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# Economic level and human longevity: Spatial and temporal variations and correlation analysis of per capita GDP and longevity indicators in China

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ABSTRACT

*Objective:* We show the variation of longevity indicators in China during the past 60 years and its correlation patterns with per capita GDP ($GDP_{pc}$) both at provincial and inner-provincial level.
*Methods:* Population data from six national population censuses in China (1953–2010) at provincial level and in several typical provinces in 2010 at county-level were selected. Four main longevity indicators were calculated. Pearson's *r* and distributed lags time series analysis between longevity indicators and $GDP_{pc}$ were conducted.
*Results:* The results show that Guangxi and Hainan Provinces maintain relatively high long-lived population (population over the age of 90) across various population censuses. The distributions of the population over the age of 80 and life expectancy are significantly affected by both contemporaneous and historical $GDP_{pc}$ at provincial level. However, areas of high long-lived population (over the age of 90) exhibit continuously stable features that lack any significant correlation with $GDP_{pc}$ both at provincial and inner-provincial level.
*Conclusion:* Our results indicate a mixed distribution pattern of several longevity indexes and different relation to $GDP_{pc}$. It shows consistent trend with Preston curve, that is, economic conditions may have limited influence on human longevity, especially for those who live longer than 90 years old. This study suggests that the economic development may favor the local residents to have access to live as old as 80 years old, but it is still difficult for most residents to reach the level of centenarians.


## 1. Introduction

Longevity is a special phenomenon of human physiology. For current average human life expectancies are less than a 100 years, the term of "centenarian" is invariably associated with longevity. With the development of human society, demand for their longevity grows correspondingly.

The term "longevity" means the especially long lived members of a population, while "life expectancy" refers to the average number of years remaining at a given age (often at birth) based on the statistical data. The case study of relation of life expectancy (LE)

*Abbreviations:* CH, the number of centenarians per one hundred thousand inhabitants; UOI, ultra-octogenarian index, proportion of over 80-year-old population in the total population; LE, life expectancy at birth; LI, longevity index, the ratio of the population above 90 years of age to the total population above 65 years of age; $GDP_{pc}$, the gross domestic product per capita.

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and economic level was initiated by Preston (1975), which showed the relationship between life expectancy at birth and income as log linear that was called "Preston curve" (Bloom & Canning, 2007; Preston, 1975; Rodgers, 2002). People in more developed regions tend to have higher average life expectancy (UNDP, 2012). Some studies have involved the relationship between longevity and local socio-economic conditions as well (e.g., Aísa, Clemente, & Pueyo, 2014; Kawata, 2009; Kim, 2012; Wilkinson, 1992). Those studies provided new insight of the relation of economic growth and health improvements. But the previous researches were almost based on the analysis of life expectancy, not specific age data from census. Nonetheless, those studies have not been sensitive to the spatial and temporal variations of longevity population and their relations to the distribution of economic level.

Since the founding of the P. R. China in 1949, six national population censuses have been conducted in 1953, 1964, 1982, 1990, 2000, and 2010, respectively. A large amount of detailed and accurate data on the number of population in every age category had been obtained. It provides valuable information and a potential basis for investigating the distribution and variation of longevity regions in China. Some studies have analyzed distribution of different age groups of population based on one or two population censuses (Fan, 2006; He, 1986; Lai, 1999; Li, Tan, Wang, & Yang, 2000), and some have considered longevity from a demographic perspective (Wang, Zeng, Jeune, & Vaupel, 1998; Zeng, Vaupel, Xiao, Zhang, & Liu, 2001; Zeng, 2004). China has experienced rapid socio-economic development over the past 30 years. But there have been few quantitative and historical studies on the distribution of longevity regions in China and the relationship between regional economic conditions.

Among several social-economic indicators, $GDP_{pc}$ is widely accepted as an efficient indicator of per capita economic conditions rather than other social and economic variables. In this study, we collected the six national population censuses and the data of per capita GDP in China, and proposed: (1) the number of centenarians per one hundred thousand inhabitants (CH) and (2) the percentage of the population aged at least 80 years (UOI); (3) the ratio of the population above 90 years of age to the total population above 65 years of age (LI) (Magnolfi et al., 2007); (4) life expectancy at birth (LE) as main indicators for longevity (see details in Section 2). Our study mainly focused on the relationship of economic development level (per capita GDP as main index) and the longevity indicators distribution patterns in China. In order to make a specific explanation of the relation, we compared both the contemporaneous and historical GDP data and longevity indicators, by using simple linear correlation (Pearson's $r$). A distributed lag model analyses was conducted as well to ensure the full long-term effect is obtained. We also selected several typical provinces with regional longevity, such as Hainan, Gaungxi, Guangdong, Shandong, Henan, and Anhui provinces, elaborating the spatial distribution of high-longevity regions and the potential relationship with $GDP_{pc}$ at county level.

## 2. Data and methods

### 2.1. Data sources

Population data were from six national population censuses in China (PCO-DPS, 1993, 2002, 2012; PSDSSBC, 1988) at provincial level (including province-level autonomous regions and municipalities). We also selected the data of several provinces with high ratio of centenarians (Guangxi, Hainan, Guangdong, Shandong, Henan, and Anhui) from population census data in 2010 at county-level to discuss the distribution pattern of regional variation of those indicators.

We just collected the data of $GDP_{pc}$ in China at the provincial level from 1980s to 2010, for China had established a national economic accounting system since 1985, thus, the $GDP_{pc}$ data before the 1980s were difficult to compare with more recent data. The specific data of $GDP_{pc}$ at county-level in Guangxi, Hainan, Guangdong, Shandong, Henan and Anhui provinces in 2010 were also collected (SSBA, 2011, 2012).

### 2.2. Selection of indexes

The proportion of centenarians was an important indicator of longevity (Poulain et al., 2004; Rosero-Bixby, 2008; Stefanadis, 2010; Willcox, Willcox, Hsueh, & Suzuki, 2006). In China, main indicators which are widely accepted to identify longevity regions (administrative region with population more than one hundred thousand people) include: (1) the number of centenarians per one hundred thousand inhabitants (CH); (2) a regional average life expectancy at birth (LE); (3) the percentage of the population aged at least 80 years (ultra-octogenarian index, UOI) (GSC, 2006). Another additional important indicator is the longevity index (LI), defined as the ratio of the population above 90 years of age to the total population above 65 years of age (Magnolfi et al., 2007).

### 2.3. Assessment of reliability and accuracy of demographic data

The national population census in 1953 was the first official national census by P. R. China though it was quite simple and the data of remote minority were obtained by indirect survey (Cressey, 1955; Shabad, 1959). The results of the second census in 1964 were not published until the early 1980s. Nevertheless, the accuracy of the first two national population censuses in 1953 and 1964 was questioned by some researchers (Aird, 1982; Kirkby, 1985), but these data still have historical value for reference. China's first high-quality population census was launched in 1982, with the assistance of the United Nations Population Fund, and the reliability of the data had been recognized by some scholars and organizations (Aird, 1982; Banister, 1984; Kirkby, 1985; Peiris, 1986).

It should be noted that the accuracy of longevity population data of Xinjiang Autonomous Region in 1953, 1964, and 1982 is questionable, especially for the centenarian's numbers. The gap between verified ages and self-reported ones by "centenarians" in Xinjiang was large (Coale & Li, 1991; Li, 1989) which does not meet the requirements as a factual basis to study. However, considering data integrity, the data of Xinjiang was still presented in Table 1. Data of Xinjiang in 1953, 1964, and 1982 are only for reference in this article.

### 2.4. Statistical analysis

We calculated the longevity indicators (CH, UOI, and LI), respectively, and the LE was calculated by using the method given in Gompertz (1825) – for each province in the census years 1953, 1964, 1982, 1990, 2000, and 2010. The same data set was analyzed using two different statistical tests, namely analysis of correlation coefficients (Pearson's $r$) and distributed lags time series analysis. The latter method is able to identify a delayed relationship between longevity indicators and $GDP_{pc}$. The analysis of correlation coefficients was conducted by using SPSS 17.0. The distribution maps (Figs. 1, 3–5) were drawn by using Arc GIS Geographic Information Systems software version 10.0 (Environmental Systems Research Institute Inc., Redlands, CA). Statistical significance was set at $P < 0.05$.

#### 2.4.1. Simple linear correlation (Pearson's r)

Pearson correlation coefficient (Pearson's $r$) is a measure of determining the extent linear correlation between two variables, and it gives a value between −1 and +1 inclusive (Pearson, 1895).