Healthy Life Expectancy Among Elderly People in China An Estimation Using Multistate Life Table Method

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Abstract:

Examination of healthy life expectancy from cognitive dimension has long been overlooked in ageing studies. Using the longitudinal database of China Health and Retirement Longitudinal Survey during 2011-13, this study fills this gap by computing active healthy life expectancy, cognitive-impairment-free life expectancy and healthy life expectancy of China's elderly population by using the multistate life table method. The study estimates that the three types of life expectancy were 19.39 years, 9.96 and 9.26 respectively at age 60 during the period of 2011-13. Significant differentials were identified across genders, urban-rural divide, regions, marital statuses, educational levels and health statuses at age 60. Results show that Chinese elderly people who are male, live in urban areas or the East Region have longer cognitive-impairment-free life expectancy, and that those who live with spouse, more educated and healthy at age 60 tend to have longer years in all three types of healthy life expectancy.
Keywords: population ageing, healthy life expectancy, the multistate life table method, cognitive-impairment-free life expectancy, longitudinal studies

Introduction

The world in recent centuries had experienced profound demographic transition driven by a drop in fertility at first and a decrease in mortality in a later phase (Kirk, 1996; Reher, 2015). Declining mortality contributed to an increase in average life expectancy worldwide from 46.9 years old in 1950 to 72.0 in 2016 (UN, 2017b), being a main driver accelerating global population ageing process (UN, 2017a).

China has also seen a rapid demographic transition in the past several decades (Banister et al., 2004). Due to the implementation of dramatic family planning policy, age structure of China's population has changed dramatically. Average life expectancy in China had steadily climbed from 47.3 years in 1953 to 76.4 in 2015 (Zhang, 2016), seeing the size of population aged 60 or over expanding from 129 million in 2000 to a stunning number at 240 million in 2017 (Ministry of Civil Affairs of People's Republic of China, 2018). Given the severity of impending population ageing in China, the country is confronting with a considerable challenge of aged care ahead (Yang, 2005).

As more people are ageing, one important question is how many years could be spent independently after retirement. To analyze the issue, many studies used healthy life expectancy (HLE) as an indicator to represent the average years of expected healthy or specific-disease-free time in the remaining life (Sanders, 1964; Dubois et al., 2006). The indicator is able to integrate the information of mortality and morbidity, being used to assess the quality of public health during the past few decades (Mathers et al., 2001).

A growing body of empirical research on elderly population's HLE, primarily based on the experience in industrialized countries, have been conducted since 1980s (Crimmins et al., 1997; Bajekal, 2005; Jagger et al., 2011; WHO, 2018). A significant global inequality of HLE at age 60 was noted by various research (Mathers et al., 2001; Mathers et al., 2003; Salomon et al., 2012). For instance, Japan led the longest HLE at age 60 at 18.7 years for males and 22.9 for females in 2016 while figures for most Sub-Sahara African countries stood below 15 years for both sexes (WHO, 2018). Salomon et al. (2012) reported most countries experienced a steady improvement of HLE at age 60 by over 1 year during 1990-2016. Socioeconomic differentials of HLE among elderly population, such as by gender, race and educational level, were also reported (Cambois et al., 2001; Sagardui-Villamor et al., 2005). The socioeconomic differentials of elderly population's HLE might be interpreted by a joint explanation rooting in multi-discipline mechanism, including sociology, biology and psychology (Gjonça et al., 2005; Austad, 2006; Barford et al., 2006; Oksuzyan et al., 2008). A comprehensive summary of how HLE differs between different socioeconomic dimensions was provided in the study of Jagger et al. (2011).

As more evidence of elderly population's HLE was reported, two significant limitations can be identified in the existing literature. One is that, thus far, the experiences of countries other than industrialized world were inadequately understood. Jagger et al. (2011) reported that among over 700 existing studies on HLE, 90% of them concentrated on the industrialized world, of which mostly are Western countries that have experienced population ageing in the past. The other one is that most existing research on elderly population's HLE only focused on physical aspect of health while examination from the cognitive dimension has long been overlooked. As deterioration of cognition function is recognized an important factor on the quality of life at old ages (Dubois et al., 2006), estimation of elderly population's HLE from cognitive aspect of health is much needed.

This study presents an examination on elderly population's HLE in China, the most populous country that has recently started a rapid process of industrialization and is currently experiencing profound population ageing. The study adopts a comprehensive measurements of health including both physical and cognitive aspects, leading extensive discussions on geographical and socioeconomic differentials of HLE of Chinese elderly population to better understand the status quo of China's elderly health. The study also sheds some new lights on China's elderly health assessment, and informs better policy formulation into optimizing China's nation aged care system to address the profound aged care challenges ahead.

This research aims to achieve the following two objectives. Firstly, it measures the length of HLE of Chinese elderly population along with two sub-indicators, active life expectancy (ALE) and cognitive-impairment-free life expectancy (CIFLE), to compare physical and cognitive aspects of health among Chinese elderly population. Secondly, it examines the difference of HLE of Chinese elderly population by gender, urban-rural divide, region, marital status, educational level and health status at age 60 to capture demographic, geographic and socioeconomic characteristics of elderly health. This is the first study that measures CIFLE of Chinese elderly population, and also the first study analyzing the characteristics of elderly HLE in China by marriage, educational level and health status at age 60. The results from this study will fill the two major gaps in the literature identified above.

The remainder of this paper is organized as follows. Section 2 reviews current knowledge of HLE of elderly population in the literature. Section 3 introduces the database and methodology, and Section 4 presents the results of analysis. Discussion and conclusion are presented in Section 5.

Background and Literature

Healthy life expectancy (HLE) was first proposed by Sanders (1964) who claimed the measurement of morbidity-free life expectancy, or healthy life expectancy, would be more favorable for evaluating the quality of public health when mortality had widely decreased to a very low level in most communities. Following Sander's idea, Sullivan (1971) conducted the first empirical study of HLE in the US and found that the average ALE in the US was 64.9 years at birth and 11.3 years at age 65 with significant gender and racial differentials identified.

As the unprecedented trend of population ageing began to sweep the world since the 1970s, growing concerns have been raised on HLE of the expanding elderly population. An increasing number of research on HLE of elderly population have investigated different lengths of HLE at age 60/65 and also examined corresponding differentials by period, space, gender and other socioeconomic aspects in the US (Crimmins et al., 2001), Japan (Yong et al., 2009) and European countries (Mathers et al., 2003; Sagardui-Villamor et al., 2005; Jagger et al., 2011).

Current research indicate that elderly population in the developed nations generally have higher HLE compared with their counterparts in the developing nations. For example, ALE at age 65 for men and women were 13.7 and 15.2 years in 2000 in Italy (Burgio et al., 2009), 11.8 and 13.6 during 1982-84 in the US (Manton et al., 1991), while only 9.0 and 9.1 in 2004 in Cambodia (Zimmer, 2006), and 10.1 and 7.6 in 2007 in Thailand (Karcharnubarn et al., 2013). Moreover, the prolongation of HLE of elderly population in industrialized countries has been larger than that of unindustrialized countries as well. WHO (2018) noted that Singapore experienced the longest extension of HLE at age 60 by 3.5 years during 2000-16, whereas Guyana merely had a growth by 0.1 simultaneously. Such considerable global disparities of elderly population’s HLE have been interpreted by multi-aspects, including differentials in economic development level, public health expenditure and distribution systems of social wealth across nations (Mathers et al., 2003).

In addition to spatial difference, HLE of elderly population also varies by gender, race and educational attainment (Crimmins et al., 2001; Jagger et al., 2011). Burgio et al. (2009) noted that while men have shorter absolute length of ALE than women, male ratio of ALE/TLE at age 65 are significantly higher than that of females. The study of Burgio et al. (2009) reported that the ratio of ALE/TLE for men and women were 52.2% and 36.1% in Finland, 52.0% and 40.3% in Portugal, 47.6% and 40.5% in France, as well as 64.1% and 47.0% in Germany. Jagger et al. (2011) reported that elderly men in the US with at least 12 education years had ALE at 12.8 years at age

65, significantly higher than the ALE (10.3 years) of those only with up to 9 education years. Crimmins et al. (2001) noted that amongst male elderly people with up to 8 education years, ALE of African American at age 65 stood at 5.1 years while corresponding figure for White American could reach 6.3 years.

In China, the body of studies on HLE of elderly population has been growing since about 2000. One of the pioneering research (Li et al., 2002) on HLE of elderly population suggested that ALE of elderly population in Beijing was 11.6 years for males and 12.1 for females in age group 60-64 in the mid-1990s. Studies on HLE of Chinese elderly population in following years reported different results of ALE at national level, with a focus on how ALE varies by geographical division, such as Gao et al. (2016) that investigated HLE of Chinese elderly population by urban and rural areas and Zhang et al. (2009) by region. A recent study conducted by Qiao et al. (2017) reported difference of HLE at age 60 by provinces in China, stating that in 2010, Shanghai ranks the highest on the length of ALE at age 65 (14.27 years for males and 16.10 for females) while Tibet ranks the lowest (9.14 for males and 10.39 for females). A few studies also examined the trend of HLE of Chinese elderly population in past decades with controversial results reported. Zeng et al. (2007) identified that the ratio of ALE/TLE had been expanding among China's oldest old between 1998-2000 while Zhang et al. (2009) reported a declining trend of the ratio of ALE/TLE of elderly population in China's most regions between 1994-2004. It is noted that most of existing research on HLE among elderly population in China has focused on physical aspects of HLE and has not shifted attention on differentials of

HLE from more dimensions other than geographic perspective.

Some international organizations also estimated HLE of China's elderly population. WHO (2018) suggested that HLE at age 60 in China experienced a steady increase from 14.6 years in 2000 to 15.7 in 2015, seeing figures rising from 13.9 to 15.0 for males and from 15.4 to 16.6 for females. It also noted that, interestingly, China's HLE at age 60 tended to stand at similar level of the corresponding average level in the world while, contrarily, China's HLE at birth was persistently three years higher than corresponding global average level, as shown in Figure 1.

[Figure 1 here]

As noted above, the existing literature on HLE of Chinses elderly population suffer from a number of limitations. Firstly, existing studies mostly focused on the measurement of ALE but overlooked the assessment of cognitive-impairment-free life expectancy (CIFLE) (Zhang et al., 2009; Gao et al., 2016; Qiao et al., 2017), which may lead to an overestimated HLE of elderly population for ignoring the demand for care services from cognitively impaired elderly. Secondly, some important socioeconomic characteristics of elderly population's HLE in China, such as differentials by education and marriage, have not been adequately investigated yet (Tang et al., 2005; Liu et al., 2009; Qiao et al., 2017). Thirdly, elderly people's health status at age 60, an initial entrance status to ageing, has not been taken into consideration when investigating the characteristics of HLE of elderly population, overlooking the strong relationship between health status at age 60 and beyond (Liu et al., 2009; Zhang et al., 2009). This study fills these major gaps in the literature by examining HLE of China's elderly population based on an enhanced health measurement from a wide array of socio-demographic dimensions, providing a more nuanced understanding on China's elderly health, which will contribute to the future formulation of China's elderly support policy and practice.

Data and Methodology

Data

The present study adopts the database of China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal survey conducted by Peking University of China. This database is chosen as it provides comprehensive longitudinal socioeconomic and health information from 17,708 Chinese residents aged 45 years or over in its three waves in 2011, 2013 and 2015 respectively. Physical and cognitive health of China's elderly population were well measured in CHARLS tracking how elderly people's health status changes over time. The research design of CHARLS had been discussed elsewhere (Zhao et al., 2012). The database of the first two waves of CHARLS were included in this study as the death information of CHARLS in 2015 wave was unavailable when the present research was conducted. Description of the selected 6,635 respondents aged 60 or over is shown in Table 1.

Measurement of Variables.

Physical Health Variable

Physical function in CHARLS is measured by Activities of Daily Living (ADL) scale. The ADL scale includes six questions to capture people's various abilities, including showering, self-feeding, dressing, using the toilet, getting into or out of bed, and controlling urination and defecation (Katz, 1983). Four options were provided following these six questions in CHARLS: 1) “No, I don’t have any difficulty”, 2) “I have difficulty but can still do it”, 3) “Yes, I have difficulty and need help” and 4) “I cannot do it”. Respondents who chose the third or fourth option would be considered as disable to conduct related activity independently in this study. Those who have any ADL disability were regarded as physically inactive otherwise physically active when estimating physical aspect of HLE. The reliability of ADL scale generated from the six questions in the two waves of data were high (Cronbach’s $\alpha = 0.82$ for CHARLS 2011, and 0.84 for CHARLS 2013).

Cognition Health Variable

Cognitive function was measured by widely used simplified Chinese version of the Mini-Mental State Examination (MMSE) scale in CHARLS, which detects various cognitive abilities, including words recall ability, Telephone Interview of Cognitive Status (TICS), and ability to draw a figure. Words recall ability test measures the episodic memory by asking respondents to recall ten nouns read by interviewers ten minutes before. TICS detects mental capacity of respondents by their awareness of the exact date of interview (year, month, day, season and the day of the week) as well as their ability to calculate 5 subtractions by 7 from 100. Ability to draw a figure evaluates the ability of respondents to draw two overlapped pentagons showed by interviewers. The total score of the simplified Chinese version of MMSE scale in CHARLS ranges from 0 to 21. The reliability of the simplified Chinese version of

MMSE scale generated from the 21 questions were also high (Cronbach's $\alpha = 0.87$ for CHARLS 2011, and 0.88 for CHARLS 2013)

Simplified Chinese version of MMSE scale was culturally translated from the international version of MMSE scale to adapt to cultural and socioeconomic conditions of China's elderly population (Zhang, 2006). Most previous studies chose 18 scores (moderate/severe cognitive impairment) as the criteria of cognitive impairment for Chinese elderly as the majority of elderly population in China has very low educational attainment (Yu et al., 1989; Gu et al., 2003; Nguyen et al., 2003; Zhang, 2006). A low level standard of cognitive impairment can reduce the possibility of measurement errors (Folstein et al., 1975; Zhang et al., 1990) as scores in MMSE might be underestimated for less educated people due to their unfamiliarity and anxiety when taking test (Zhang, 2006). The practice of choosing a lower criteria of MMSE for less educated population had also been applied in some studies in Western countries (Matthews et al., 2009). Consistent with previous studies, this study adopts 18 scores as cognitive impairment standard, which is proportionately 12 scores in CHARLS (CHARLS has technically and carefully reduced the number of questions from 30 to 21 (Hu et al., 2012)).

Socio-Demographic Variables

This study considers those who didn't have any ADL disabilities and cognitive impairments as overall healthy, as showed in Table 2. This improved indicator includes both physical and cognitive conditions, which differs from measurements used in many existing studies. According to the improved measurement, baseline description of physical and cognitive health statuses in 2011 has been presented in Table 1 while transition relationships between different health statuses during 2011-13 are illustrated in Figure 2. As presented, Table 1 suggests that 10.18% of respondents were physically inactive and 31.49% cognition-impaired in 2011.

This study examines the differentials of HLE, ALE and CIFLE from a wide array of social demographic dimensions, including age, gender, urban-rural divide, region, marital status, educational level and health status at age 60. These dimensions reflect social and economic stratification in Chinese society, which has been experiencing rapid and consequential socioeconomic change in the past decades (Wu et al., 2018). Examinations from age-gender dimension provides insights into overall health inequality between sexes and different birth cohorts in China, which experienced substantially hard living conditions when China was still an extremely undeveloped country. A better understanding on elderly health inequality will be captured by exploring HLE from the perspective from urban-rural divide and region since China has experienced a significantly uneven regional development in the past decades (Wu et al., 2018). Dimensions of marital status, educational level and health status at age 60 are rarely examined in the literature and examinations from these dimensions would contribute to a more comprehensive understanding on health inequality among elderly population regarding its socioeconomic aspect.

Among the selected geographic and sociodemographic variables, region was divided into three categories, the East Region, the Middle Region and the West Region according to the standard of National Bureau of Statistics of China (2016).

The East Region and the West Region both includes 10 provinces (for the East Region: Fujian, Hebei, Beijing, Jiangsu, Guangdong, Liaoning, Shanghai, Tianjin, Zhejiang and Shandong, and for the West Region: Yunnan, Qinghai, Sichuan, Xinjiang, Inner Mongolia, Chongqing, Gansu, Guangxi, Shanxi and Guizhou) while the Middle Region includes 8 (Jiangxi, Heilongjiang, Shanxi, Jilin, Anhui, Hubei, Henan and Hunan). The other variables were dichotomized into two groups: marital status was dichotomized into "in marriage" (married and also lived with spouse) and "not in marriage" (including devoiced, spouse passed away and never unmarried) while educational level into "illiterate" and "non-illiterate" according to whether or not respondents had attained primary school education. Health status at age 60 was also dichotomized into "healthy" and "unhealthy" according to whether or not respondents reached the standard of health definition at age 60.

[Table 1 here]

[Figure 2 here]

[Table 2 here]

Methodology

The study employs the multistate life table method to compute HLE (Gu et al., 2001). This method can measure transition probability from one health status to another and compute expected life expectancy of different health statuses by constructing multistate life tables. The rationale of adopting the multistate life table method instead of the most widely used Sullivan method (Sullivan, 1971; Dubois et al., 2006) is that the multistate life table method allows transition between different health statuses, which is superior to the stationary assumptions used in Sullivan method. The multistate life table method also allows the comparison of HLE between different subpopulation groups, such as by marital statuses or educational levels, which cannot be achieved by Sullivan method due to commonly limited availability of life tables from the socioeconomic dimensions (Jagger et al., 2011).

Estimation of Transition Possibility

The multistate life tables in this study were constructed involving following procedures, which have been widely used in the empirical studies of demographic and actuarial analysis (Jagger et al., 2011; Chen et al., 2017) but has not adequately applied in understanding HLE of elderly population in China.

First, we estimated the parameters that represented transition possibility between the initial and terminal health statuses. The study defined H_x^i as health status *i* at age *x* and H_{x+t}^j as health status *j* at age *x+t* (*i* and *j* represented different health statuses). According to the Markov hypothesis, we assumed that the status at age *x+t* was only depended by the status at age *x* and with no relationship to any status before age *x*. Under this hypothesis, transition possibility from status *i* at age *x* in 2011 to status *j* at aged *x+t* in 2013 was denoted as $P_{x,x+t}^{i,j}$:

$$P_{x,x+t}^{i,j} = \frac{H_{x+t}^j}{H_x^i}$$

Then, multinomial logit models were used to parameterize transition possibility. If the status *i* was established, multinomial logit models could be constructed as follows:

$$\ln \frac{P_{x,x+t}^{i,j}}{P_{x,x+t}^{i,i}} = \alpha_{i,j}(t) + \beta_{i,j}(t)x, i \neq j$$

In the logit model above, *x* denoted age, and $\alpha_{i,j}$, $\beta_{i,j}$ represented parameters that would be estimated by the maximum likelihood estimation method. As the multinomial logit model above only illustrated differentials of HLE by age, other variables were added into the logit models to examine differentials of HLE by more socio-demographic dimensions. For example, gender was included into the logit model above for analyzing age-gender specific HLE, and subsequently educational level was introduced, so age-gender-specific HLE by educational levels could be examined.

Next, likelihood ratio *chi* test was adopted to examine the significance of each logit model. Results showed the absolute values of -2 long likelihood (-2LL) in likelihood ratio *chi* test for each nested model (e.g. gender-age-education) were all less than previous model (e.g. gender-age), and the difference values between the nested model and the previous model were all significantly greater than the corresponding critical value of likelihood ratio *chi* test, which means differentials of HLE by corresponding variables were statistically significant. Results of the likelihood ratio *chi* test have been presented in Table 3.

Construction of Multistate Life Tables

After obtaining $P_{x,x+t}^{i,j}$, $e_{x,x+t}^{i,j}$ representing expected remaining life in status *j* if respondents were in status *i* at age *x*, can be computed. First, we coded the status of healthy as 1, unhealthy as 2 when estimating HLE, physically active as 1, physically inactive as 2 when estimating ALE, and cognitive-impairment-free as 1, cognition-impaired as 2 when computing CIFLE. Death was coded as 3 for all three indicators. Such coding method helps us not only capture overall level of HLE but also understand characteristics of ALE and CIFLE respectively. The three series of codes then were utilized to construct corresponding matrixes of $\boldsymbol{P}_{x,x+t}$ respectively as follows (as death was an irreversible status, the first two elements of third row in $\boldsymbol{P}_{x,x+t}$ were 0 and the third element was 1).

$$\boldsymbol{P}_{x,x+t} = \left(P_{x,x+t}^{i,j}\right) = \begin{pmatrix} P_{x,x+t}^{1,1} & P_{x,x+t}^{1,2} & P_{x,x+t}^{1,3} \\ P_{x,x+t}^{2,1} & P_{x,x+t}^{2,2} & P_{x,x+t}^{2,3} \\ 0 & 0 & 1 \end{pmatrix}$$

Next, the matrixes of survivors, $\boldsymbol{l}_{x,x+t}$ could be constructed following the conventional life table method based on $\boldsymbol{P}_{x,x+t}$:

$$\boldsymbol{l}_{x,x+t} = \begin{pmatrix} l_{x,x+t}^{1,1} & 0 & 0 \\ 0 & l_{x,x+t}^{2,2} & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Then based on $\boldsymbol{P}_{x,x+t}$ and $\boldsymbol{l}_{x,x+t}$ above, life tables can be constructed to obtain $e_{x,x+t}^{i,j}$ by employing sequent procedures:

$$\boldsymbol{l}(x+t) = \boldsymbol{l}(x) * \boldsymbol{P}_{x,x+t}$$

$$\boldsymbol{L}(x+t) = \frac{t}{2} * [\boldsymbol{l}(x+t) + \boldsymbol{l}(x)]$$

$$\boldsymbol{T}(x) = \sum_{k=x}^{\omega} \boldsymbol{L}(k)$$

$$\boldsymbol{e}(x) = \boldsymbol{T}(x) * \bar{\boldsymbol{l}}(x+t)$$

Note: $\mathbf{L}(\mathrm{x})$ denotes person-years matrix and $\mathbf{T}(\mathrm{x})$ represents accumulative person-years matrix; $\mathbf{e}(\mathrm{x})$

is life expectancy matrix; ω denotes the highest age; $\bar{\mathbf{l}}(x)$ refers to diagonal matrix, and the elements in main diagonal are $l^{i,j}(x) = [\sum_{j=1}^{3} l^{i,j}(x)]^{-1}$. When $[\sum_{j=1}^{3} l^{i,j}(x)]^{-1}=0$, $l^{i,j}(x) = 0$.

[Table 3 here]

Results

Unlike the previous research, this study examines both physical and cognitive aspects of health when estimating healthy life expectancy (HLE). In this study, HLE of Chinese elderly population are measured by four indicators, active life expectancy (ALE), cognitive-impairment-free life expectancy (CIFLE), healthy life expectancy (HLE), and total life expectancy (TLE). Furthermore, HLE will be analyzed from a number of dimensions, including gender, urban-rural divide, region, marital status, educational level and health status at age 60.

Sex-age-specific HLE

Age and gender are important dimensions when examining HLE. Differentials of HLE by age and gender are essential indicators when assessing the quality of public medical services. In this study, sex-age-specific ALE, CIFLE, HLE and TLE of Chinese elderly population during 2011-13 are examined and results have been presented in Table 4 and Figure 3.

Overall, for both sexes, TLE stands at 22.87 years, ALE at 19.39, CIFLE at 9.96, and HLE at 9.26 at age 60 respectively in China. The levels of all indicators decrease as age increases with a slower declining pace at older age while considerable differentials among different indicators and between genders have been observed.

Clearly, ALE of Chinese elderly population is substantially higher than corresponding CIFLE, while CIFLE is higher than HLE by a considerably smaller extent, indicating that the life of Chinese elderly people spent in health status would face a steep drop if taking both physical and cognitive aspects of health into consideration. Differentials of HLE by gender are also significant among Chinese elderly population with women having a longer TLE but a shorter HLE than men. As shown in Figure 3, male CIFLE considerably exceeds that of women and also, male ratios of ALE/TLE and CIFLE/TLE are both higher than females. The gendered differentials suggest that the longer TLE enjoyed by Chinese elderly women might not be necessarily translated into quality of life at old ages, corresponding to the so-called male-female health-survival paradox reported previously that women live longer but men live healthier (Oksuzyan et al., 2008). Recent studies find that women, even in the most undeveloped countries, can enjoy longer life expectancy than their male counterparts (Barford et al., 2006). However, it has been suggested that the extended life expectancy of women tend to be with more chronic diseases and limitation of activities of daily living (Van Oyen et al., 2013). The major reason for gendered differentials of HLE can be attributed to the different distributions of mortality between genders. Higher mortality of men at all ages suggest men who are relatively frail tend to pass away before old ages and that only men who are healthier can survive into later life. Explanations for male-female health-survival paradox include differentials of biological factors, lifestyle and social roles between sexes, but the exact mechanism still has not been completely understood (Oksuzyan et al., 2008).

[Table 4 here]

[Figure 3 here]

Sex-age-specific HLE by urban-rural divide

China has a considerable urban-rural stratification resulting from the legacy of *hukou* registration system, which was implemented in the late 1950s as an invisible wall to prevent unplanned population movement into urban areas (Chan, 1994; Chan et al., 1999; Sicular et al., 2007; Chan, 2010). The urban-rural dual structure, as a result, sees substantial inequality regarding every socioeconomic aspect of society from pension system, education to health services (Cai, 2011). As a reflection of China's long-lasting urban-rural stratification, HLE of Chinese elderly population shows distinctive differentials between urban and rural areas.

As shown in Table 5 and Figure 4, the urban-rural differentials of the four indicators exhibit contrasting patterns. Elderly residents in China's urban areas have significantly longer lengths than their counterparts in rural areas in three indicators, CIFLE, HLE and TLE, while for ALE, differentials between urban and rural areas are insignificant. As an example, at age 60, CIFLE of urban residents (14.59 years) is considerably higher than that of rural residents (8.21 years) while ALE in urban areas (19.22 years) and rural areas (19.56 years) are similar (see Table 5).

The higher CIFLE of urban elderly residents can be explained by their advantages in accessing education and health resources associated with *hukou* system, which maintains a minimum level of social security and living standard in urban areas. The insignificant urban-rural differentials of ALE can also be attributable to the decades-long *hukou* system regarding differentiations in pension availability between urban and rural areas. Compared with urban elderly population, Chinese rural elderly residents are less likely to be covered by pension system, and if covered, with less pension benefits. As a result, rural elderly residents are also more likely to participate in agricultural production activities to fend themselves, which in turn, through frequent farm works, helps them maintain a better physical function at old ages. Therefore, elderly population in rural areas have more or less the same level of ALE as their urban counterparts while other indicators, such as CIFLE and HLE, are less favorable.

[Table 5 here]

[Figure 4 here]

Sex-age-specific HLE by region

With its vast territory, China also sees a massive regional diversity regarding socioeconomic, cultural and geographic aspects. Since the late 1970s, the country's reform and opening-up policy has dramatically changed China's society and exaggerated the existing uneven development gaps among regions (Fan, 1995). In this study, the substantial development gaps between China's economically prosperous East Region and the relatively backward inland Middle/West Region has been embodied by the significant regional differentials of HLE among Chinese elderly population.

As shown in Table 6 and Figure 5, it is clear that HLE of the East Region are longer than those of both the Middle Region and the West Region. The East Region all ranks the highest regarding the absolute length of TLE, HLE, ALE and CIFLE at age 60 so as to the ratios of ALE/TLE, CIFLE/TLE and HLE/TLE (see Figure 5c and 5d). The better performance of the East Region in HLE has been observed in both genders. The regional differentials of HLE of Chinese elderly population imply that in terms of elderly health, the Middle/Western Region is still much backward compared with the East Region, on which the increasingly enlarging uneven regional development in recent years, especially the income level (Xiong, 2005; Wu et al., 2018) and health care provision (Li et al., 2010), might play a role.

[Table 6 here]

[Figure 5 here]

Sex-age-specific HLE by marital status

Marriage is the pivotal relationship throughout adulthood and later life. Numerous research suggest people in marriage relationship have better either physical or mental health outcomes than those unmarried (Robles et al., 2003; Koball et al., 2010). However, due to a lack of life table by marital status, differentials of HLE by marital status has long been underexplored in the literature. By using the multistate life table method, this study fills the gap in the literature by presenting empirical evidence of differentials of HLE by marital status among Chinese elderly population.

As presented in Table 7 and Figure 6, a positive marriage-health link could be clearly identified. For both sexes, elderly people in marriage relationship have significantly higher ALE, CIFLE, HLE and TLE at all ages than those not in marriage relationship. At age 60, ALE, CIFLE, HLE and TLE of people with marriage relationship are 1.58, 1.45, 1.62 and 0.19 years higher respectively than those of people not in marriage relationship. In addition, elderly people in marriage relationship enjoy a larger ratio of ALE/TLE, CIFLE/TLE and HLE/TLE throughout all ages (see Figure 6b, 6c and 6d). Such marital differentials suggest marriage relationship provides significant and lasting benefits on wellbeing, resulting in a longer and also healthier life. Marital differentials of HLE among Chinese elderly population are in line with previous studies elsewhere showing that marriage imposes positive influence on health for people at old ages regardless of gender, race and marriage duration (Goldman et al., 1995; Pienta et al., 2000).

[Table 7 here]

[Figure 6 here]

Sex-age-specific HLE by educational levels

Educational inequality is a strong predictor of health inequality (Von dem Knesebeck et al., 2006). A higher educational level generally means a greater exposure to access health care services, healthier lifestyles and less occupation-related health risks (Lantz et al., 2001; Marmot et al., 2004; Luy et al., 2011; Van Baal et al., 2016). Despite of ample studies on education-health link, thus far, how educational inequality influences HLE, especially CIFLE, at old ages has not been adequately understood.

This study advances the understanding on educational health inequality by presenting HLE by educational levels among Chinese elderly population.

As expected, CIFLE and HLE are both positively correlate with educational attainment at old ages, with the length of CIFLE of non-illiterate elderly reaching approximately twice as that of illiterate elderly throughout all ages and so as to the ratio of CIFLE/TLE (see Figure 7b). By contrast, difference of ALE between illiterate and non-illiterate is insignificant. For example, for both illiterate and non-illiterate, ALE are at 19.3 years at age 60 (see Table 8).

Educational differentials of HLE among Chinese elderly population show different patterns in its two sub-indicators: ALE and CIFLE. This suggests that the influence of educational attainment might be different on cognitive and physical aspects of health. The plausible explanation is that more educated people are more likely to take jobs demanding cognitive tasks and practices before retirement, which might contribute to a better cognitive function at old ages while for those less educated, they are more likely to be farmers or take agriculture-related occupations in China, which require frequent labor activities but less cognitive practices. By combining both cognitive and physical perspectives, the findings in this study provides further evidence on educational health inequality that goes beyond ALE, which suggest although educational attainment is positively associated with the overall HLE, the educational influence on health in later life is considerably stronger on cognitive rather than physical aspect.

[Table 8 here]

[Figure 7 here]

Sex-age-specific HLE by health status at age 60

Transition of health status is a continuous instead of discrete process (Liang et al., 2010). A substantial body of studies demonstrate that later-life health status can be influenced by health events occurring in previous life phases (Blackwell et al., 2001; Case et al., 2005; Crimmins, 2005). As health status at age 60 reflects the health outcomes of accumulated environmental risks in childhood and adulthood, and age 60 is the official retirement age in many countries including China, this study introduces health status of elderly people at age 60 as a new dimension when examining the differentials of HLE. Corresponding results have been shown in Table 9 and Figure 8.

As presented, results show that for elderly people who were unhealthy at age 60, their ALE, CIFLE, HLE and TLE, without exception, are significantly lower than those who were healthy at age 60. Their ratios of ALE/TLE, CIFLE/TLE and HLE/TLE also stand at a substantially lower level compared with those who were healthy at age 60. Moreover, unhealthy elderly people at age 60 see a faster deteriorating speed of health beyond age 60, resulting a continuously wide gap of HLE at all ages between people who were health and those unhealthy at age 60. The lower HLE and the continuity of unhealthy status among unhealthy elderly at age 60 suggest that health outcomes at the entrance of old ages is not only a result from prior retirement life events but also associate with the level of health and subsequent health trajectory at old ages. Exposure to health risks in childhood and adulthood can exert a long lasting influence on wellbeing throughout people’s lifecycle (Henly et al., 2011;

Wyman et al., 2011). The findings from the dimension of health status at age 60 provide new evidence on the association of health before and after retirement, and also demonstrate that a better understanding of HLE at 60 could serve a good predictor of future healthy trajectory of elderly and therefore could provide better information for projection of future needs of aged care services.

[Table 9 here]

[Figure 8 here]

5. Conclusion and Discussion

The study provides a comprehensive analysis of healthy life expectancy (HLE) from a new perspective incorporating both physical and cognitive dimensions for a society that is currently experiencing both dramatic social transformation and rapid ageing. HLE is an important indicator for understanding of population wellbeing and the efficiency of public health care system. The evidence provided in this study allow us to better understand overall level and disparities of HLE in a country currently experiencing social changes and industrialization, which shares considerable similarities and differences with the experience in other populations at the similar stage of development, such as Southeast Asia or East Asia (Seol, 2015; Arifin et al., 2016; Chuakhamfoo et al., 2016).

By using the multistate life table method, this study identifies that the lengths of ALE, CIFLE, HLE and TLE of China's elderly population at age 60 stood at 19.39 years, 9.96, 9.26 and 22.87 respectively during 2011-13. Compared with HLE in the developed countries, length of ALE at age 65 of China's elderly population (15.41 for both sexes, see Figure 3) are similar to that in the developed countries reported by previous studies, such as ALE in the US at 15.0 years in 1990 (Crimmins et al., 2001), Spain at 12.7 years in 1999 (Sagardui-Villamor et al., 2005), Italy at 13.1 in 2003 (Burgio et al., 2009), and Japan at 13.5 in 2004 (Yong et al., 2009). On the contrary of ALE, CIFLE of Chinese elderly population is remarkably lower than those previously reported in the developed countries. For example, CIFLE at age 65 are 8.48 years for men and 5.44 for women in China, which are substantially lower than those at 13.8 for men and 15.5 for women in Canada (Dubois et al., 2006). CIFLE at age 70 stands at 4.59 years in China, also considerably lower than corresponding level at 12.5 years in the US (Suthers et al., 2003). Results of this study suggest that if taking both physical and cognitive aspects of health into consideration, HLE of Chinese elderly population is much lower than their counterparts in the developed world.

The differences of ALE and CIFLE between China and the developed countries can be attributed to the different age patterns of mortality and life experiences at early ages. On the one hand, Chinese elderly people have gone through higher mortality before old ages due to more exposure to poverty, hunger and wars when China was still an undeveloped agricultural country, implying those who are physically fragile tend to pass away before they reach old ages. Ju et al. (1989) reported that elderly people in high mortality countries are more likely to be healthy as they have survived from the risks and diseases in childhood and adulthood. Wing et al. (1985) suggested that African American who are socioeconomically disadvantaged enjoy a lower mortality than White American after around 75 years old as African American surviving at very old ages tend to be the fittest of black after experiencing higher mortality at younger ages. Therefore, owning to the selection effect of mortality, people in China are more selected at old ages than those in the developed countries and consequently more likely to be physically healthier. On the other hand, unlike elderly population in the developed countries, the majority of China's elderly people have less opportunities to access education at early ages. Most of China's elderly people are illiterate due to their early life experience that had been full of social turbulence when China's was still a semi-colonial and semi-feudal society, a period characterized by economic and cultural backwardness in China's history (Zhang, 2006; Zeng, 2014). Lower educational level has been demonstrated as a strong predictor of worse cognitive function at old ages (Filley et al., 1997; Gu et al., 2003; Nguyen et al., 2003). Hence the commonly low educational attainment among Chinese elderly people, especially the very old age group (Zhang, 2006), can be a principle cause for their relatively lower CIFLE when compared with people in the developed countries.

In addition to the overall level of HLE among China's elderly population, the study also exhibits that HLE of Chinese elderly population has significant differentials in a number of socio-demographic dimensions. Elderly people in China who are female, living in the Middle/Western Region and rural areas, not in marriage relationship, less educated and unhealthy at age 60 have significantly shorter HLE. The socio-demographic differentials of HLE among elderly population in China root in the enormous socioeconomic disparities in this country.

As for the gendered differentials, longer male HLE have been observed in many other countries (Austad, 2006; Oksuzyan et al., 2008; Van Oyen et al., 2013) and widely explained by higher male mortality at all ages due to gendered difference in lifestyle and risk taking (Dobson, 2006). In addition, in the context of Chinese society, the deep-seated male preference in Chinese culture can also play an important role. China’s families, especially those in the traditionally undeveloped rural and western inland areas, tend to invest in their sons’ education and other development opportunities rather than their daughters (Hesketh et al., 2011). Consequently, girls are disadvantaged in nutrition intake, education and employment opportunities and social capital accumulation. Elderly women respondents in CHARLS, especially those from rural areas, tend to live under the negative influence of son preference, and therefore, have lower HLE in later life.

The significant geographic differentials of HLE by urban-rural divide (for CIFLE) and region (both ALE and CIFLE) among Chinese elderly population can be explained by considerable spatial development gaps regarding the living standard and income level in China (Bao et al., 2002; Lu et al., 2002). During the last decades, urban areas and the East Region enjoy more advantages in foreign direct investment (Houkai, 2002), policy support (Lu et al., 2002), infrastructure construction (Démurger, 2001) and labor migration (Fu et al., 2012), resulting a significant development gap between urban and rural areas and between the East Region and the Middle/West Region. For example, in 2013, the average annual income in China’s

East Region was 1.40 times of that in the Middle Region and 1.51 times in the West Region while annual income in urban areas was 2.62 times of that in rural area (Wu et al., 2018). For Chinese elderly population, the urban-rural income gap is also considerable, with annual income of urban elderly reaching 2.46 times of that rural elderly in 1991 and 3.81 times in 2000 and still increase in recent years (Xiong, 2005). As a reflection of disadvantage in socioeconomic stratification, elderly people who live in rural and the Middle/West Region suffered lower HLE consequently.

The study have also examined HLE of Chinese elderly population from three new dimensions, marital status, educational level and health status at age 60, which have not been adequately understood in the existing literature. Results of this study support the claim that longer HLE, in particular longer CIFLE, are more likely to correlate with the existence of marriage, higher level of education and a good health condition at age 60. This might be illustrated by the positive association between educational attainment, marriage and health, as well as the so-called “stickiness” of health (Lynch et al., 2010; Hariyanto et al., 2014a, 2014b). Although the positive correlation between education, marriage and health has been well established, few research in the existing literature have pay special attention to HLE. The higher HLE of more educated elderly people can be attributed to their healthier lifestyle and better social economic status, such as less smoking (Martin et al., 2011), higher income (Gregorio et al., 2002) and easier access to medical and health care services (Meara et al., 2008). Kaplan et al. (2015) suggested that due to a higher possibility of unemployment, people with less educational attainment suffer a greater risks of mental stress and also have less economic and social capital to buffer these negative impacts on health. Similar to education-health link, marriage relationship is also positively associated with health. Married people have been found having a lower risk of cardiovascular diseases, a more regular production of endocrine and an improved immune systems than those unmarried (Robles et al., 2003). Pienta et al. (2000) suggested that the protection effect of marriage can produce lasting positive consequences on health in later life, such as less chronic illnesses, functional limitations, and disability among married elderly people. The better health outcome brought by higher educational attainment and marriage relationship can extend to old ages possibly via the mechanism of so-called “the stickiness” of health status, which means that health status tend to remain within the same status rather than change to another one over two years (Lynch et al., 2010; Hariyanto et al., 2014a, 2014b). According to “the stickiness” of health status, previous health status plays as an important role in predicting the following health trajectories as individual lifestyle is prone to stay stable in a long term if without interventions (Henly et al., 2011). Hence, elderly people who were healthy at age 60 are more likely to maintain healthy status and enjoy a higher HLE than those who were unhealthy at age 60. The positive correlation between HLE and health status at age 60 implies the importance of developing and sticking to healthy lifestyle before old ages. This would be especially important for Chinese elderly as they have suffered significantly harder living conditions before retirement than elderly in the developed countries, and consequently they might have a substantially more enormous demand for aged care services than expected in the coming decades.

One striking finding in this study is that rural elderly people and those who are less educated have similar ALE to, or even slightly longer than, urban elderly and more educated people. This seemingly puzzling finding has a number of plausible explanations. Firstly, the mortality of elderly people who are in rural areas and less educated are generally higher than those who are in urban areas (Zimmer et al., 2007) and more educated (Lleras-Muney, 2005). Therefore survived less educated elderly in rural areas tend to be more physically healthy via the selection effect of mortality as explained above (Zeng et al., 2001). Second, after decades-long economic development, environment in urban areas tend to be more-polluted than rural areas in China, especially regarding to the quality of air and water that has been found deteriorating significantly in Chinese mega cities in recent years (Shao et al., 2006). The relatively more polluted environment might contribute to worse health outcome for elderly people in urban areas (Zeng et al., 2001). Third, another key factors is the inaccessibility to pension system among elderly people who are less educated and live in rural areas in China. Pensions in China are generally more accessible for elderly people who have state sectors jobs before retirement. Jobs in government or state-own enterprises are more available to those with urban *hukou* identification and higher educational level. Less educated rural residents are less employed in government sectors or state-own enterprises and have less access to pension system, consequently, facing a greater financial pressure at old ages. Therefore, less educated elderly in rural areas need to engage in labor intensive activities in the fields to make ends meet in later life, forcing them to perform physical exercises more frequently than their counterparts in urban areas, which might have contributed to relatively better physical function and a higher ALE.

The new knowledge produced in this study improved our understanding of elderly health. For the first time, the study reports HLE from the perspective of cognition and corresponding overall level among Chinese elderly population. It also examines HLE from a wide array of perspectives, including three underexplored dimensions, educational level, marital statues and health status at age 60, expanding current understanding on HLE to the less investigated socioeconomic perspective. The findings in this study could inform the formulation of aged care policy and practice in China and elsewhere in a number of ways. Firstly, results of the analysis report a substantially lower HLE after introducing the measurement of cognitive function into health definition, implying a more considerable demand for aged care than estimated before. It is imperative to establish a national long-term care system at its earliest to provide sustainable and systematic care provision for elderly population in China. Secondly, due to the relatively shorter HLE of females and the correlation between education, marriage and HLE, it is necessary to take policy actions to achieve gender equality in education to protect women’s equal right for educational opportunity. In addition, as elderly females are more likely to be widowed, socially conservative attitude toward elderly remarriage in China and in many other countries may need to be changed to foster a wider social acceptance of remarriage at old ages. Thirdly, this research demonstrates that elderly people living in rural areas and the

Middle/West Region have considerably lower overall HLE than their counterparts in urban areas and the East Region, therefore more attention should be paid to the demand for aged care for rural elderly residents, especially those in the Middle/West Region. A more balanced region development strategy would improve the overall wellbeing of rural elderly people, especially in terms of improvement of employment rate, educational facilities and health care infrastructures. Targeted government investment to minimize the disparities in the distribution of health care resources would be welcome. Finally, as demonstrated in this study, health status at aged 60 is a not only good predictor of health trajectory of older ages, but also is a cumulative result of prior life experience, aged care policy should be integrated in the general health care services throughout people's lifecycle, including but not limited to the intervention in old ages.

A few limitations are noted in this study. Due to insufficient waves of data, this study is unable to identify the trends of ALE, CIFLE and HLE among China's elderly population over time. The multistate life table method requires longitudinal data of at least two waves, so to examine the trend of HLE by the multistate life table method would require at least four waves of longitudinal data, which is out of the scope of current CHALRS database. This might be achievable in the future after future waves of CHARLS become available. It is also noted that the database of CHLARS used in this study only covers un-institutionalized elderly residents, which may contribute to a higher HLE in this study as elderly people in aged care institutions are more likely to be unhealthy. However, the exclusion of institutionalized elderly people may not pose a severe bias affecting the results of this study as the number of this group is still very low in China, only accounting for less than 0.5% of the total elderly population in 2017 according to the Ministry of Civil Affairs of People's Republic of China (2018). Despite the limitations, this study provides a comprehensive analysis of HLE among Chinese elderly population from both physical and cognitive aspects, and it provides new insights into characteristics of HLE by socio-demographic dimensions, which were not sufficiently examined in the existing literature. The findings from this study might contribute to better policy responses to address China’s profound impeding challenges of ageing population and aged care provision, which would also have implications for other countries where demographic transition has been taking place.

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Tables

Table 1 Description of key variables in CHARLS in 2011

	Physically inactive	Physically active	Cognition-impaired	Cognitive-impairment-free	Total
Age					
60-69	284	3,898	1,001	3,181	4,182
70-79	241	1,672	748	1,165	1,913
80≤	151	389	341	199	540
Gender					
Male	298	3,050	711	2,637	3,348
Female	378	2,909	1,379	1,908	3,287
Places of residence					
Urban	109	1,279	223	1,165	1,388
Rural	567	4,680	1,867	3,380	5,247
Region					
East	210	2,012	605	1,617	2,222
Middle	235	1,945	680	1,500	2,180
West	231	2,002	805	1,428	2,233
Marital status					
In marriage	473	4,696	1,427	3,742	5,169
Not in marriage	203	1,263	663	803	1,466
Educational level					
Illiterate	358	2,153	1,456	1,055	2,511
Non-illiterate	318	3,806	634	3,490	4,124
Total	676	5,959	2,090	4,545	6,635

Source: China Health and Retirement Longitudinal Survey 2011

Table 2 Definitions of different health statuses

Health statuses	Definition
Physically inactive	With any ADL disabilities
Physically active	No any ADL disabilities
Cognition-impaired	MMSE scores under 12 in CHARLS
Cognitive-impairment-free	MMSE scores at least 12 in CHARLS
Healthy	No any ADL disabilities and MMSE scores at least 12
Unhealthy	Any ADL disabilities or MMSE scores under 12
Death	Individual passed away

Table 3 Transition probability models and corresponding results of likelihood ratio *chi* test

	Multinomial logit models	**ALE**			**CIFLE**			**HLE**		
		-2LL	-2(lnL0-lnL1)	P	-2LL	-2(lnL0-lnL1)	P	-2LL	-2(lnL0-lnL1)	P
Model 1	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1, i \neq j$	6318.73	-	-	8527.07	-	-	9103.25	-	-
Model 2	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1 + \gamma_{i,j}(t) * gender, i \neq j$	6297.17	21.56	0.000	8416.08	110.99	0.000	8972.47	130.78	0.000
Model 3	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1 + \delta_{i,j}(t) * residence, i \neq j$	6297.78	20.95	0.000	8458.68	68.39	0.000	9047.58	55.67	0.000
Model 4	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1 + \delta_{i,j}(t) * residence + \gamma_{i,j}(t) * gender, i \neq j$	6274.65	22.52	0.000	8341.28	74.8	0.000	8910.51	61.96	0.000
Model 5	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1 + \rho_{i,j}(t) * east + \tau_{i,j}(t) * middle + \epsilon_{i,j}(t) * west +, i \neq j$	6299.22	19.51	0.000	8520.23	6.84	0.009	9090.91	12.34	0.000
Model 6	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1 + \rho_{i,j}(t) * east + +\tau_{i,j}(t) * middle + \epsilon_{i,j}(t) * west + \gamma_{i,j}(t) * gender, i \neq j$	6278.13	19.04	0.000	8409.07	7.01	0.008	8959.61	12.86	0.000
Model 7	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1 + \theta_{i,j}(t) * marriage, i \neq j$	6306.85	11.88	0.001	8501.34	25.73	0.000	9073.42	29.83	0.000
Model 8	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1 + \theta_{i,j}(t) * marriage + \gamma_{i,j}(t) * gender, i \neq j$	6288.31	8.86	0.003	8404.49	11.59	0.001	8959.59	12.88	0.000
Model 9	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1 + \mu_{i,j}(t) * education, i \neq j$	6300.53	18.2	0.000	8152.64	374.43	0.000	8819.62	283.63	0.000
Model 10	$\ln(P_{x,x+t}^{i,j}/P_{x,x+t}^{i,i}) = \alpha_{i,j}(t) + \beta_{i,j}(t)x_1 + \mu_{i,j}(t) * education + \gamma_{i,j}(t) * gender, i \neq j$	6280.85	16.32	0.000	8128.85	287.23	0.000	8779.53	192.94	0.000

Note: "residence" refers to the urban-rural divide; "east", "middle" and "west" denote the East, the Middle and the West Region.

Table 4 HLE of Chinese elderly population by gender and age 2011-13

	All				Male				Female			
	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE
60	19.4	10.0	9.3	22.9	19.2	11.7	11.2	21.8	19.5	8.1	8.1	23.8
70	11.9	4.6	4.2	15.0	11.7	5.8	5.5	14.0	11.9	3.4	3.4	15.8
80	6.2	1.6	1.5	9.0	6.2	2.2	2.2	8.0	6.2	1.1	1.0	9.6
90	2.8	0.5	0.4	5.0	2.8	0.7	0.7	4.3	2.8	0.3	0.3	5.4
100	1.2	0.1	0.1	2.9	1.2	0.2	0.2	2.5	1.1	0.1	0.1	3.1

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

Table 5 HLE of Chinese elderly population by places of residence, 2011-13

	All				Male				Female			
	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE
Rural areas												
60	19.2	8.2	7.7	22.2	19.0	10.0	9.6	21.0	19.4	6.2	5.5	23.2
70	11.8	3.4	3.1	14.4	11.6	4.5	4.3	13.3	11.9	2.3	2.0	15.3
80	6.2	1.1	1.0	8.6	6.1	1.5	1.4	7.6	6.2	0.6	0.6	9.2
90	2.9	0.3	0.3	4.8	2.9	0.4	0.4	4.1	2.8	0.2	0.2	5.3
100	1.2	0.1	0.1	2.8	1.3	0.1	0.1	2.3	1.2	0.0	0.0	3.0
Urban areas												
60	19.6	14.6	13.5	24.8	19.7	16.5	15.7	24.0	19.6	12.7	11.1	25.6
70	11.9	7.6	6.8	16.5	12.0	9.1	8.5	15.8	11.9	6.0	5.1	17.2
80	6.2	2.9	2.6	9.9	6.3	3.9	3.6	9.2	6.1	2.1	1.7	10.4
90	2.7	0.9	0.8	5.4	2.8	1.2	1.1	4.8	2.6	0.5	0.4	5.8
100	1.1	0.2	0.2	3.0	1.1	0.4	0.3	2.6	1.0	0.1	0.1	3.2

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

Table 6 HLE of Chinese elderly population by region 2011-13

	All				Male				Female			
	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE
East Region												
60	19.9	10.7	10.0	22.6	19.7	12.3	11.9	21.5	20.1	9.0	8.0	23.6
70	12.3	5.1	4.7	14.8	12.1	6.3	6.0	13.9	12.4	3.9	3.4	15.7
80	6.6	1.9	1.7	8.8	6.5	2.5	2.4	8.0	6.6	1.3	1.1	9.4
90	3.0	0.6	0.5	4.9	3.0	0.8	0.7	4.3	3.0	0.4	0.3	5.3
100	1.1	0.1	0.1	3.1	1.2	0.2	0.2	2.6	1.1	0.1	0.1	3.3
Middle Region												
60	19.6	9.9	9.3	23.9	19.6	11.9	11.4	22.8	19.7	8.0	7.1	24.8
70	12.0	4.5	4.2	15.9	12.0	5.8	5.6	14.8	12.0	3.3	2.9	16.6
80	6.3	1.6	1.5	9.6	6.3	2.2	2.1	8.6	6.2	1.1	0.9	10.2
90	2.8	0.5	0.4	5.4	2.9	0.7	0.7	4.6	2.8	0.3	0.3	5.8
100	1.1	0.1	0.1	3.1	1.2	0.2	0.2	2.6	1.1	0.1	0.1	3.3
West Region												
60	18.6	9.2	8.4	22.4	18.4	11.0	10.3	21.4	18.8	7.3	6.2	23.3
70	11.2	4.1	3.7	14.5	11.1	5.2	4.8	13.6	11.3	2.9	2.4	15.3
80	5.9	1.4	1.2	8.6	5.7	1.9	1.7	7.7	5.9	0.9	0.7	9.2
90	2.7	0.4	0.4	4.8	2.6	0.6	0.5	4.2	2.6	0.2	0.2	5.2
100	1.1	0.1	0.1	2.7	1.1	0.2	0.2	2.4	1.1	0.1	0.1	3.0

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

Table 7 HLE of Chinese elderly population by marital status 2011-13

	All				Male				Female			
	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE
In marriage												
60	20.0	10.3	9.6	22.9	19.7	11.8	11.4	22.1	20.5	8.3	7.3	24.3
70	12.5	4.9	4.5	15.0	12.3	5.9	5.6	14.3	12.8	3.5	3.0	16.3
80	6.8	1.8	1.7	8.9	6.7	2.3	2.2	8.3	6.9	1.1	1.0	10.0
90	3.2	0.6	0.5	4.9	3.2	0.7	0.7	4.5	3.2	0.3	0.3	5.7
100	1.4	0.2	0.2	2.8	1.4	0.2	0.2	2.6	1.3	0.1	0.1	3.3
Not in marriage												
60	18.4	8.8	8.0	22.7	17.8	11.0	10.5	21.0	18.6	7.7	6.7	23.4
70	11.2	4.0	3.6	14.9	10.8	5.4	5.1	13.5	11.3	3.2	2.7	15.5
80	5.9	1.4	1.3	8.9	5.7	2.1	1.9	7.8	6.0	1.0	0.9	9.4
90	2.7	0.4	0.4	5.0	2.7	0.6	0.6	4.2	2.8	0.3	0.2	5.4
100	1.2	0.1	0.1	2.9	1.2	0.2	0.2	2.4	1.2	0.1	0.1	3.1

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

Table 8 HLE of Chinese elderly population by educational level 2011-13

	All				Male				Female			
	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE
Illiterate												
60	19.3	7.8	7.4	22.2	19.0	8.7	8.7	20.1	19.5	7.5	6.9	23.1
70	11.8	3.3	3.2	14.8	11.6	3.9	3.8	13.0	11.9	3.1	2.9	15.5
80	6.2	1.1	1.1	9.1	6.1	1.4	1.3	7.7	6.2	1.0	1.0	9.6
90	2.8	0.3	0.3	5.2	2.9	0.4	0.4	4.3	2.8	0.3	0.3	5.5
100	1.2	0.1	0.1	3.0	1.2	0.1	0.1	2.5	1.1	0.1	0.1	3.1
Non-illiterate												
60	19.3	12.4	11.5	22.9	19.3	12.6	11.2	22.3	19.5	12.1	11.7	24.3
70	11.8	7.4	6.7	15.0	11.7	7.6	7.1	14.5	11.9	7.0	5.9	16.0
80	6.2	3.3	3.0	8.7	6.2	3.5	3.2	8.4	6.1	3.0	2.5	9.4
90	2.8	1.3	1.1	4.7	2.8	1.4	1.2	4.5	2.6	1.1	0.9	5.1
100	1.1	0.5	0.4	2.7	1.1	0.5	0.5	2.5	1.0	0.4	0.3	2.9

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

Table 9 HLE of Chinese elderly population by health statuses at age 60 2011-13

	All				Male				Female			
	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE	ALE	CIFLE	HLE	TLE
Healthy												
60	19.5	10.7	10.1	23.0	19.7	12.1	11.7	21.9	19.7	9.2	8.3	24.0
70	12.2	6.0	5.7	15.5	12.3	6.7	6.5	14.4	12.3	5.1	4.7	16.4
80	6.9	3.4	3.3	9.9	6.9	3.6	3.6	8.9	6.9	3.0	2.8	10.7
90	3.7	2.1	2.2	6.3	3.7	2.2	2.2	5.6	3.7	1.9	1.9	6.9
100	2.2	1.6	1.6	4.2	2.2	1.6	1.6	3.9	2.2	1.5	1.5	4.7
Unhealthy												
60	16.5	8.1	7.6	22.7	17.0	10.2	9.8	21.7	17.0	6.2	5.5	23.6
70	8.7	3.2	2.9	14.6	9.1	4.3	4.1	13.6	9.1	2.2	2.0	15.5
80	3.6	1.0	0.9	8.6	3.9	1.3	1.2	7.6	3.9	0.7	0.6	9.3
90	1.3	0.2	0.2	4.8	1.4	0.3	0.3	4.0	1.4	0.2	0.1	5.3
100	0.4	0.1	0.0	2.8	0.5	0.1	0.1	2.3	0.5	0.0	0.0	3.1

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

Figures

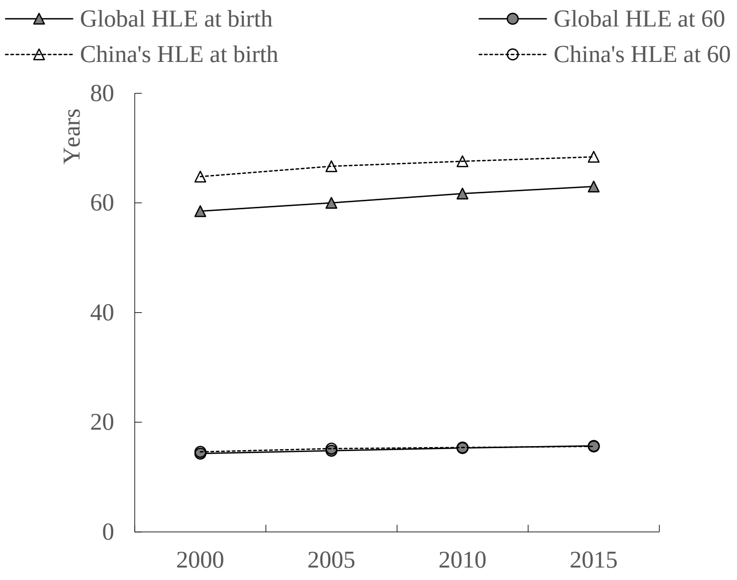

Figure 1 Trend of TLE and HLE at birth and age 60 in China 2000-15

Source: Life expectancy and Healthy life expectancy: Data by country from WHO,

http://apps.who.int/gho/data/node.main.688

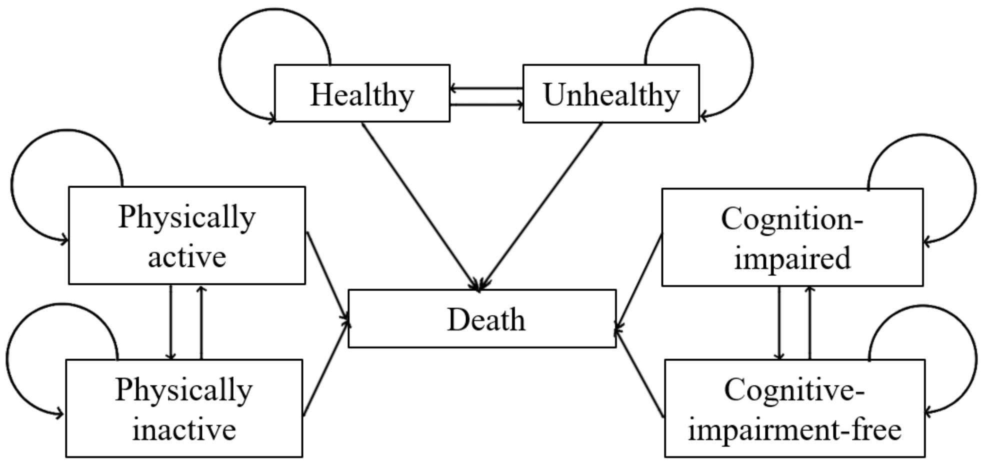

Figure 2 Transition relationships between different health statuses

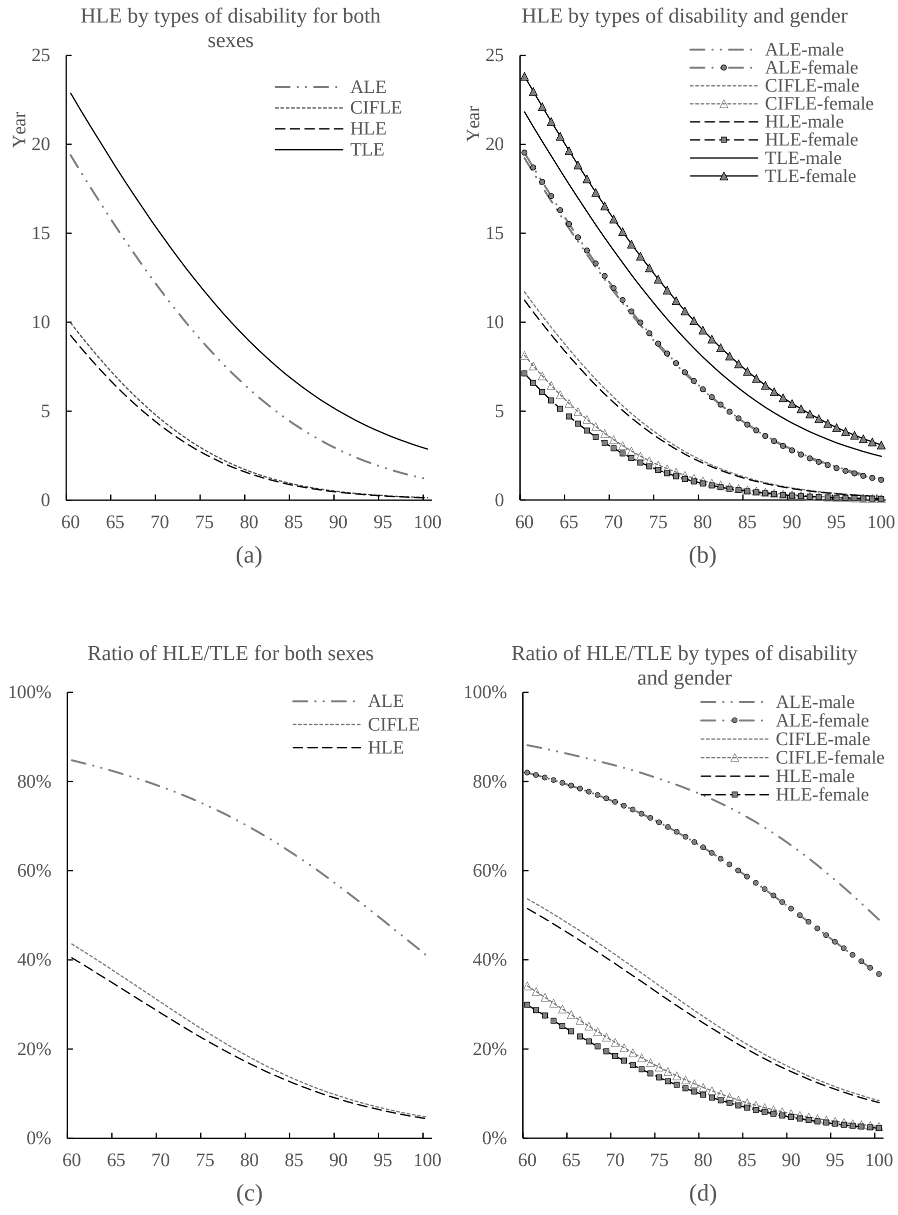

Figure 3 HLE of Chinese elderly population by gender 2011-13

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

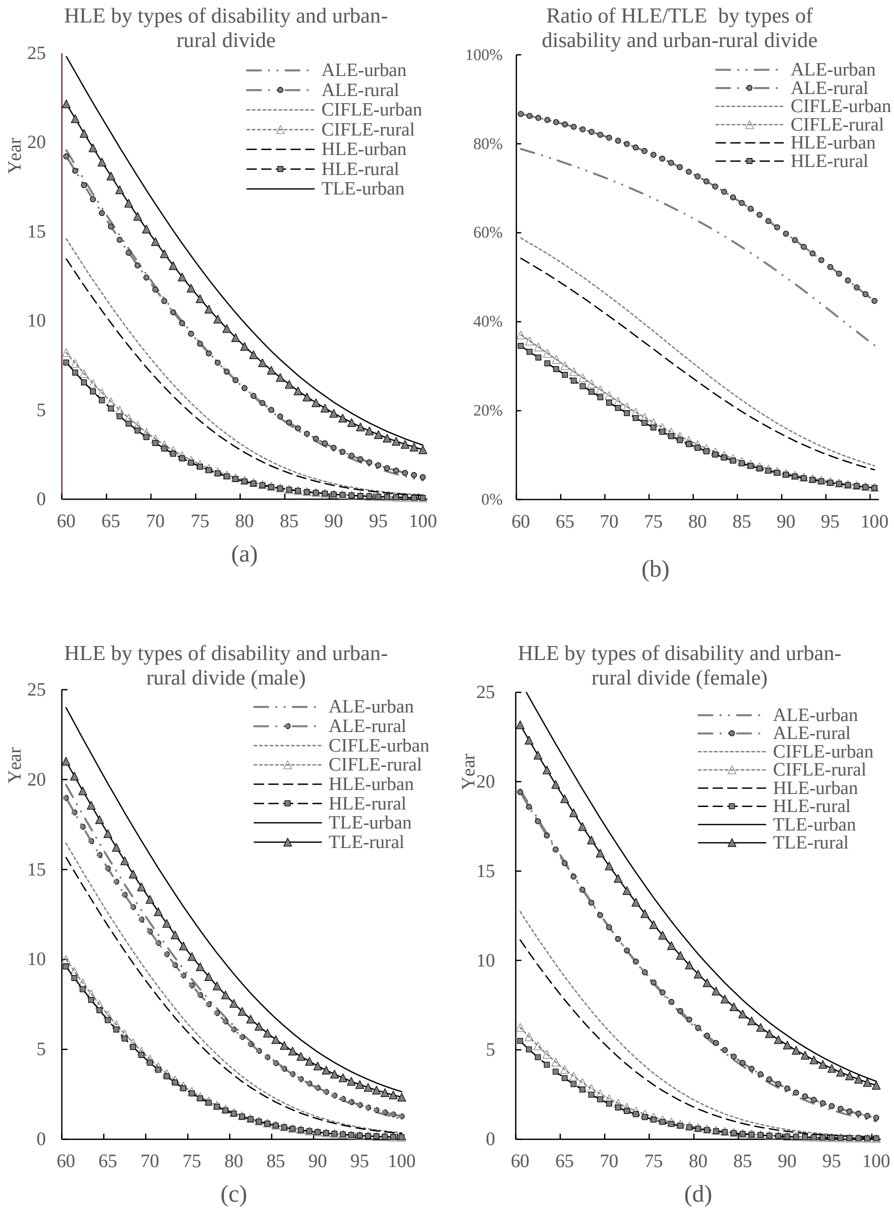

Figure 4 HLE of Chinese elderly population by urban-rural divide, 2011-13

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

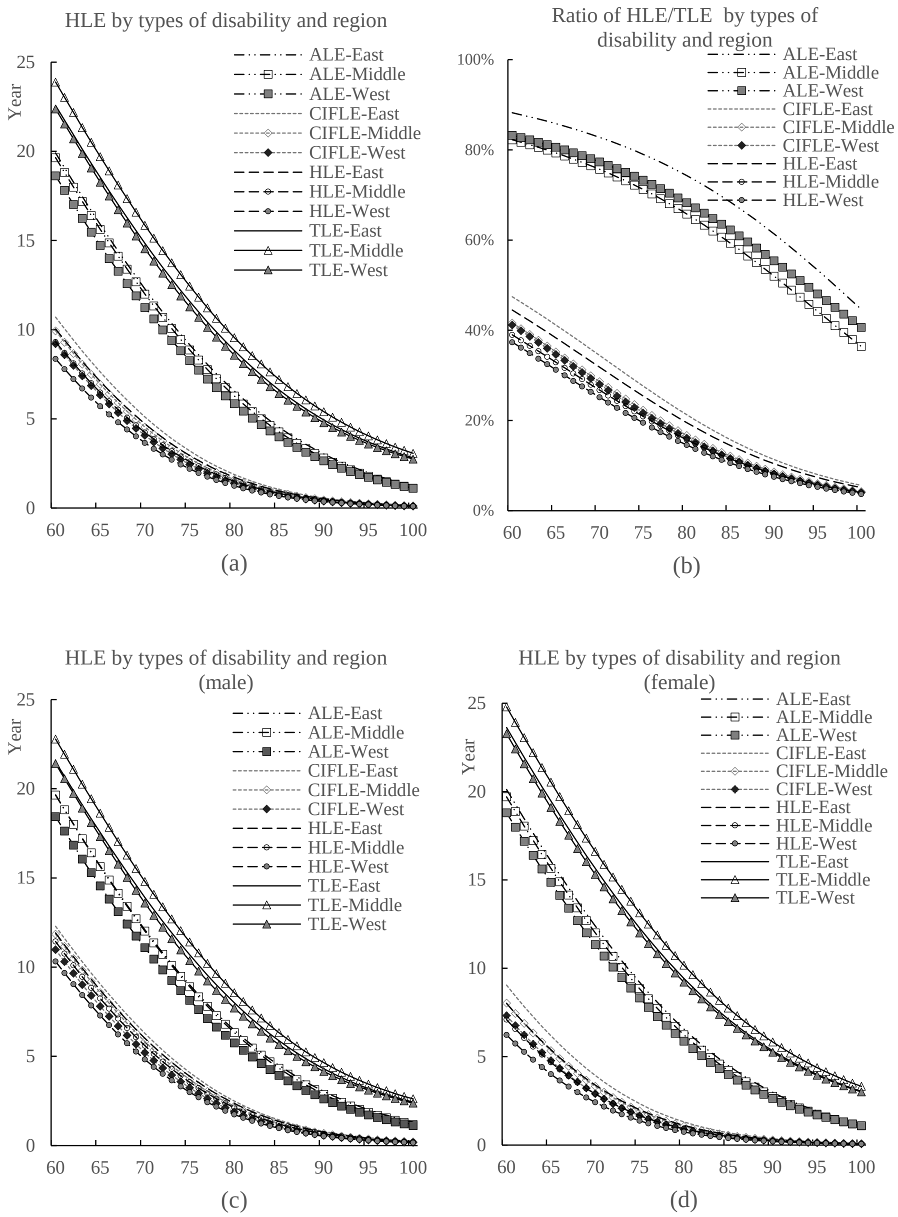

Figure 5 HLE of Chinese elderly population by region 2011-13

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

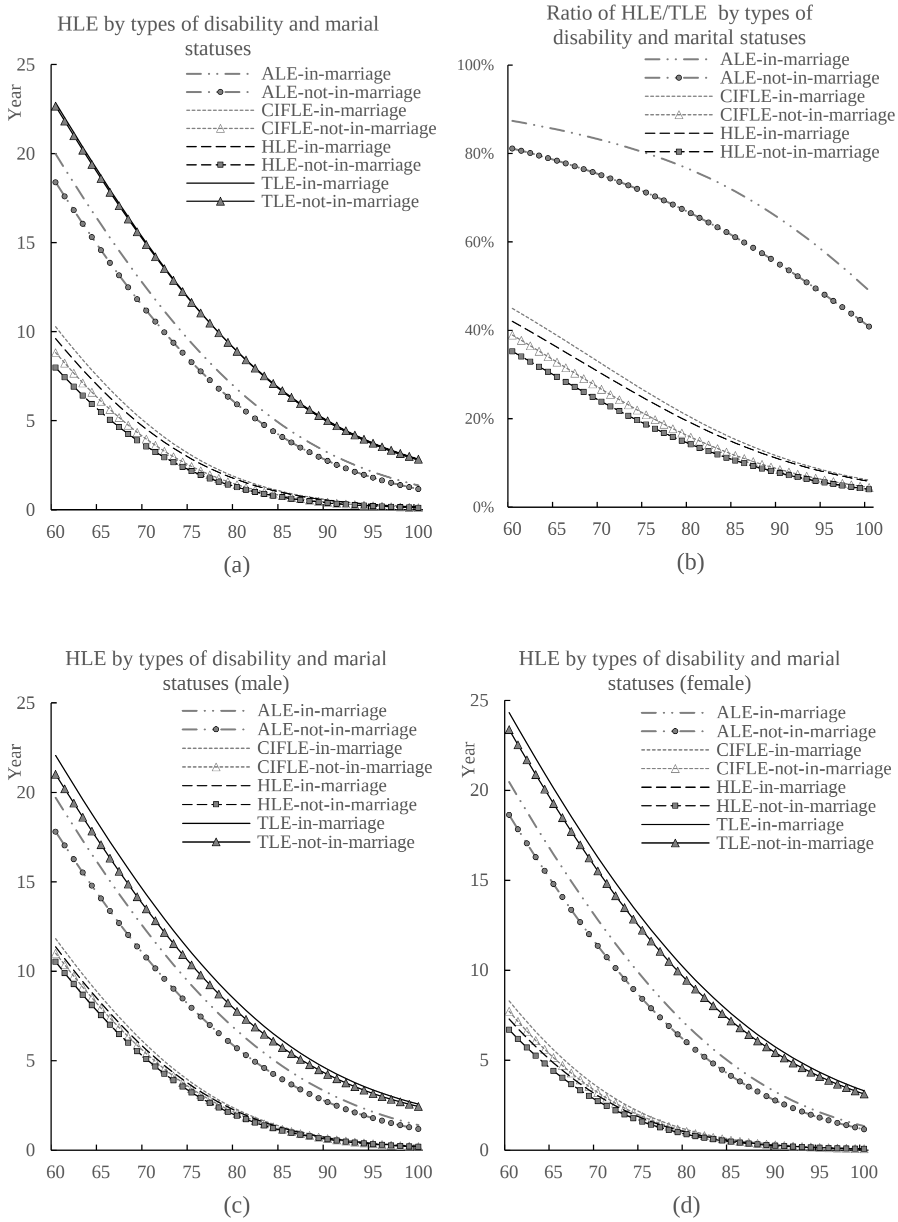

Figure 6 HLE of Chinese elderly population by marital statuses 2011-13

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

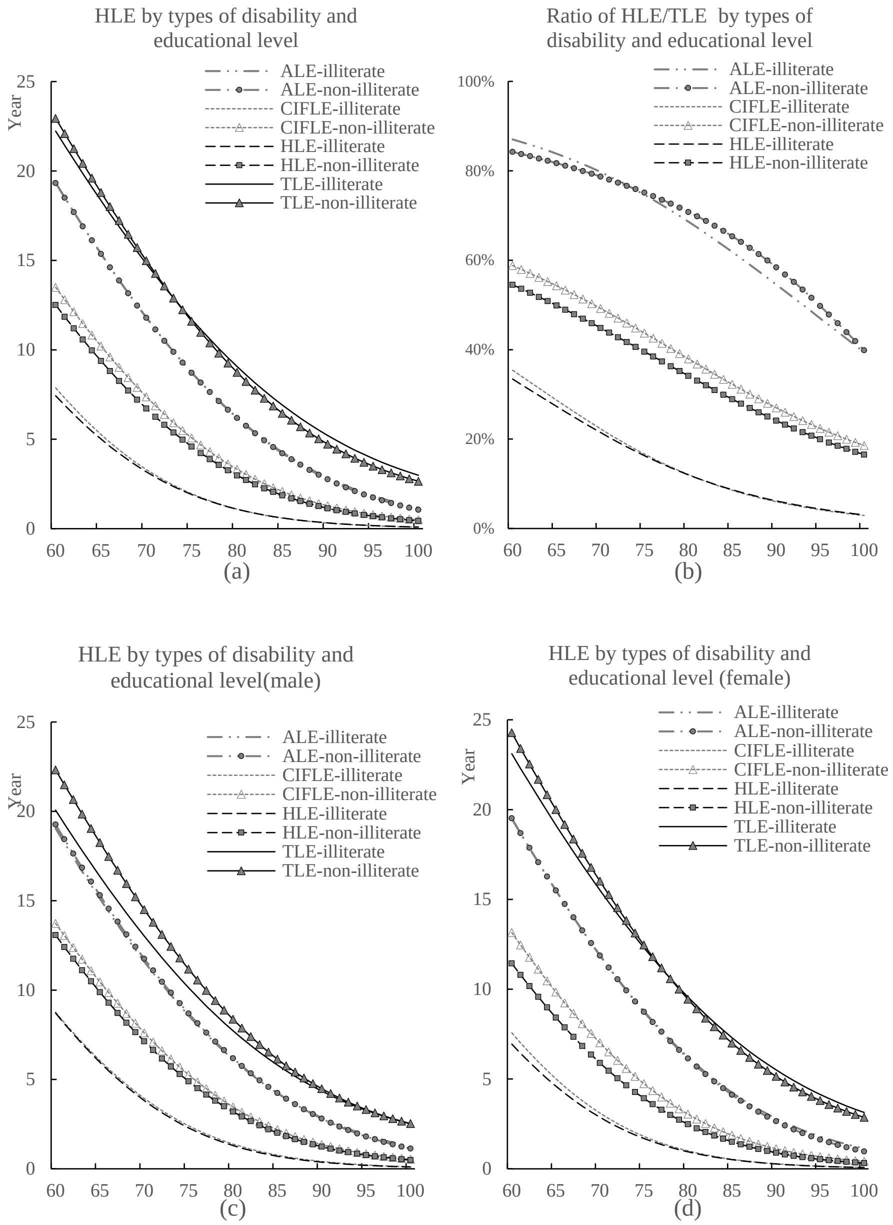

Figure 7 HLE of Chinese elderly population by educational level 2011-13

Source: China Health and Retirement Longitudinal Survey 2011 and 2013

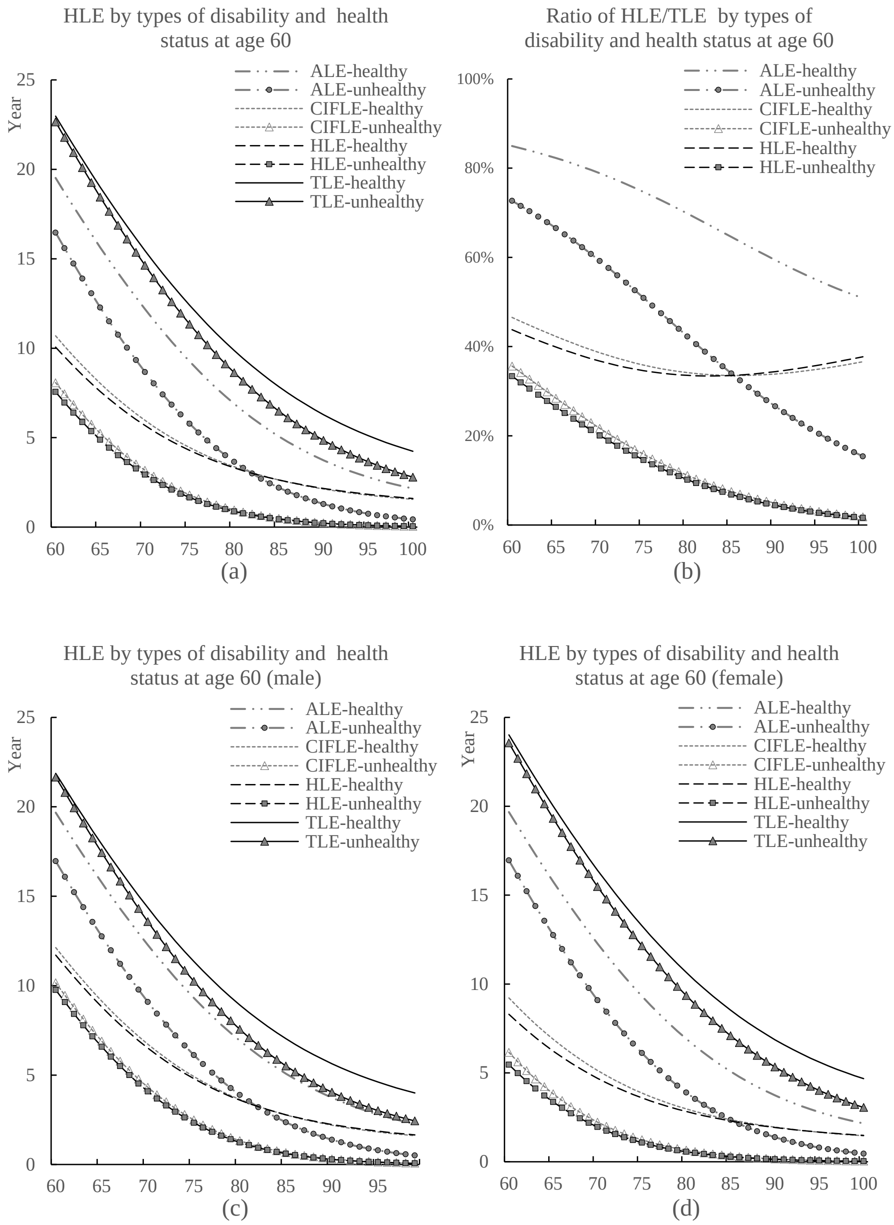

Figure 8 HLE of Chinese elderly population by health status at age 60 2011-13

Source: China Health and Retirement Longitudinal Survey 2011 and 2013