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Forecasting China's Mortality[1]

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Abstract

China's life expectancy at birth is currently being debated; the 2010 census data may exaggerate the figure and its rate of increase. In this paper, with an extension of the Lee-Carter method for limited data, we use China's 1982, 1990 and 2000 censuses to forecast the mortality pattern and life expectancy for the 2000 to 2030 period. We find that the annual increase in life expectancy from 2000 to 2030 is predicted to be 0.18 years for males, and 0.23 years for females, and the infant mortality rate is predicted to decline to 10.39‰ in 2030 for males, and to 20.32‰ for females.

Keywords

Lee-Carter method, life expectancy at birth, infant mortality rate, China

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Introduction

The level of mortality in the countries around the world dropped rapidly between the 1950s and the beginning of the 21stcentury, while life expectancy increased dramatically. In 1950, 50% of the countries had a life expectancy of less than 50 years. By the beginning of the 21st century, the life expectancy in over half the countries had reached over 70 years. In addition, 25% of the countries saw their life expectancy rise to over75 years (Ren, 2007).

Enormous social changes took place in China in the 20th century. Both the level of mortality and life expectancy changed dramatically. In the period 1928-1931, the average male life expectancy among the peasant population in China was 34.9 years, and the figure for female peasant population was 34.6 years (Xu, 1960). At the beginning of the 1950s, the Chinese had a life expectancy of approximately 50 years, and this figure reached about 65 years in the early 1980s, 67.9 years in 1990, and 71 years in 2000 (Huang et al., 2008). Banister and Hill (2004) estimate that life expectancy increased 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. However, since the 21stcentury, scholars have begun to "question" the levels of mortality and life expectancy that the Government of China publishes. For example, in the "Report on the Work of the Government," delivered by Premier Wen Jiabao at the first session of the 11th National People's Congress on 5 March, 2008, life expectancy was mentioned to have reached 75 years in 2005. This figure was questioned by Professor Zhong Nanshan, President of the Chinese Medical Association, who was of the opinion that the figure could not represent the actual figure for the whole of China due to the fact that the observation points were mainly located in cities. The figure, as such, had overestimated the life expectancy of the Chinese population. However, based on the preliminary results from the sixth nationwide population census of 2010 in China, which provides rich data with regard to both the level of mortality and life expectancy, it is shown that that infant mortality is 3.82‰ (3.73‰ for male infants and 3.92‰ for female infants) (PCO, 2012). The calculation based on the census has shown that life expectancy is 77.9 years (75.6 years for men, and 80.4 years for women). It is obvious that these figures are, comparatively speaking, on the high side.

Apart from the dispute regarding both the level of mortality and life expectancy, the current retirement age and pension shortfall in China are also widely contentious. As far as the current legal retirement age in China is concerned, the overall average retirement age for the urban population is 56.1 years—58.3 years for men and 52.4 years for women (Human Resources Development Report (2011-2012)). The Ministry of Human Resources and Social Security has indicated that it will introduce a policy recommendation to postpone, in a flexible manner, the pension age on the basis of wide public consultations from all walks of life in response to a widening pension shortfall of income and expenditure. If the level of mortality drops and life expectancy increases, there will be a growing pension expenditure deficit with regard to individual old age social security accounts if the planned number of months for pension payment is not adjusted in response to the decreasing level of mortality and interest rate fluctuations (Wang and Ren, 2012).

The increasing life expectancy is a contentious issue in itself. Since the 1920s, almost all the assumptions about the maximum life expectancy made by scholars and institutions have been repeatedly broken by what has been actually observed. Oeppen and Vaupel (2002) have demonstrated that for 160 years the observed national maximum life expectancies have shown nearly linear growth. On average, the annual increase is 0.25 years (3 months). Oeppen and Vaupel (2002) believe that best-performance life expectancy has steadily increased by a quarter of a year per year, and that this trend will continue. However, many U.S. or international organizations do not agree with this view. For example, the United Nations (2005) forecasted in 2004 that the female US population would see a year on year increase of 0.11 year in life expectancy in the next 50 years, but Bongaarts (2006) believes that that life expectancy is likely to increase by an average of about 7.5 years over the next 50 years, i.e. 0.15 years per year on average.

It is necessary for us to predict the future level of mortality and the life expectancy in order to have a clear understanding of the current and future level of mortality and life expectancy, and issues that relate to retirement age and pension shortfall. Lee and Carter (1992) created the Lee-Carter mortality forecasting method. Based on the rich historical data on mortality, they used the method to undergo a stochastic forecast of the US mortality. The method was then greatly improved upon before being applied to those countries with limited data.

In what follows, we explain briefly an improved method that uses limited data to forecast mortality, introduce the basic data used, present the results and end with a conclusion.

Method[2]

Lee and Carter (1992) make use of the time series of mortality rate data for the $t(t = t_1, t_2, \cdots t_n)$ years. Based on the fact that the horizontal change is far more distinct than thepattern change in the change of the mortality rate, the method uses Singular Value Decomposition (SVD) to convert the age-specific death rates in terms of a time-varying parameter, i.e. a time series vector problem, into a time series single variable problem, and then

[2]For a detailed introduction of the method, please refer to Wang and Ren (2012).

uses the standard time series analysis method to undergo a stochastic death rate analysis of the US population. The formulae expression is as follows:

$$\ln m_x(t) = \alpha_x + \beta_x \kappa_t + \varepsilon_{x,t} \quad (1)$$

In which,

$$\hat{\alpha}_x = \frac{1}{t_n - t_1 + 1} \sum_{t=t_1}^{t_n} \ln \hat{m}_x(t) \quad (2)$$

And $\hat{\beta}_x$ and $\hat{\kappa}_t$ are generally obtained by applying SVD to the matrix $\ln \hat{m}_x(t) - \hat{\alpha}_x$ B. Bell(1997) used the latest observed death rates to carry out predicative forecasting, which produced a better result than $m_x(t_n)$. The expression is as follows:

$$\ln \dot{m}_x(t) = \ln \hat{m}_x(t_n) + \hat{\beta}_x\left(\dot{\kappa}_t - \hat{\kappa}_{t_n}\right), t > t_n \quad (3)$$

But in many developing countries, including China, the continuous death rate data over a long period of time is not available. In order to solve this problem, Li et al.(2004) presume that κ_t obeys a random walk process and introduce a forecasting expression for limited data.

Assuming that age-specific death rates $m_x(u_0), m_x(u_1), \cdots, m_x(u_T)$ for a total of T+1 years at different points in time u_0, $u_1, \cdots$, u_T ordered sequentially have been collected, the age-specific logarithmic mean is to be worked out first similar to the continuous Lee-Carter method:

$$\hat{\alpha}_x = \frac{1}{T+1} \sum_{t=0}^{T} \ln \hat{m}_x(u_t) \quad (4)$$

Then , apply SVD to the matrix $\ln \hat{m}_x(u_t) - \hat{\alpha}_x$ to obtain the corresponding $\hat{\beta}_x$ and $\hat{\kappa}_{u_0}, \hat{\kappa}_{u_1}, \cdots, \hat{\kappa}_{u_T}$. As for the time factor, the floating random-walk model is used for fitting:

$$\hat{\kappa}_{u_t} - \hat{\kappa}_{u_{t-1}} = d\left(u_t - u_{t-1}\right) + \left(\varepsilon_{u_{t-1}+1} + \varepsilon_{u_{t-1}+2} + \cdots, \varepsilon_{u_t}\right) \quad (5)$$

In $\varepsilon_i \sim N\left(0,\sigma^2\right)$, σ is a constant. The unbiased estimator of the floating parameter d can be obtained by using the following expression:

$$\hat{d}=\frac{\sum_{t=1}^{T}\left(\hat{\kappa}_{u_t}-\hat{\kappa}_{u_{t-1}}\right)}{\sum_{t=1}^{T}\left(u_t-u_{t-1}\right)}=\frac{\hat{\kappa}_{u_T}-\hat{\kappa}_{u_0}}{u_T-u_0} \quad (6)$$

The variance σ^2 can be obtained by using the following expression:

$$\hat{\sigma}^2=\frac{\sum_{t=1}^{T}\left[\left(\kappa_{u_t}-\kappa_{u_{t-1}}\right)-d\left(u_t-u_{t-1}\right)\right]^2}{u_T-u_0-\frac{\sum_{t=1}^{T}\left(u_t-u_{t-1}\right)^2}{u_T-u_0}} \approx \frac{\sum_{t=1}^{T}\left[\left(\kappa_{u_t}-\kappa_{u_{t-1}}\right)-\hat{d}\left(u_t-u_{t-1}\right)\right]^2}{u_T-u_0-\frac{\sum_{t=1}^{T}\left(u_t-u_{t-1}\right)^2}{u_T-u_0}} \quad (7)$$

The estimated standard deviation of the floating parameter d is $\sqrt{\operatorname{var}\left(\hat{d}\right)}$, which can be obtained by using the following expression:

$$\sqrt{\operatorname{var}\left(\hat{d}\right)}=\sqrt{\frac{\operatorname{var}\left[\sum_{t=1}^{T}\left(\varepsilon_{u_{t-1}+1}+\varepsilon_{u_{t-1}+2}+\cdots,\varepsilon_{u_t}\right)\right]}{\left(u_T-u_0\right)^2}}=\sqrt{\frac{\sigma^2}{u_T-u_0}} \approx \frac{\hat{\sigma}}{\sqrt{u_T-u_0}} \quad (8)$$

When $t>u_T$, κ_t produces the estimate, i.e.:

$$\dot{\kappa}_{u_{T+1}}=\hat{\kappa}_{u_T}+d+\varepsilon_{u_{T+1}} \quad (9)$$

Additionally, Han and Wang (2010) believe that $d=\hat{d}+\xi$, $\xi \sim N\left(0,\operatorname{var}\left(\hat{d}\right)\right)$, and when the sample size is relatively small, the volatility of ξ should not be ignored. The effect of ξ should be included in the κ_t modelling so that the predicted value of the time factor κ_t at any time is：

$$\dot{\kappa}_{u_{T+k}}=\hat{\kappa}_{u_T}+\sum_{i=1}^{k}\left(\hat{d}+\xi_i\right)+\sum_{j=1}^{k}\varepsilon_{u_{T+j}}=\hat{\kappa}_{u_T}+k\hat{d}+\sum_{i=1}^{k}\xi_i+\sum_{j=1}^{k}\varepsilon_{u_{T+j}} \quad (10)$$

In which $\zeta=\sum_{i=1}^{k}\xi_i \sim N\left(0,k\times\operatorname{var}\left(\hat{d}\right)\right)$, $\zeta=\sum_{j=1}^{k}\varepsilon_{uT+j} \sim N\left(0,k\times\sigma^2\right)$。

Using the above model, Han and Wang (2010), as well as Wang and Ren (2012), made use of different data to forecast China's mortality. The data used by Han and Wang (2010) are from Chinese cities and they focused on pension insurance. As such, the research is oriented towards the life expectancy of 60-year-old men and women in cities. The research undertaken by Wang and Ren (2012) was also oriented towards the analysis of pension insurance. Based on the mortality rate data from three of China's censuses, which were carried out in 1982, 1990 and 2000, the above method was used for forecasting. Apart from paying attention to the decrease in male and female mortality rates, we, however, also keep an eye on the decrease in life expectancy and infant mortality. This approach not only provides a basis for the adjustment of life expectancy and infant mortality in the 2010 census, but also, hopefully, is able to grasp future changes in the life expectancy of the Chinese population.

Data

China conducted three national censuses: in 1982, 1990 and 2000. Because the Chinese adopt Shengxiao (a lunar marking of years with twelve animals) to mark years, and almost everyone knows the animal corresponding to the year when he or she was born, it is possible to calculate one's age according to Shengxiao. Therefore, in each census there is little misreporting and age heaping, and the reporting of ages is rather accurate (Coale, 1984; Coale and Banister, 1994). After misreporting and age heaping are checked with Whipple's index and Myer's index, it is found no significant age preference and heaping exist in the censuses (Qiao, 1992; Li and Sun, 2003).

However, because the collected mortality data in the censuses are retrospective, deaths are underreported (Li and Sun, 2003). Many scholars have analysed the mortality data from these three censuses (Jiang et al., 1984; Huang, 1994; Li and Sun, 2003; Banister and Hill, 2004), and there exist some discrepancies in their findings. Huang et al. (2008) have provided mortality rate data obtained from the three censuses carried out in 1982, 1990 and 2000. Since the data come from the analysis by the authors into these three censuses, data consistency is generally good and is also very close to the life expectancies and infant mortality rates published by the government. As such, their data will be used here as the basis for the forecast. We have reproduced below the sex-specific life expectancies and infant mortality rates obtained from the three censuses carried out in 1982, 1990 and 2000 provided by Huang et al. (2008).

Table 1. Life expectancies and infant mortality rates from three censuses

Census year	Life expectancy (years)		Infant mortality rate (‰)	
	Male	Female	Male	Female
1982	63.64	66.51	53.86	50.42
1990	66.62	69.17	39.22	43.96
2000	69.17	72.72	28.85	35.40

Results

First, let us examine the mortality rate changes. Table 2 shows as the age increases, the mortality rate for each age group has a general downward trend. For the 0 age group, the mortality rate is relatively high, which indicates that a baby has a higher mortality rate soon after birth. The rate starts to go down for the 1-4 age group with the lowest rate likely being recorded for the 10-14 age group. After that, as the age increases, the mortality rate gradually increases. The increase is relatively stable from the 15-19 to 60-64 age groups. Starting from the 65-69 age group, the mortality rate increases rapidly as the age increases. The observation of the mortality rate for the same year and the same age group with different sexes shows that except the 0 age group, the mortality rate for females is lower than that for males across all age groups.

Table 2. Age-specific mortality rate forecast for 2010, 2020 and 2030（‰）

Age group	2010		2020		2030	
	Male	Female	Male	Female	Male	Female
0	20.53	29.42	14.61	24.45	10.39	20.32
1-4	1.01	0.76	0.63	0.41	0.39	0.22
5-9	0.39	0.27	0.24	0.14	0.14	0.07
10-14	0.31	0.13	0.20	0.06	0.01	0.02
15-19	0.57	0.21	0.40	0.09	0.28	0.04
20-24	1.17	0.38	1.00	0.20	0.85	0.11
25-29	1.48	0.56	1.38	0.37	1.29	0.24
30-34	1.97	1.02	1.94	0.86	1.91	0.73
35-39	2.53	1.60	2.46	1.54	2.39	1.48
40-44	3.40	2.40	3.22	2.38	3.04	2.37
45-49	4.62	3.37	4.17	3.19	3.77	3.03
50-54	6.68	4.74	5.77	4.21	4.98	3.73
55-59	10.15	7.38	8.62	6.43	7.32	5.60
60-64	15.90	8.97	12.94	6.85	10.52	5.24
65-69	25.04	16.50	20.31	13.24	16.47	10.62
70-74	44.85	33.00	37.57	28.10	31.47	23.92
75-79	78.36	58.84	69.31	52.74	61.30	47.27
80-84	160.29	100.23	177.05	90.02	195.56	80.85
85-89	179.19	145.58	159.79	130.08	142.48	116.23
90-94	257.65	236.03	230.96	216.81	207.04	199.17
95-99	289.05	259.72	251.81	225.59	219.36	195.94
100+	433.73	355.01	422.95	335.87	412.43	317.77

Next, let us take a look at the life expectancy changes. As far as the life expectancy median age

Table 3. Life expectancies over the years（years of age）

Year	Male			Female		
	Median age	Upper limit	Lower limit	Median age	Upper limit	Lower limit
2000	69.17	-	-	72.72	-	-
2001	69.37	69.66	69.08	72.93	74.04	71.70
2002	69.61	70.01	69.19	73.18	74.69	71.44
2003	69.84	70.32	69.34	73.42	75.21	71.30
2004	70.06	70.60	69.49	73.65	75.67	71.22
2005	70.28	70.87	69.66	73.88	76.08	71.19
2006	70.50	71.13	69.83	74.11	76.47	71.19
2007	70.71	71.38	70.00	74.33	76.82	71.21
2008	70.92	71.62	70.17	74.55	77.16	71.25
2009	71.12	71.85	70.34	74.76	77.48	71.30
2010	71.32	72.08	70.51	74.97	77.79	71.37
2011	71.52	72.29	70.68	75.18	78.08	71.45
2012	71.71	72.50	70.85	75.38	78.37	71.53
2013	71.90	72.71	71.02	75.59	78.64	71.62
2014	72.09	72.91	71.19	75.78	78.91	71.72
2015	72.27	73.10	71.36	75.98	79.17	71.83
2016	72.45	73.29	71.52	76.17	79.42	71.94
2017	72.62	73.47	71.69	76.36	79.67	72.05
2018	72.80	73.65	71.85	76.55	79.91	72.17
2019	72.96	73.82	72.01	76.74	80.15	72.28
2020	73.13	73.99	72.17	76.92	80.38	72.41
2021	73.29	74.16	72.32	77.10	80.61	72.53
2022	73.45	74.32	72.48	77.28	80.84	72.65
2023	73.61	74.48	72.63	77.46	81.06	72.78
2024	73.76	74.63	72.78	77.63	81.27	72.91
2025	73.91	74.78	72.93	77.80	81.49	73.04
2026	74.06	74.92	73.07	77.97	81.70	73.17
2027	74.20	75.06	73.22	78.14	81.90	73.30
2028	74.34	75.20	73.36	78.31	82.11	73.43
2029	74.48	75.34	73.50	78.48	82.31	73.56
2030	74.62	75.47	73.64	78.64	82.51	73.69

in table 3 is concerned, the life expectancy shows an upward trend for both males and females. From 2000 to 2030, the male life expectancy would increase from 69.17 years to 74.62 years. The overall increase within 30 years is 5.45 years with an average annual increase of 0.18 years. Between 2000 and 2010, the annual increase is 0.22 years; between 2010 and 2020, the annual increase is 0.18 years; between 2020 and 2030, the annual increase is 0.15. The female life expectancy increases from 72.72 years in 2000 to 78.63 years in 2030. The overall increase within 30 years is 5.92 years. Between 2000 and 2010, the annual average increase is 0.23 years; between 2010 and 2020, the annual increase is 0.20 years; between 2020 and 2030, the annual increase is 0.17 years.

Finally, let us examine the changes with regard to the infant mortality rate. As shown in figure 1, the infant mortality rate has an overall downward trend over time. The rate for male infants decreases from 28.85‰ in 2000 to 10.39‰ in 2030, while the figure for female infants decreases from 35.40‰ in 2000 to 20.32‰ in 2030.

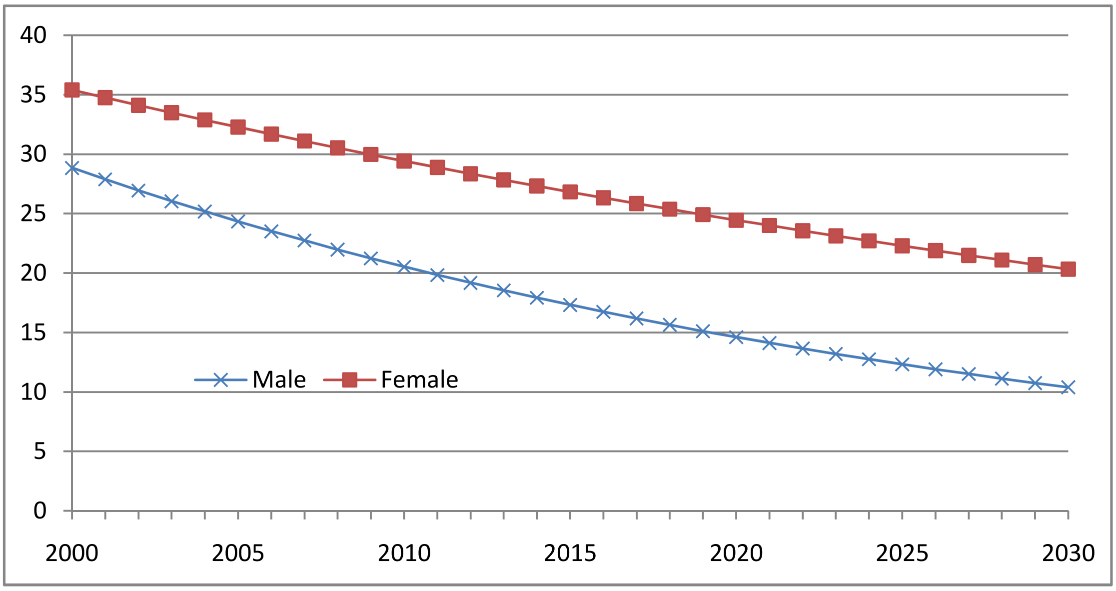

Figure 1. Infant mortality rate (per thousand)

Discussion

In 2008, the Ministry of Health of China launched a strategic study, entitled "Healthy China 2020," which sets out policies in areas, such as public health and drug policies, in order to promote good health in China. On 17 August, 2012, the Chinese Ministry of Health published a document entitled "A Strategic Research Report on 'Healthy China 2020'", according to which the life expectancy will have reached 77 years by 2020. However, based on the historical data, our own research forecast shows that the male life expectancy in China will likely reach73.13 and the female life expectancy will probably reach76.92 by 2020. There is clearly a discrepancy between our forecast and the data in the above strategic research report. Even if we have overestimated the mortality rates and underestimated life expectancies prior to 2000 and only use the contentious figure of 73 years for 2005, it would still mean that the life expectancy would have to increase by 4 years over a 15-year period from 2005 to 2020. To achieve this target, the life expectancy would have to increase by 0.27 years annually. However, the annual increase of the best-performance life expectancy observed by Oeppen and Vaupel (2002) over a 160-year period is 0.25, and Bongaarts (2006) believes that life expectancy is likely to increase by an average of 0.15 years per year over the next 50 years. Both figures are lower than the expectancy figure detailed in the "A Strategic Research Report on 'Healthy China 2020'".

In 2011, the Chinese Ministry of Health published a document entitled "Annual Development Report on Health Care for Women and Children", which pointed out that in 2010, the national infant mortality rate was 13.1‰, a decrease of 59.3% compared with 2000. This means that the infant mortality rate was 32.19‰ in 2000. This figure is close to our own figure as shown in table 1. However, in the last ten years, the infant mortality rate calculated by the government has decreased far too rapidly.

With the economic development and an increase in living standards, the mortality rate has declined and life expectancy has increased. Under the circumstances of low income and low life expectancy, the average life expectancy will increase by a relatively large margin when there is a small increase in the national per capita income. When the national per capita income reaches a certain level, average life expectancy will increase relatively slowly (Preston, 1975). Since China is currently experiencing steady economic development, the environment for a dramatic drop in the mortality rate or a rapid increase in life expectancy does not exist. In addition, because environmental pollution has a distinct impact on human health and mortality, it can be foreseen that the mortality rate in China will not decrease very rapidly (Huang, 2002). How to provide accurate data with regard to the level of mortality and life expectancy by making use of more data sources and more accurate methods is a pressing problem to be solved.

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