The decline in mortality caused by CVD diseases accounted for 37% of the increase in LEAB among both men and women, although the mortality caused by malignant tumor reduced the increase in LEAB by 31% (Rao and Chen 1993).

In the 1990s, the accessibility of health care was worsened and the CMS system collapsed in the rural China. Correspondingly, the number of village health officials decreased by 18-33% and the number of hospitals and health care centers decreased significantly at township and village levels from the 1970s to the 1990s (Lok 1995; Wong and Gabriel 1998). Consequently, people in rural areas experienced reduced access to medical care. For example, the proportion of rural residents with cooperative medical system coverage dropped from over 85-90% in 1975 down to less than 5-10% in 1997 (Tomlinson 1997; Wang et al. 2005). Moreover, escalating health care costs became unaffordable for the rural poor. For instance, out-of-pocket payment of farmers for the healthcare services significantly increased from 106% in 1991 to 149% in 2003 as of their net per capita income. About 46% of sick persons did not visit physicians for checkups although they were supposed to do so, and 30% of patients could not afford for hospitalization who required such services (Mao 2006). According to the third National Health Services Survey in 2003, nearly 80% of rural residents lacked health insurance (Minister of Health, China 2003). However, it was in the 1990s that China sped-up its economic reform. As a result, the economic growth rate reached 8-9% each year. The rapid economic growth had more than balanced the negative impact on LEAB caused by reduced health care resources.

Improved education could be another major contributor to the gained LEAB in the 1990s. Education improved substantially in this decade. The percentage of population who were illiterate dropped from 15.88% in 1990 to 6.72% in 2000, and the number of persons with junior college and above per 100000 persons has increased from 1422 in 1990 to 3611 in 2000 (National Bureau of Statistic of China 2003). One of the factors contributing to the gained LEAB could be the government effort in poverty alleviation that has allowed people in poor areas to access health care.

As compared to the 1980s, the shared percentage of IMR and U5MR to the gained LEAB tended to be smaller in the 1990s. One possible explanation is the increase trend in overweight and obesity among young children in the same period (Luo and Hu 2002). It is also interesting to note that the contribution of rural female IMR to LEAB was negative due to its increase in the 1990s. This can be linked to girl discrimination which could be a combination of the culture of son preference and one-child policy (Banister 2003). Family planning and reproductive health services programs in the 1990s continued to benefit women's survivorship, which resulted in more improvement during reproductive ages for women than men.

In summary, our decomposition shows that the percentage share of each age to the changes in LEAB over time varies. On average, the young ages had more substantial contribution to the changes in LEAB, while older ages have contributed more years to LEAB since 1980. These two trends are in line with the epidemiologic transitions (Orman 1971), and on the track of the trajectory of evolution of LEAB in developed countries (Wilmoth 2002; Cheung and Robine 2005). This overall pattern of compositional contributions to LEAB by age-specific mortality decline across seven decades is in accordance with the epidemiological transition (Cook and Dummer 2004; Phillips 1994). This epidemiological transition theory argues that high mortality associated with famine and infectious disease epidemic causes a low LEAB when a society is undeveloped. As the society develops the decline in infectious diseases coupled with increasing mortality and morbidity caused by lifestyles and degenerative diseases result in an increased LEAB (Cook and Dummer 2004). However, unlike some recent studies conducted in developing countries, which show increases in both child and adult mortality since 1980 as a results of a decline in the quality of basic education, unaffordable health services, and HIV/AIDS (Doctor 2001; Kapoor and Anand 2002), our decomposition of LEAB shows that mortality rates at all ages for both sexes except rural IMR have decreased. This contrast in findings further suggests that the decline in mortality is attributed to the rapid economic growth and more accessible reproductive health services as mentioned earlier.

Because the cause-specific mortality data in China are not publicly accessible, it is very difficult to further explain the observed age patterns of contribution to LEAB. Ren and colleagues showed how gender differentials in the cause of death affect gender differentials in LEAB since 1980 (Ren, Zheng, and Cao 2005). However, this study does not address changes in the contribution of age pattern or cause of death to LEAB. Moreover, the analysis did not consider geographic location nor did it separate infancy from childhood in age groups. The analysis may have omitted important differences in LEAB resulting from location and infant mortality.

One methodological concern is that neither the discrete method nor the continuous method considers the heterogeneity in mortality of population with the same age. Heterogeneity in mortality is well-recognized (Vaupel, Manton, and Stallard 1979). Many frail persons could be saved by improved medical technology, thus the reserve capacity of each person with the same age to resist of external invasion of disease or even death varies in a given period. In other words, the number of their future person-year lived by persons saved due to medical technology is likely to be smaller than those with the same age but naturally selected persons. In order to take this into consideration, new formulas for decomposition need to be developed. In this regards, the continuous method is relatively easier to incorporate such factors than the discrete method.

Another concern is that our current study is unable to incorporate health status. Numerous studies have shown that in some countries, healthy life expectancy is advancing at a slower pace than total life expectancy (Robine and Michel 2004). Given that healthy life expectancy is more important to achieve the successful aging (Robine and Michel 2004), studies on decomposition of healthy life expectancy are clearly warranted.

Finally, this study only examined the effect of age-specific mortality change on the change in LEAB. We are unable to explore and quantify the causes that led to the change in mortality across ages by incorporating socioeconomic development, health policies, and so forth. Studies incorporate these factors in decomposing LEAB are necessary, which helps us to identify the general trend of major contributors to the change in LEAB across times and also has profound implications for public health policymaking. Another noteworthy issue is that future research should consider heterogeneity in mortality across its subpopulation differentiated by its social and spatial inequalities (Cook and Dummer 2003; Gao et al. 2002; Huang and Liu 1995).

CONCLUDING REMARKS

The uniqueness of this study lies in its decomposition of LEAB across seven decades from 1929/31 to 1999/2000 in China. During the seven decades, China witnessed numerous events such as civil wars, social disruptions, famines, social reforms, and rapid economic growth. The decomposition captures how these historical events affected LEAB, thus providing a relatively full spectrum of changes of LEAB in China over the 20th century. The annual increase of LEAB was the largest in the 1930-50 periods, while the increase in LEAB has been stable in the past two decades with 2-3 years each decade. Major factors contributing to these gains include the cessation of wars, societal institution changes, the establishment of healthcare system and epidemic control for the main infectious diseases, economic reforms, reproductive health promotion and women's empowerment, and socioeconomic development (Banister 1987; Banister and Hill 2004; Campbell 2001; Cook and Dummer 2004; Jamison et al. 1984).

It is clearly that the health status of the Chinese population has been dramatically improved over the past seventy years, and China's socioeconomic and public health development trajectory certainly follows the broad pattern of the traditional epidemiological transition model (Cook and Dummer 2003; Hsiao 1995). However, China's population faces challenges related to population aging, increasing population living with HIV/AIDS, and continued high use of tobacco combined with problems caused by rapid urbanization, emerging and re-emerging infectious diseases and widening inequalities in health and healthcare (Cook and Dummer 2003; Riley 2004). The future age pattern of the shared contribution to LEAB will be largely determined by solutions of these issues.

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Table 1 LEAB (years) by Sex and Residence, 1929/31 to 2000, China

	Year						
	1929/31	1936/41	1956/58	1973/75	1981/82	1989/90	1999/2000
Males (yrs)	***33.82***	***41.12***	***60.21***	***63.61***	***66.21***	***68.35***	***70.61***
Inc. as compared to the previous available year (yrs)	---	7.29	19.09	3.40	2.60	2.14	2.25
Annual inc. (yrs)	---	0.81	1.06	0.20	0.37	0.27	0.22
Females	***33.61***	***45.77***	***64.41***	***66.30***	***69.12***	***71.91***	***74.28***
Inc. as compared to the previous available year (yrs)	---	12.16	18.64	1.88	2.83	2.79	2.37
Annual inc. (yrs)	---	1.35	1.03	0.11	0.40	0.35	0.24
Males, Urban	***NA***	***NA***	***NA***	***NA***	***69.08***	***70.70***	***73.99***
Inc. as compared to the previous available year (yrs)					---	1.62	3.29
Annual inc. (yrs)					---	0.20	0.33
Females, Urban	***NA***	***NA***	***NA***	***NA***	***72.74***	***75.05***	***78.34***
Inc. as compared to the previous available year (yrs)					---	2.31	3.29
Annual inc. (yrs)					---	0.29	0.33
Males, Rural	***NA***	***NA***	***NA***	***NA***	***65.56***	***67.59***	***68.95***
Inc. as compared to the previous available year (yrs)					---	2.03	1.36
Annual inc. (yrs)					---	0.25	0.14
Females, Rural	***NA***	***NA***	***NA***	***NA***	***68.35***	***70.91***	***72.29***
Inc. as compared to the previous available year (yrs)					---	2.56	1.38
Annual inc. (yrs)					---	0.32	0.14

Note: NA, not available.

Table 2 Percentage of Total Contribution in Increased LEAB by Age and Sex, 1936/41 to 2000, China

	Period					
Ages	1936/41 vs 1929/31	1956/58 vs 1936/41	1973/75 vs 1956/58	1981/82 vs 1973/75	1989/90 vs 1981/82	1999/2000 vs 1989/90
Males						
0	3.9	36.1	-6.5	27.3	43.1	9.3
1-4	70.3	22.5	-7.2	47.3	21.4	9.0
5-14	38.9	5.6	-7.7	13.3	8.2	4.4
15-24	8.3	6.6	7.5	0.3	0.7	5.7
25-39	-2.0	12.0	19.4	4.8	0.9	3.1
40-59	-11.8	13.7	45.5	13.0	8.7	22.1
60-79	-7.0	3.4	45.9	-3.1	13.5	41.8
80+	-0.6	0.0	3.1	-3.0	3.6	4.5
Total	100.0	100.0	100.0	100.0	100.0	100.0
Females						
0	11.0	31.4	-3.4	15.9	19.2	-8.5
1-4	42.8	27.4	3.1	43.6	20.5	10.5
5-14	24.3	6.5	-15.4	12.5	7.4	4.4
15-24	12.2	6.8	9.6	1.4	1.3	10.4
25-39	7.3	11.5	18.9	7.6	8.8	9.9
40-59	2.4	10.8	34.5	15.9	14.9	25.8
60-79	0.4	5.0	50.2	8.0	20.0	40.6
80+	-0.4	0.6	2.5	-4.9	7.9	6.8
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 3 Percentage of Total Contribution in Increased LEAB by Age, Sex, and Residence, 1981/82 to 2000, China

Ages	Urban		Rural	
	1989/90 vs 1981/82	1999/2000 vs 1989/90	1989/90 vs 1981/82	1999/2000 vs 1989/90
Males				
0	37.5	13.5	46.2	-3.0
1-4	11.1	4.8	23.9	13.1
5-14	5.8	3.8	8.9	5.5
15-24	0.4	6.6	0.0	2.4
25-39	-1.4	4.9	0.9	-3.9
40-59	8.4	16.3	8.1	30.2
60-79	32.9	42.2	9.3	51.0
80+	5.3	7.9	2.7	4.6
Total	100.0	100.0	100.0	100.0
Females				
0	11.8	7.0	20.5	-48.6
1-4	16.7	5.4	22.5	17.0
5-14	3.8	2.8	7.9	6.6
15-24	2.9	6.0	1.2	13.9
25-39	6.6	5.9	8.6	13.5
40-59	19.2	20.0	14.6	36.7
60-79	29.0	40.0	18.8	51.6
80+	9.9	12.9	5.9	9.3
Total	100.0	100.0	100.0	100.0

Figure 1 Remaining Life Expectancy at Each Age by Sex, 1929-2000, China

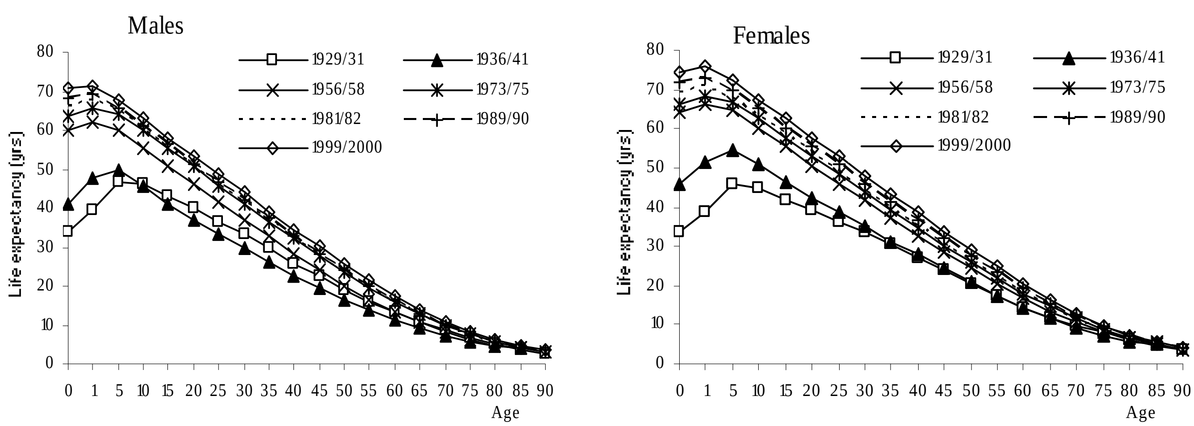


Figure 2 Decomposing the Gained LEAB by Age and Sex, 1936/41 to 2000, China

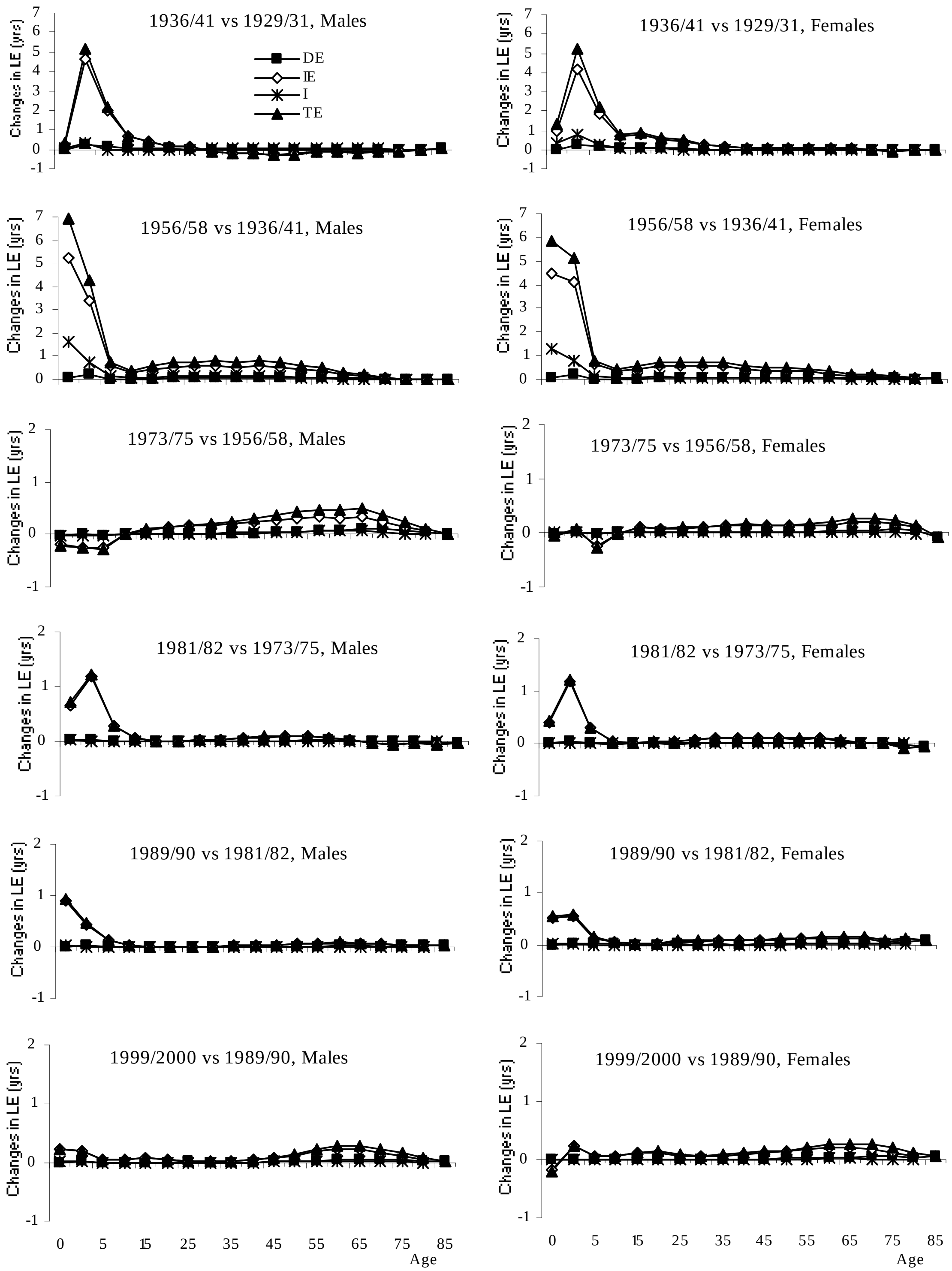
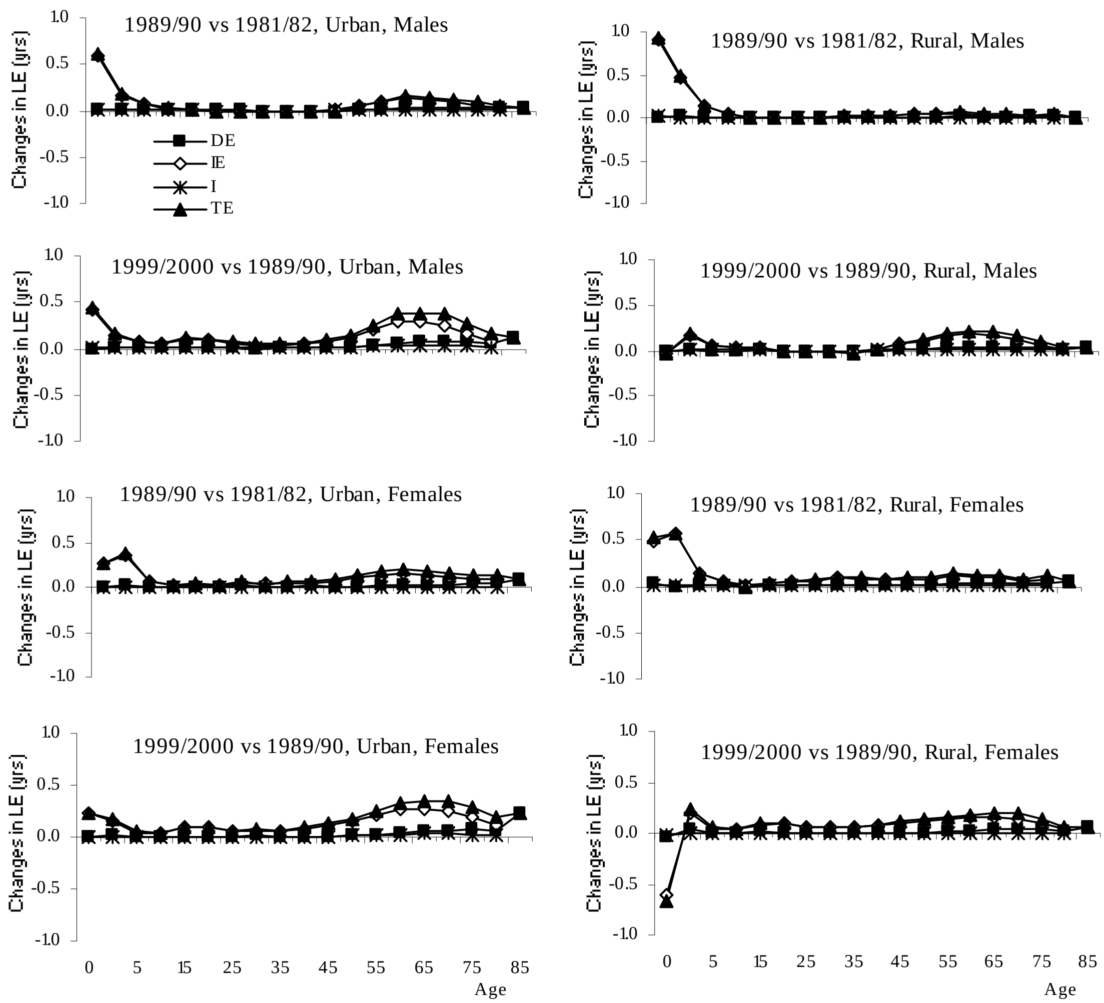


Figure 3   Decomposing the Gained LEAB by Age, Sex, and Residence, 1981/82 to 1999/2000, China



[1] The notations we use are slightly different from those in Arriaga's method. For detailed derivations, see Arriaga (1984).