Population Aging and Economic Growth in China

A thesis submitted by

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Abstract

Population aging has become one of the most urgent tasks for the Chinese government to deal with. My thesis has two parts. In the first part, I run a cross-country growth rate regression on the growth rate of the percent of population of 65 and over using data of 97 sample countries from 1960 to 2010. I also run the regression with five-year intervals to allow for more variation in the key variable. All the regression results show that population aging has no economically nor statistically significant relationship with economic growth. To check for the possibility that the effect of aging on the economy varies with time, I also run regressions including time interaction term. The results imply that aging has a statistically significant impact on economy, but the impact is time-varying. The second part is a case study of China and Japan. I compare China with Japan and find that the current age distribution in current China is similar to Japan in 1986. What is going to happen in China is unsure. If China follows Japan's path, China's economy will eventually deteriorate. But the differences between the two countries might actually save China and actions could be taken by the government to relieve the aging problem.

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I. Introduction

China is currently going through a serious population aging problem. Besides the usual reasons such as increased life expectancy, the main and unique reason why China is suffering from this problem is because of a government Family Planning Policy. This policy is also known as the one-child policy, and limited families to having one child. If people choose to have more than one child, fines are imposed based on the income of the family and other factors, for instance, how many children this family already has. Punishment is even more severe for those working for government agencies or government-owned companies. Not only do they have to pay the fines, they will also lose their jobs. This policy was introduced in 1978 and enacted on September 18 of 1980, with the aim of decreasing the population of China, improving the living standard, and alleviating the shortage of supplies. At that time, the Chinese government also believed that population quality could be improved by controlling births, since people can access larger amounts of resources, such as education and health care.

About 30 years have passed since the enacting of the one-child policy. Chinese authorities claim that the policy has prevented millions of births. But it has resulted in a serious population aging problem. According to the National Bureau of Statistics of China, the share of elderly over 65 years old in the total population rose from 6.20% in 1995 to 9.67% in 2013, and the Elderly Dependency Ratio (ODR, the proportion of dependents per 100 working-age people) increased from 9.2% to 13.1%, which imposes a huge economic burden on the working population. Worried about the shrinking labor force, the Chinese government announced a new two-child Policy in

August 2013, which allows married couples to have two children if one spouse is the only child of the family. Surprisingly, the expected baby boom did not come. What is worse, there are no signs of a rebound in the birth rate (see Figure 1).

To further solve the problem of falling worker numbers, in October 2015, the Chinese government announced an end to the one-child policy, meaning all married couples are allowed to have two children without any restrictions. Although Chinese people are very supportive of the abolishment of the one-child policy and feel that having siblings are beneficial for children's growth, many young couples claim that they are not considering a second child in the short term since the cost of raising children is just too high for a couple to bear. Thus, whether a baby boom will come is uncertain.

Just like China, the population aging is a major concern for Japan. According to the Japan Statistics Bureau, the share of elderly (over 65 years old) in the total population increased from 14.56% in 1995 to 25.1% in 2013. Population aging in Japan happened earlier and is a much more serious problem than in China. Thus, Japan can serve as a reference for China to assess the seriousness of the current population aging condition, and be used to predict what might happen in China unless policies are undertaken to prevent or relieve this problem. The reason of choosing Japan as the comparison is because Japan is the only country that is similar to China in culture and has a serious aging problem.

Besides China and Japan, population aging is a phenomenon common to most countries including developed and developing countries in the past few decades. Many countries have experienced considerable demographic change because of it. ***Figure 2*** shows the dramatically increasing trend in the share of the population over age 65 of the world[1]. There are the world maps of the years 1960 and 2014 in the appendix. The darker the color, the greater the percent of the population aged 65 or older. From the graph, it is shown that the color of the world is much darker in 2014 than it was 54 years ago.

There are three purposes of this study. The first goal is to understand the past and current aging population situation of the world, specifically in China. The second goal is to explore the relationship between population aging and economic growth by using econometric models. Finally, I will take a deep look into China's situation with Japan working as a reference and investigate that if population aging is going to have large negative impacts on China's economy.

This paper consists of seven sections. Section 1 is the introduction part. Section 2 presents the literature review. Section 3 introduces the basic model used in this paper. Section 4 describes the data and section 5 provides the regression results while Section 6 includes case studies of Japan and China. Conclusions are given in Section 7.

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[1] Data of share of population of 65 and above are obtained from the World Bank.

II. Literature Review

Substantial attention has been paid to the impact of population aging on a country's economy. But there is no consensus about whether population aging has a positive, negative or even no impact on a country's growth.

A widely accepted view on the relationship is as follows. Due to the increased life expectancy and low fertility rate, aged people are occupying a higher share of the total population, which means decreased labor input, a higher dependency ratio and other negative effects on a country's economy. For instance, Yashiro (1997) argues that population aging has negative impacts on Japan's economy in terms of labor market impacts, macroeconomic consequences and fiscal effects. This opinion coincides with Lindh and Malmberg (2009) when investigating the relationship between European Union economic growth and the population age structure. By taking a quantitative approach, they show that the increase in the dependency ratio has an adverse impact on the per capita GDP growth rate and the share of the population of 65 and over has a robust negative effect, which means the sign of the coefficent is always negative no matter what kind of controls included. In addition, Hashimoto and Tabata (2010) establish a small open two-sector (health care and non-health care) overlapping generations model and find that labor tends to shift to the health sector to meet the increasing demand of health care due to the population aging, which lowers the productivity of the non-health sector and probably brings down capita income growth. Also, after running a cross-country analysis with a base sample of 45 countries, Acemoglue and Johnson (2006) claim that there is no evidence to show that increase in life expectancy, which is one of the main causes for population aging, is related to the increment of income per capita.

However, in the contrast to this popular view, Futagami and Nakajima (2002) use an extended life cycle growth model and comment that economic growth is not necessarily adversely affected by population aging. Similarly, Bloom, Canning and Fink (2010) claim that population aging might have a negative but small impact on developed countries' economy, but is not likely to have substantial influence on developing countries. Furthermore, by adding the population aging variable into the Neoclassical Economic Growth Model, Bao (2011) argues that dual effects, both positive and negative effect, are imposed on the regional economy by population aging. The positive impact is brought by the growing demand of certain industries, such as health care products and retirement services. On the other hand, the negative impact is the labor shrinkage of labor supply, which would certainly jeopardize a country's economy. The net effect is unclear since it depends on many other factors. However, the base line is that when the share of the elderly passes above certain level, the negative impact will dominate. Tosun (2003) establishes the Basic Diamond Overlapping Model and points out that international capital mobility serves as a buffer while endogenous fiscal policy might worsen the situation. But the net effect waits to be tested empirically. When investigating the effect of health on economics, Weil (2007) uses adult survival rate for men and age of menarche as measurements for health and observes that countries with better health are usually more likely to gain higher economic growth rate. Health is generally associated with higher life expectancy and lower mobility rate (Murray and Lopez 1997), one of the major causes for population aging. In addition, Herrmann (2014) investigates 20 countries including both developing and developed countries and finds that the rise in the elderly dependency ratio is often accompanied by the fall in the young dependency ratio. Hence, the total dependency ratio might not increase much. The labor shortage brought by population aging in developing countries can be at least partially alleviated by the rapid increase in rural-urban migration since rural areas tends to be younger. Thus, if viewed in a broader scope of economic relationships, population aging seems to be less challenging.

Furthermore, there are some papers that argue that population aging might even promote the economic growth. For example, Bloom, Canning and Sevilla (2004) contend that health, which is measured by life expectancy, has a significantly positive impact on economic growth. Moreover, Asia and Pueyo (2013) jointly consider the rising demand for health-care services and the increased saving prepared for more years of retirement. The combined effect of labor shifting to the health-care sector and accumulation of capital on a country's economy is not clear. However, they claim that when capital mobility is imperfect and country is big enough, it is probable that the capital accumulation effect dominates so that population aging is beneficial for the economy. In the same way, Li, Zhang and Zhang (2007) show using a cross-country analysis that due to the dominance of the capital accumulation effect, longevity has a positive effect on the economy. Additionally, Mason and Lee (2013) suggest that instead of a passive effect on the labor market, a longer life has an insignificant effect on lifetime labor supply and can actually result in larger lifetime consumption, which improves the economy.

When comes to the situation of China, there are lots of disputes about the impact of population aging. Wang, Cai and Zhang (2004) analyze the demographic structure of China and forecast that due to the rapid increase of the share of elderly, China can no longer enjoy the population bonus. A large share of the population of 65 and over will actually drag down China's economy. Guo, Li and Yuan (2013), based on data from national census and predictions from the United Nations, argue that aging is going to greatly impede China's economic growth in many aspects, such as labor supply, capital accumulation and technology development. Papers with similar ideas are Hou (2007) and Zhang (2006).

In contrast, Li (2013) comprehensively analyzes the positive impact of population aging on China's economic growth and claims that initial stage of aging, which is with high birth rate and low share of the elderly and usually is known as the population bonus period, is favorable for economy development. At the same time, population aging is an important drive for technology development and transformation of economic growth pattern from largely relying on international capital investment and exports to depending on domestic demand. Furthermore, it also promotes large-scale management of agriculture to make better use of human capital. In the same manner, Zhao (2004) points out that population aging is beneficial for increasing human capital investment, producing more skilled labor and promoting the development of the aged industry. Also, Wang (2014) establishes the Dynamic Overlapping Generations Model and endogenizes the labor supply and human capital decisions. He argues that young people with visions and rational expectations would choose to invest in improving human capital to provide more skilled labor inputs, which actually fits educational data in China. This will greatly lower the cost of population aging.

However, some papers believe that the impact of aging on China's economy is vague. For example, by introducing population aging factors into the Solow Model, Li (2013) finds that population aging has varying effects, which can be positive, negative or insignificant, on the economic balanced growth path. The variation is contingent on factors, such as saving rate and the age of population. Additionally, Li and Zhang (2015) incorporate old-age dependency ratio in Solow model and find that population aging is likely to have both positive and negative effect on China's economic growth. Specifically, in short run, there is negative effect on income. On the other hand, in long run, old-age dependency ratio and income per-capita are positively related.

III. Model Section

According to the Solow Growth Model, the economy has a constant returns to scale production function, taking the form of:

$$Y_{it} = (A_{it}H_{it})^{\alpha} K_{it}^{\beta} L_{it}^{1-\alpha-\beta} \qquad (1)$$

where Y is the output, which in here is the GDP. L denotes the input of land, which is assumed to be constant in this paper, and after taking logs, it will just become a time invariant country-specific term. Thus, without loss of generality, it can be neglected. K denotes the capital input, A is the TFP (total factor productivity), which represents the technology level, H_{it}, it is the effective units of labor, and $H_{it} = h_{it}N_{it}$, where h_{it} is human capital and N_{it} is the total population. To make economic conditions of different countries more comparable, this paper only uses values without units, such as growth rates, ratios and so on.

Once logs are taken, the production function will become:

$$\log(Y_{it}) = \alpha \log(A_{it}) + \alpha \log(h_{it}) + \alpha \log(N_{it}) + \beta \log(K_{it}) + (1 - \alpha - \beta) \log(L_{it}) \qquad (2)$$

To relax the model, this paper assumes that production function is not necessarily constant returns to scale, and the parameters of TFP, human capital and population do not need to be the same.

$$\log(Y_{it}) - \log(Y_{it-1})$$

$$= \alpha\log(A_{it}) - \alpha\log(A_{it-1}) + \alpha\log(h_{it}) - \alpha\log(h_{it-1}) + \alpha\log(N_{it}) - \alpha\log(N_{it-1})$$

$$+ \beta\log(K_{it}) - \beta\log(K_{it-1}) + (1-\alpha-\beta)\log(L_{it}) - (1-\alpha-\beta)\log(L_{it-1}) \quad (3)$$

Equation (2) is approximately equivalent to

$$\mathrm{g}(Y_{it}) = \alpha\,\mathrm{g}(A_{it}) + \alpha\,\mathrm{g}(h_{it}) + \alpha\,\mathrm{g}(N_{it}) + \beta\,\mathrm{g}(K_{it}) + (1-\alpha-\beta)\,\mathrm{g}(L_{it}) \quad (4)$$

Based on the equation above, this paper assumes that the growth rate of real GDP of country i at the time t, $gGDP_{it}$ is a linear function of share of the population of 65 and over, other labor characteristics and some economic characteristics, which are incorporated to capture the demographic and economic condition. The model used for the cross-country analysis here is the OLS fixed effect model and is expressed as:

$$gGDP_{it} = \alpha_t + \gamma_i + \beta_0 + \beta_1 gPop\_over\_65_{it} + \beta_2 gTFP_{it} + \beta_3 gTrade_{it} + \beta_4 gPop_{it} +$$
$$\beta_5 gEmp_{it} + \beta_6 gPop\_below\_14_{it} + \beta_7 gHumanCapital_{it} + \beta_8 gUrbanpopulation_{it} +$$
$$\beta_9 gTFP_{it} \times gPop\_over\_65_{it} + e_{it} \qquad (5)$$

Here, the dependent variable, $gGDP_{it}$ is the growth rate of real GDP for country i at time t. $Pop\_over\_65_{it}$, which is the share of population of 65 years old and over for country i at time t and indicates the severity of population aging, is the variable of interest. $Trade_{it}$ is the trade ratio of real GDP for country i at time t, and is used to measure the openness of each country. Based on Levine and Renelt (1992), the trade ratio is robustly and positively correlated with output. Pop_{it} is the population of country i at time t. It is normally believed that countries with larger populations are more likely to have higher economic growth because of the "population bonus". Emp_{it} is the employment to total population ratio of country i at time t. $Pop\_below\_14_{it}$ is the share of population of 14 and below and is used for estimating the young-age dependency ratio. $Urbanpopulation_{it}$ is the share of urban population of the whole country and work as an indicator of how urbanized or how developed the country i is. TFP_{it}, total factor productivity, measures the technology level. $HumanCapital_{it}$ is human capital and this paper also uses Barro's enrollment rate as an indicator of human capital. Furthermore, This paper incorporates the interaction term, $TFP_{it} \times Pop\_over\_65_{it}$. The reason for including the interaction term is that the impact of aging on the economy may vary with change of TFP. Intuitively, if TFP increases, the impact of aging may be lower (in magnitude) since increased TFP means increased labor productivity and less labor is needed. Therefore, TFP growth can at least partially offset the hazard of decreasing working labor caused by aging. Accordingly, the sign of β_9 is expected to be positive. The g before variables means that variables are in growth rates.

In addition, βs are unknown parameters, and γ_i is the time-invariant country-specific term, and the inclusion of α_t is to control the for time trend. e_{it} is the error term in this model.

IV. Data Section

In this paper, the descriptions of the variables are provided in ***Table 1***. The data used mainly come from the World Bank and Penn World Tables. Real GDP, population, employment, real consumption of households and government, the human capital variables and TFP come from the Penn World Tables. Data measured in dollars are all calculated in 2005 U.S. dollars. On the other hand, the key variable, the share of population of age 65 and over and other variables, including the age structure variables, population density, life expectancy, birth rate, and population share of age over 65, the share of urban population, and the share of trade to GDP, are from the World Bank. In addition, this paper also includes Barro-Lee's tertiary enrollment ratio with 5-year intervals as an alternative indicator of human capital. To change the dataset into yearly one, this paper uses Stata command "ipolate" to create linear interpolation of education attainment values on year assuming the growth rate is constant for every five years.

The data used in this paper cover a large number of countries from 1960 to 2010. Some countries are excluded because of having severely incomplete data for some variables for certain years. This paper ends up with 97 countries, which are listed in the ***Table 2***. Among the 97 countries, 36 countries are from Africa, 17 are from Asia, 20 are from Eruope,12 are from North America, 9 are from South America and 3 are from the Oceania, which makes the sample diversified enough to represent the whole world. In 2014, the mean of the key variable, share of population aged 65 and over, of the sample used here is 8.44%. Compared with mean of 4.98% in 1960, there is about 70% growth. Among the 97 sample countries in this paper, 37 countries have a share of elderly below 5%, 28 countries including China fall in the ［5，10）range, 14 countries are in the ［10，15）range, 16 countries are in ［15，20）, while two countries, Japan and Germany, have over a 20% population share of age over 65. In 2014, the country with maximum share of population aged 65 and over, which is about 25.79%, is Japan and the country with minimum value of 2.35% is Gambia. What is more concerning is that the mean of the growth rate of the elderly share is steadily greater than one over the past 5 years and with a generally upward trend.

Table 3 shows the summary statistics of the variables for 97 countries from 1960 to 2010 for yearly data. For the 97 sample countries selected in this paper, some data for certain variables are still missing. This paper chooses to dummy them out. That is to create a dummy to flag the missing value and then replace that with zero. Since the dataset of this paper has about 5000 observations, the effect of missing data is negligible.

Table 4 shows the summary statistics of the variables for the 97 countries from 1960 to 2010 for data at five-year intervals. Compared with yearly data, the standard deviation of the key variable,$gPop\_over\_65_{it}$, increases from 1.36 to 6.91 while the mean increases from 0.8 to 4.26. Thus, using data with five-year intervals could potentially avoid of the problem of lack of variation in the yearly data.

V. Results

To comprehensively investigate the relationship between population aging and the economy, which, in this paper, is the relationship between the share of the population of 65 years old and over and the real GDP growth rate, this paper runs both fixed and not fixed effect. In the regression with fixed effect, time trend variable and country-fixed effect are added to capture time trend and country-specific characteristics. In addition, ***Table 5*** shows the panel unit root test in levels and in growth rates. IPS and LLC denote two different methods of testing, Im-Pesaran-Shin and Levin-Lin-Chu test respectively. IPS and LLC share many similarities. But LLC fits better for medium size data with homogeneity, such as macroeconomic and industrial data. Meanwhile, IPS is more suitable for small sample data with heterogeneity. Also, attention needs to be paid to choosing lags and autocorrelations when using IPS. Since LLC requires the panel to be strongly balanced, IPS is mainly used. The null and alternative hypotheses of LLC and IPS are slightly different, as shown below.

$$\text{Levin-Lin-Chu (LLC)} \begin{cases} Ho: Panels\ contain\ unit\ roots \\ Ha: Panels\ are\ stationary \end{cases}$$

$$\text{Im-Pesaran\_Shin (IPS)} \begin{cases} Ho: All\ panels\ contain\ unit\ roots \\ Ha: Some\ panels\ are\ stationary \end{cases}$$

The ✔denotes having a unit root and ✗ is otherwise. In levels, almost all regression variables suffer unit root. On the other hand, by using IPS unit root test, it shows that demographic structure variable in growth rates, gpercent_pop_over_65, still follows a unit root. However, the variable proves to be stationary by LLC. Since LLC does a better job when dealing with macroeconomic data, LLC applies better than IPS in this case. Thus I believe that the gpercent_pop_over_65 is stationary. In summary, due to the unit root problem in levels, this paper is only going to run regressions in growth rates.

In addition, there are two indicators of human capital, one of which comes from Penn World Tables and the other one is the tertiary enrollment rate, obtained from Barro and Lee's dataset. This paper does not use the primary enrollment ratio as many previous paper did. The reason is that the mean of primary enrollment rate is 84.3 and standard deviation is 20.6. It seems that having education of primary schools is a basic characteristic for every people, thus a person with primary education cannot be counted as a skilled one. And this reason is also valid for not using secondary enrollment ratio. In addition, the primary enrollment rate is almost constant and really high for many countries. For example, for countries, such as China, the United Kingdom, the United States and Japan, this ratio is 100, which means that the growth rate is 0. Furthermore, regressions are run with yearly data and data with five-year intervals from 1960 to 2010 respectively since yearly data might with little variations.

i. Regressions with yearly data

Table 6 shows the regression results in growth rates with and without country fixed effects. Columns (1) and (2) use human capital from Penn World Tables, while column (3) and (4) use the total tertiary enrollment rate as the indicator of human capital. The coefficients of the key variable, percent_pop_over_65, are statistically significant at the 10 percent level in column (1) and (3), and are not significant in column (2) and (4). However, the signs are all negative, as expected, regardless of with or without fixed effects. The growth rates of TFP, population, and employment ratio are always positive and significant, as predicted. And the impact of growth rates in the urban population and the percent of population below 14 become insignificant after adding fixed effects. This less significance might come from the low variance of variables, which can be easily captured by a constant after adding the fixed effects. On the contrary, the growth rate of trade percent in GDP is shown to have no significant relationship with the growth rate of GDP with and without fixed effect, which can also be blamed on the lack of variation. What is worth mentioning is that the interaction term is always significantly positive, indicating with aging level fixed, the increase in growth rate of TFP can at least partially offset the negative impact, if there is, of aging.

When human capital from PWT is included, human capital has a significantly positive impact on economic growth. However, in contrast, the impacts of tertiary enrollment rate not significant. One explanation for this is that human capital from PWT is composed of average years of schooling and return to education. On the other hand, the human capital variable from Barro and Lee's database just measures the enrollment ratio of tertiary education with little variation overtime. In addition, the data of tertiary enrollment rate are at five-year intervals. In order to transform into yearly data, I assume the enrollment rate is a linear function of year for every five years, which will make the growth rates of enrollment rate are similar for every five years. Thus, for regression of yearly data, the human capital from PWT is much better at capturing the productivity of human.

Since the regression include interaction term between two continuous variables, g(TFP) and g(pop_over_65). To determine the economic significance, I first need to find the conditional expectation of g(GDP) given a marginal increase in g(pop_over_65) and holding g(TFP) constant, which is

$$\frac{\partial E[g(GDP)|g(TFP), g(pop\_over\_65)]}{\partial\, g(pop\_over\_65)} = \beta_1 + \beta_9 \cdot g(TFP)$$

The elasticity is $[\beta_1 + \beta_9 \cdot \overline{g(TFP)}] \cdot \frac{\overline{g(pop\_over\_65)}}{\overline{g(GDP)}}$, while the standardized coefficient is $\left[\beta_1 + \beta_9 \cdot \overline{g(TFP)}\right] \cdot \frac{std(g(pop\ over\_65))}{std(g(GDP))}$. Suppose I compare the difference in the impacts between the 90^{th} and 10^{th} percentiles of the g(TFP) distribution, the expression for semi-standardized coefficient measuring the economic significance is

$$\frac{\{E[GDP\ growth|g(pop\ over\ 65)(90^{th}), \overline{g(TFP)}] - E[GDP\ growth|g(pop\ over\ 65)(\ 10^{th}), g(TFP)]\}}{sd(g(GDP))}$$
$$= \frac{[g(pop\ over\ 65)(90^{th}) - g(pop\ over\ 65)(\ 10^{th})]\times[\beta_1 + \beta_9 \cdot \overline{g(TFP)}]}{sd(g(GDP))}$$

Similarly, the semi-elasticity is $\frac{[g(pop\ over\ 65)(90^{th}) - g(pop\ over\ 65)(\ 10^{th})]\times[\beta_1 + \beta_9 \cdot \overline{g(TFP)}]}{Mean(g(GDP))}$.

***Table** 7* shows the economic significance by using four different methods. The biggest value is 0.09, which is much smaller than 0.2, the cutoff value frequently used. Thus, population aging has no economically significant impact on economic development.

ii. Regressions with data with five-year intervals

Table 8 shows the unit root test for variables with five-year intervals. By using IPS method, most of variables in levels suffer from unit root. On the other hand, all the variables in growth rates are stationary. Thus, for data with five-year intervals, I will only run regressions in growth rates.

Table 9 shows the regression results in growth rates with and without fixed effects. Same as before, column (1) and (2) use human capital from Penn World Tables, while column (3) and (4) use total tertiary enrollment rate as the indicator of human capital. Surprisingly, the key variable becomes insignificant in all columns. As as the case with the regression with yearly data, the growth rates of TFP and population prove to have significant and positive relationship with economic growth. In addition, almost all other variables become insignificant except for coefficient of the growth rate of trade percent is significant after adding the fixed effect. However, the sign is negative, implying that with higher growth of trade percent is associated with lower economic growth, which does not fit the reality. Also, both of the indicators of human capital, the growth rate of human capital from PWT and the growth rate of tertiary enrollment rate, prove to have positive but insignificant impact on GDP growth.

Table 10 shows the economic significance of the regression. All the values are below 0.2, meaning there is no economic significance of population aging on GDP growth.

iii. Regressions separately for continents

Table 11 shows the regression using human capital from the PWT with fixed effect and yearly data since human capital from the PWT does a better job than the enrollment rate. The reason for not running the model with data with 5-year intervals is the lack of enough observations for some continents. ***Table 11*** shows the coefficients of the variable of interest are not statistically significant. Except for Europe and South America, they are all negative.

In conclusion, all the regressions with fixed effect show that the sign of variable of interest, the share of population of 65 years old and over, is negative but not statistically and economically significant. This implies that population aging does not have a significant relationship with economic growth.

A possible explanation for the impact of aging on economic growth is not as important as the impact of growth of population and TFP. Thus the dependent variable is mostly explained by population growth and technology growth. There is also another possibility that the effect of population aging on the economy changes over time. For instance, there may be a trigger value of share of population of 65 and over. Once the percentage reaches this value, there is significant effect of aging on the economy. Just like what happened in Japan. But if the percentage is below that, the impact of aging is insignificant.

iv. Regressions including interaction term with time

To check for the possibility that the effect of aging on the economy varies with time, the following regression model is specified:

$$gGDP_{it} = \alpha_t + \gamma_i + \beta_0 + \beta_1 gPop\_over\_65_{it} + \beta_2 gTFP_{it} + \beta_3 gTrade_{it} + \beta_4 gPop_{it}$$
$$+ \beta_5 gEmp_{it} + \beta_6 gPop\_below\_14_{it} + \beta_7 gHumanCapital_{it}$$
$$+ \beta_8 gUrbanpopulation_{it} + \beta_9 gTFP_{it} \times gPop\_over\_65_{it}$$
$$+ \beta_9 Time_t \times gPop\_over\_65_{it} + e_{it} \quad (6)$$

where $Time_t$ uses 1960 as the base year, meaning $Time_{1960} = 0$， $Time_{1961} = 1$ and so on.

Table 12 and Table 13 show the regression results in growth rates including the time interaction term for yearly data and for data at five-year intervals, respectively. Take the regression with fixed effect with yearly data using human capital from PWT (Column 2 of Table 12) as an example, it shows that before 1974, the growth of share of elderly as a statistically significant positive impact on economic growth. However, after 1974, the impact becomes significantly negative. For regression for data at five-year intervals with fixed effect, the turning point is year 1985. For instance, in 2005, the net impact on economy imposed by aging is -1, meaning if the growth of share of elderly increases, the economic growth decreases by the same amount.

VI. Case study of Japan and China

This case study is to analyze the current and past population aging situation of China and Japan and to find the similarities and differences between the two countries. In addition, Japan is used as the comparison to asses and predict the situation in China.

The case study consists of four parts. Part I describes population aging in China. Part II is the description of population aging in Japan. Both Part I and II is divided into two sections: causes and characteristics of aging. Part III compares between the two countries and Part IV is a discussion of this analysis.

Part I Population aging in China

i. Possible causes of population aging

(a) Increased life expectancy

One of main causes of aging in China is increased life expectancy due to the development of technology, especially health care. ***Figure 3*** shows the life expectancy from 1960 to 2013 for Japan, China, developed and developing countries. The life expectancy of China increases from 69.5 in 1990 to 75.4 in 2013. Despite the substantial increase, the life expectancy of China still falls behind other countries. According to the World Factbook of the Central Intelligence Agency, for 2015, China ranks 99th of all countries and regions. Based on research of Canning and Sevilla (2004) and Weil (2007), health is believed to have positive relationship with economic growth. In addition, low life expectancy also represents that the share of population aged 65 and over is largely composed of young old, who, compared with the old old, have a smaller demand for health care and are equipped with higher level of labor capacity and self-care ability.

But life expectancy only counts the years a person is expected to live at birth without considering the quality of their life. Consequently, Healthy Active Life Expectancy (HALE) is introduced to measure the average number of years a person can live free of disability and in an independent state. According to the World Health Organization (WHO), HALE for China is 68 in 2012, meaning about an average of 7 years of a Chinese person's life are of low quality and highly depend on others' help. As for Japan, having a life expectancy of 83 and with a HALE of 78, people on average live longer and much healthier than Chinese people and thus exert smaller burden on the working labor. Therefore, one urgent task for China is to improve the health level to make working labor more productive and aged people more independent.

(b) One-child Policy

Except from 1958 to 1961 when China had a negative population growth because of the great famine, China experienced a population explosion between the 1950s and the 1970s. It took China just 10 years, from 1964 to 1974, to increase its population from 0.6 billion to 0.9 billion. Why did Chinese population grow so fast? One reason is that in Chinese traditions, it is generally believed that the more children you have, the more blessed you are. Another significant reason is the campaign, “Proud Mother”, launched by Chairman Mao in the earlier fifties to advocate births. At that time, Mao believed “strength lies in numbers”. Larger population means larger labor pool and stronger armed forces to prepare for World War III, which Mao strongly believed would happen. At that time, Mao is highly admired by people in China and his campaign was well received. It was pretty normal for a woman to have five or more children. According to the United Nations, the average fertility rate from 1950 to 1970 is about 6, which is four times of that in 2015. This “proud mother” campaign greatly increased the population base in China.

Lots of problems were brought by the large population. It directly caused tightening supply of food and imposed a huge burden on the ecological environment and resources, which further jeopardized the Chinese living standard by shrinking job and education opportunities and decreasing welfare. Take the supply of food as an example. In spite of the fact that China is the world’s second largest country by land, it has surprisingly small arable land per person. According to the Food and Agriculture Organization, the arable land per person in 2013 for China is 0.08, which is considerably less than the average of 97 sample countries of 0.23. The situation is even worse for Japan, with arable land per person 0.03. Ranked in order from highest to lowest, China is ranked 73rd out of 97 while Japan is ranked 91st. With limited land, it became harder and harder to feed the rapidly growing population. Consequently, controlling population growth seemed to be the best solution at that time.

The Chinese government was inspired by “An Essay on the Principles of Population” proposed by Thomas Robert Malthus claiming that “the populations of the world would increase in geometric proportions while the food resources available for them would increase only in arithmetic proportions". In simple words, the shortage of food supply is due to the uncontrolled increase in population. Thus, the one-child policy was introduced in 1978 and enacted in 1980. Every couple can only have one child except some special cases, such as people from ethnic minorities and from rural areas. Otherwise, people have to pay for "social maintenance fees" since having an extra child means occupying more resources, such as education and health welfare. This one-child policy was supposed to be active for only 10 years, however it was not abolished until 2015.

Due to the one-child policy, the share of the population aged 14 and below dropped dramatically while the share of the population aged 65 and over increased largely. ***Figure 4*** shows the demographic structure of China from year 1960 to 2014. While the graph seems to be promising since the share of population between 14 to 64 is increasing, there will be a sharp decline in around a decade when the baby boom generation retires and the labor force is mainly composed of children with no siblings.

ii. Characteristics of Population Aging in China

(a) Large number of aged population

Being the country with biggest population that is about 18.82 percent of the world population, China has a large number of aged population but not a large share. ***Table 14*** and ***Figure 5*** show the share of population of 65 and over from 2005 to 2095. The 97 sample countries are sorted into two categories according to the World Bank, 27 developed and 70 developing. The data of 2005 come from the World Bank, while the rest are predictions obtained from the Population Division of United Nations. China's current share of elderly is about half of the average share of developed countries and is much less than what Japan has. From this perspective, China is not aged at all. However, considering the big population base of China, the number of the elderly is enormous. For example, in 2015, the elderly population of developed countries is about 180,808,000. And China only has around 131,429,000. What's worse, China is expected to have rather rapid aging. Based on the predictions from United Nations, in the following four decades, from 2015 to 2055, there is going to be an exponential increase of elderly share from 9.55% to 31.02%. It will eventually surpass that of developed countries in year 2055 and arrive at steady rate about 33%, about two percent less than that of Japan. But Japan's rise in elderly population was much slower and was sustained over a much longer period.

(b) Get old before get rich

Unlike the developed countries experiencing population aging, China is probably not going to be rich before it becomes a very old country. According to the United Nations, a country having a share of elderly over 10% is counted as an aged one. With a share of the elderly about 9.5 percent in 2015, China for now can almost satisfy this condition. Although with a high GDP, with the so-called "Growth Miracle" and all the exciting developments, such as massive infrastructure projects, high-speed train and metropolises like Shanghai and Beijing, China indeed is a poor country when it comes to GDP per capita. According to the World Bank, the GDP per capita of China in 2013 was $12,196, which is about 66.6% of the average of 97 sample countries of $18,310. ***Figure 6*** shows the scatter plot of GDP per capita and share of population ages 65 and above in 2014. It only includes aged countries and China. Altogether 31 countries are included. The red point denotes China and the orange one represents Japan. Both of them are below the fitted line. Since aged countries are more likely to be developed countries, it is worth comparing Japan and China with the world. ***Figure*** *7* shows scatter plot in 2014 of all sample countries except five countries with incomplete data. Japan and China are below the fitted line again, which means that countries as old as they are, on average, are richer. On the other hand, countries with same level of development are usually younger. Accordingly, the biggest question is how is China is going to survive with an increasing elderly ratio while still being poor? Will China's growth miracle be over or not?

(c) Large share of young old

As mentioned above, the elderly in China is largely composed of young old, who are more independent than the old old. Thus, the young old do not impose that big a burden on society, and even under certain circumstances, they could contribute the labor supply. They might not work in companies, but they can definitely be informally employed and make home productions.

According to a survey conducted by the China Research Center on Aging, about 66.47% of aged people are responsible for taking care of their grandchildren. To be specific, about 60% to 70% of children younger than two and a half years old are mainly raised by their grandparents. While for children older than 3 years old, the share drops sharply to around 40%.

(d) Huge floating population

Based on Wikipedia, the definition of floating population, which is also referred to as "internal migration", refers to "migrants in China without local household registration status through the Chinese Hukou system". The Hukou system originated from the Xia Dynasty of ancient China (2100BCE to 1600 BCE) and it identifies an individual's residence and basic information such as name, parents, and spouse. If you have Hukou in an area, you are eligible to enjoy certain benefits that are exclusive to people with Hukou in that area. Accordingly, it is normally believed that Hukou in more developed areas, such as Beijing and Shanghai is more valuable than in less developed areas.

To a certain extent, because of the Hukou system, China can be viewed as a union of areas. As a Chinese citizen, you do not need to have a visa to travel across China. But you need Hukou status under certain circumstances, such as access to education. Children can only take high school and college entrance exam where their Hukou belongs except with certain exceptions. For example, in Shanghai, if the parents are in the program of introducing high-skilled workers, the child is permitted to take the entrance exam in Shanghai. The requirements are not extremely demanding.

However, the majority of the floating population don't meet that demand. In case that people might flood into developed cities, there are some restrictions imposed if you want to "migrate". Nowadays, the Chinese government is thinking of cancelling the Hukou system. But that kind of big change might take some time and people already having Hukou in developed cities are certainly going to oppose that.

According to the Report on China's Migrant Population Development published by the National Health and Family Planning Commission of China, the floating population in 2014 is about 0.252 billion, about 18% of total population. Usually, aged people and children, called "left-behind children", stay where their Hukou belongs. Because aged people prefer to stay where they are familiar and children can be better taken care of by their grandparents since their parents are usually busy with work. Also, people with Hukou status in developed cities, especially Shanghai and Beijing, are not likely to move.

$$The\ probability\ of\ internal\ migration = \frac{Share\ of\ internal\ migration}{Share\ of\ working\ population} = \frac{18\%}{73.61\%} \approx 24.45\%$$

This means that about 1 out of 4 working labor move to more developed cities to work. However, this is definitely an underestimate since share of working labor in developed cities should be deducted from the denominator. This large floating population makes impossible to run regression on China's provincial panel data. But this high probability of internal migration might be beneficial for the economy development, since the labor is highly likely to work where has the highest MPN (marginal product of labor).

Part II Population aging in Japan

i. Causes of population aging in Japan

Japan, certainly, is one of countries with the most seriously aging problem. Being the country with aging history of 30 years, Japan now has the world's highest share of population of 65 and above, which is 25.79% in 2014. The speed of aging in Japan is much higher than other developed countries. For recent years, Japan has experienced low or even negative GDP growth rates, which is often blamed on the decline in the labor force due to aging. The question is what are the main reasons behind this?

(a) Increased life expectancy

Similar to China, increased life expectancy is a key contributor, probably the most important one, to population aging. Japan has the highest life expectancy of all countries. The average life expectancy has increased from 67.7 years in 1960 to 83.3 years in 2014. According to the World Health Rankings, the average life expectancy for males is 80.2 years, while for females, it is about 87.2 years. But what contributes to this world leading longevity? Starting with the success of preventing infectious diseases that endangers infants and young children, Japan managed to decrease the mortality rate among children. Meanwhile, the increase in medical services has led to the rise in survival rates from all kinds of diseases. However, progresses in only those aspects cannot explain why Japan is leading in life expectancy since other developed countries, like the United States and the United Kingdom, with life expectancy of 78.8 and 80.9 respectively, are equipped with at least equivalent levels of medical services. Therefore, what is so unique about Japan? One possible explanation for the secret of longevity is eating habits. Daily meals for Japanese are made up of healthy food, such as tofu, seaweed, fish and octopus, which impose low level of risk to health. Another popular answer is that elderly in Japan have relatively stress-free lives. Thanks to the tradition in Asia that children should take care of their retired parents, aged Japanese do not need to worry much about financial matters, thus they can enjoy their final years without stress from bills. According to Japan National Institute of Population and Social Security Research, in 2010, about 42% of people aged 65 and over live with their children. This ratio is decreasing over time (see ***Figure 8***), but still is large. This also potentially explains why the average life expectancy for females in Japan is about 7 years longer than that for males. In Japanese traditional culture, females are supposed to stay at home and take care of children, and earning money is the duty only for males. This has changed greatly in recent years, but is still true for some Japanese families. ***Table 15*** shows the labor participation ratio in 2014, female labor participation ratio for Japan is 49.2%, which is much lower than the average of developed countries of 68.31%. And the rate for China is 64% in 2014, according to the World Bank.

(b) Decreased fertility

Figure 9 shows the fertility rate of Japan, China and the average of 97 sample countries. The fertility rate is the average number of children that a woman is estimated to give birth to in her lifetime. Japan has a rate lower than 2 for more than 30 years. This means sooner or later, Japan is going to experience negative population growth since the replacement ratio to maintain the same population size is above 2. Actually, Japan's population has shrunk for three years. In 2014, the population declined by about 200,000, which is about one-third of the Boston population. The Japanese government has put lots of effort to institute pro-natal policy interventions to encourage births and to counteract the decreasing birth rate. The fewer children a family has means a greater education investment per child, leading to higher education for many women. Higher educated women have greater a possibility of labor working, which will further decrease the fertility rate since there is trade-off between having children and the pursuit of career.

ii. Characteristics of Population Aging in Japan

The most distinguished characteristic of population aging in Japan is how rapid it is. From 1960 to 2014, the share of elderly in the United Kingdom has increased from 11.7% to 17.8%. That of the United States has changed from 9.1% to 14.3%. However, the share of aged population in Japan went from 5.7% to 25.8%. With the highest proportion of elderly, population aging in Japan outweighs all other nations. There is a report from *Japanese Time* telling that because of population aging, the convicts are going grey. About 10.4% of new inmates are composed of seniors. Another important feature of Japan is that the country has little immigration. Unlike Japan, although with low fertility rate, the United States has rather low aging process due to taking in millions of immigrants every year, who are mostly young people. Besides impediments to immigration like the language barrier and cultural differences, the Japanese government does not welcome immigrants. According to the *New York Times*, an article written by Hiroko Tabuchi in 2011 states that “Japan keeps a high wall for foreign labor”. The Japanese government seems to want to keep Japan as “an ethnically homogeneous nation” and a nation of “one race, one civilization, one language and one culture” (Former Japanese Prime Minister Tarō Asō). However, concerned about continuously shrinking and aging labor force, an Asahi Shimbun survey in 2015 shows that 51% of respondents are supportive of accepting more immigrants. This ratio is only 26% in the poll of 2010.

Part III Comparison between China and Japan

Table 16 shows the comparison of demographic and economic characteristics for Japan and China. The two countries share many similarities such as the fast speed of the two countries' aging. Japan has been through the rapid aging for the past decades, while China has experienced for past several years and is forecast to have rapid aging. In 2014, they have same growth rate of population of 65 and over, which is about 2.85%. In addition, both of the countries experienced baby boom from 1950s to 1980s. According to the PWT, from 1952 to 1989, population in China has increased by 197%, and that for Japan has increased about 142%. The year 1957 is the first time that the population growth rate first dropped below 1% in Japan, and that for China is 1997. In addition, the share of elderly in both countries is predicted to increase before 1965. Besides, the culture of China and Japan resemble each other. Being neighbors to each other, the impact of Chinese culture on Japan goes back to the Qin Dynasty (221 to 206 BC). Especially in the Han (206 BC to 220AD) and the Tang Dynasty (618-907 AD), those two countries had rather close relationships. Later, because of decreased communication, Japan started to evolve its own culture. However, those two cultures still have many similarities. For example, in both countries, children are obliged to support their parents at least financially. In China, there is a national law that requires children to frequently visit their parents older than 60 to satisfy their financial and spiritual demands. There are cases that aged parents sued their children for not visiting them enough. China and Japan are also alike in the aspect of immigration, which is generally thought to be an effective solution to population aging. There are not many immigrants in Japan, while for China, net migration is negative. Accordingly, both of the countries could not possibly count on solving the population aging problem through immigration. What is worth mentioning is that although it is currently experiencing a negative growth rate of GDP, Japan, like China, also had its own glorious economic period. Economic miracle not only describes today's China, but also portrays the past Japan.

In ***Table 16***, column "Equivalent" displays the year when Japan has the same level of data as China has now. There are two reasons for the unavailable data. The first is that the variables in Japan and China are not comparable, such as the population and area. The other reason is that the variable is not monotonic with respect to time. For example, the total dependency ratio goes up and down, instead of increasing or decreasing over time. Therefore, it is not meaningful to find the "equivalent" year. The column "Equivalent" shows that most of data fall in the $[1975,1995]$ range with the only exception for the average years of schooling, which is using data of 2010. Therefore, it is an underestimate of current China. Besides, Urban population (%), life expectancy and death rate are excluded when calculating the mean since larger "equivalent" year for these variables is preferred. The mean of "Equivalent" is 1986, implying the current China is of equivalent level to Japan of 1986. With the similarity between the two countries, Japan can work as a reference for China.

In China, first of all, it is predicted to have the diminishing birth rate, fertility rate and also increasing life expectancy. Thus the growth rate of population is going to decrease and even fall below zero. The growing share of elderly and dependency ratio of old will cause shrinkage of labor and impose a burden on the economy. If migration status stays invariant, the aging of the population will eventually jeopardize China's economy. No more economic miracle. What's worse, the GDP per capita in China is equivalent to that of Japan in 1978, which is earlier than 1986. This means that the population is as aged as that the Japan of 1986, but China is poorer. Without enough capital accumulation to prepare for the incoming aging, the economy in China might deteriorate faster than Japan. What is worse, according to figure 5, the rise in elderly's share in China in the future decades is much faster than what Japan had, which will leave China no time to prepare.

Part IV My opinions

Is China really going to face that tragic future?

The answer is uncertain. First of all, whether the population aging is as serious as predicted is uncertain. Unlike other countries, the drop of fertility rate in China is largely due to the mandatory government family planning policy instead of voluntary choices. Thus, the abolishment of the one-child policy might not raise the fertility rate by a lot, but it certainly will slow down the fall of fertility rate, to an extent. In spite of the similarities between Japan and China, there are large differences. To start with, China is a country with huge territory and large population, which is about 25.4 and 10.7 times that of Japan respectively. It is totally reasonable to view China as a union of several smaller countries, just like the European Union. Nevertheless, it is a union with larger capital and labor mobility, which can work as buffers to aging according to Tosun (2003). With little limitations for capital, capital can always go to where it has the highest return. In fact, instead of flooding into more developed cities, capital in China already has the trend of flowing to secondary cities, especially into the real estate industry. But compared to the United States, China is far behind. According to Hsieh and Klenow (2009), because the inefficient allocation of resources, the total factor productivity (TFP) is lowered by 30%-50%. Thus, if the Chinese government could relieve this inefficiency, TFP will go up and thus increase the marginal return to capital and labor. Consequently, labor demand decreases and stimulates the economy. If possible, China could slightly relax the restrictions of foreign capital inflows to attract more capital. On the other side, China is a country with imbalanced aging conditions and a high level of internal migration, which contributes largely to economic development. If the Hukou system is abolished successfully one day, there will be a higher degree of labor mobility. Also, China is probably the country with lowest average retirement age, which is about 55 years old, according to the Ministry of Human Resources and Social Security of China. The general legal retirement age for males is now is 60, and for females is 50. In contrast, the average retirement age in Japan is 61 years old according to the Ministry of Health, Labor and Welfare, and the Japanese government has decided to raise the official age of retirement to 65 by 2025. Similar to Japan, in order to deal with aging, the Chinese government is working on postponing the retirement age by 5 years gradually, meaning postponing several months every year. If assuming the average age that Chinese start working is 20, the average years of life time work is 35. Thus postponing retirement age by 5 years means increasing labor by about 14.3% and this lessens the amount of pension to be paid. What's more, labor and capital are not the only drivers of economic growth, productivity also plays an important role. Presumably, the growth of productivity allows a higher level of tolerance of aging. In other words, technology can work as a substitute for labor. With technology, labor could be more productive, accordingly less labor will be needed. Also, population aging will force China to put more focus on the aged industry and transfer from labor-intensive industries into technology-intensive or service industry. According to the estimation from World Bank, the service industry only composes 48.1% of China's GDP, which is lower than average of sample developed countries of 73.71% and smaller than the total sample average of 58.91%. Finally, because of the "democratic centralism" adopted by the Communist Party of China (CPC), the enacting of policies is much easier in China than most of the countries including Japan, which means the Chinese government might actually respond to population aging problem faster.

VII. Conclusion

In conclusion, what might happen in China is unsure. If China exactly follows what Japan has experienced, the country will be in big trouble. But the differences between the two countries may save China. For example, the Chinese government is working on postponing the retirement age and has announced the abolishment of the one-child policy. What's more, in January of 2016, the late-marriage leave, allows a person to have longer marriage leave if he or she is married late[2], is cancelled. What the Chinese government can do in the future to further alleviate the situation is to increase labor and capital mobility by relaxing restrictions and abolishing the Hukou system. Furthermore, since one of the main reasons that hinder the recovery of fertility rate is the increasing cost of raising children, the Chinese government should invest more in education to improve the quality of public schools so that people would be less likely to send their children into private schools for potential higher quality of education but with more expensive fees. In addition, more day care centers of high quality should be built to provide convenience for working parents and to relieve them from the stress of taking care of babies to have a break. Also, the development of aged care industries should be encouraged, which will stimulate demand and create jobs, thus improve the economy.

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[2] For males, if getting his first marriage after 25 years old is counted as married late. For females, the requirement is getting married about 22 years old.

VIII. Appendix

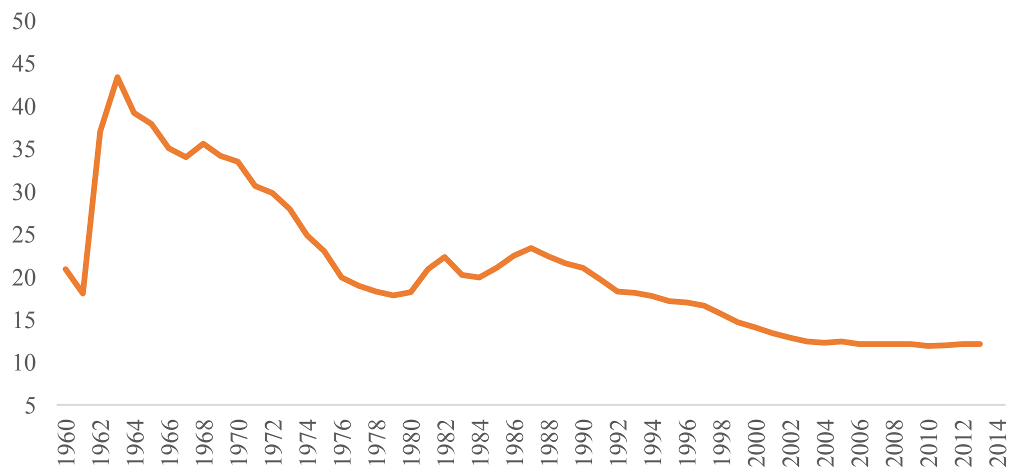


Figure 1 Birthrate of China

Source: National Bureau of Statistics of China

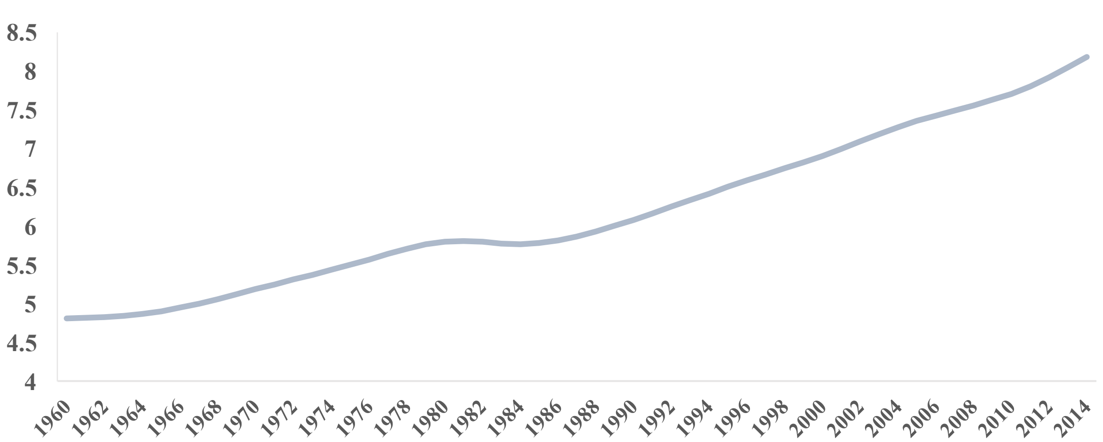
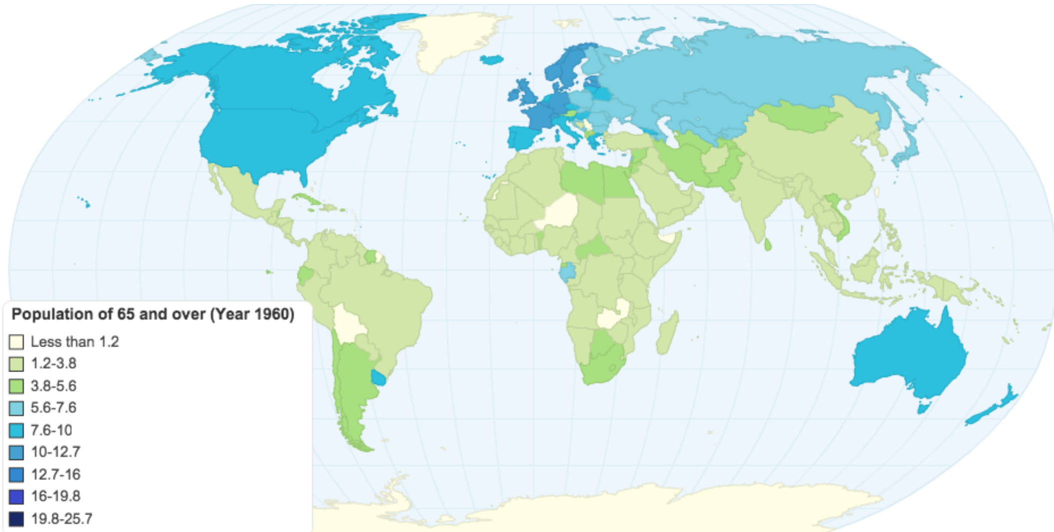


Figure 2 Population ages 65 and above (% of total world population)

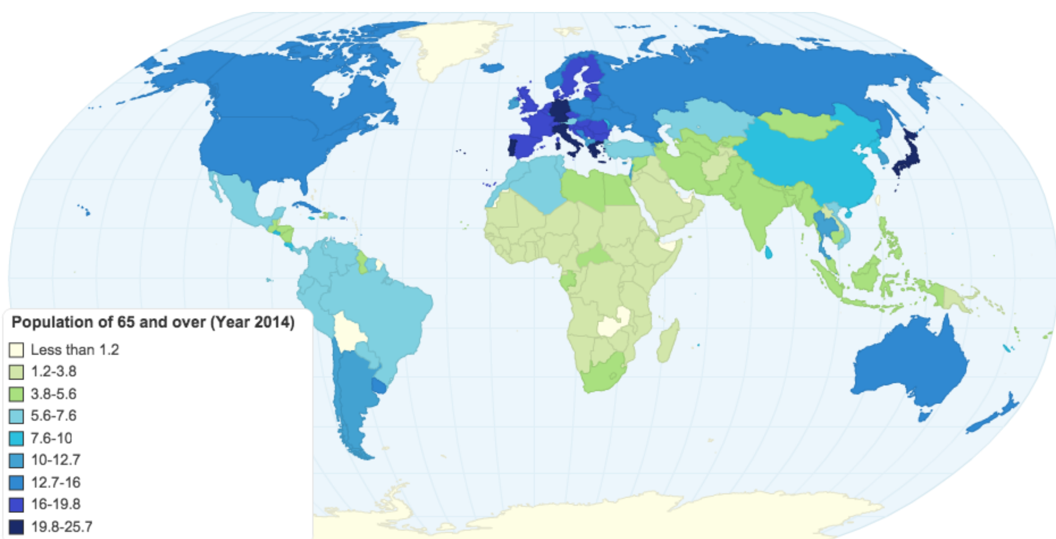
Source: World Bank estimation based on the data from the United Nations Population Division's World Population Prospects.

Figure 3 Population of 65 and over of year 1960



Source: World Bank estimation based on the data from the United Nations Population Division's World Population Prospects.

Figure 4 Population of 65 and over of year 2014



Source: World Bank estimation based on the data from the United Nations Population Division's World Population Prospects.

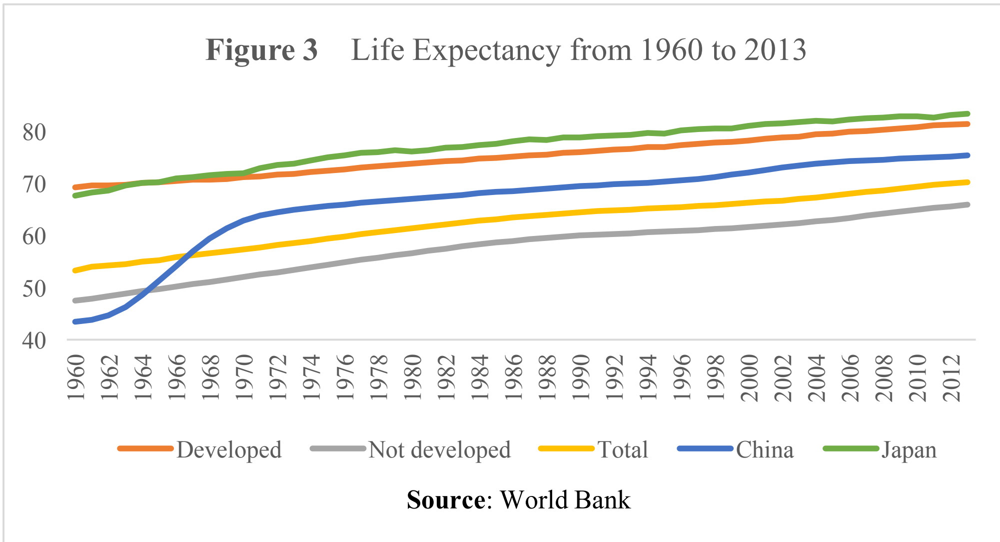


Figure 3 Life Expectancy from 1960 to 2013
80
70
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1968
1970
1972
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1976
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1980
1982
1984
1986
1988
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1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Developed
Not developed
Total
China
Japan
Source: World Bank

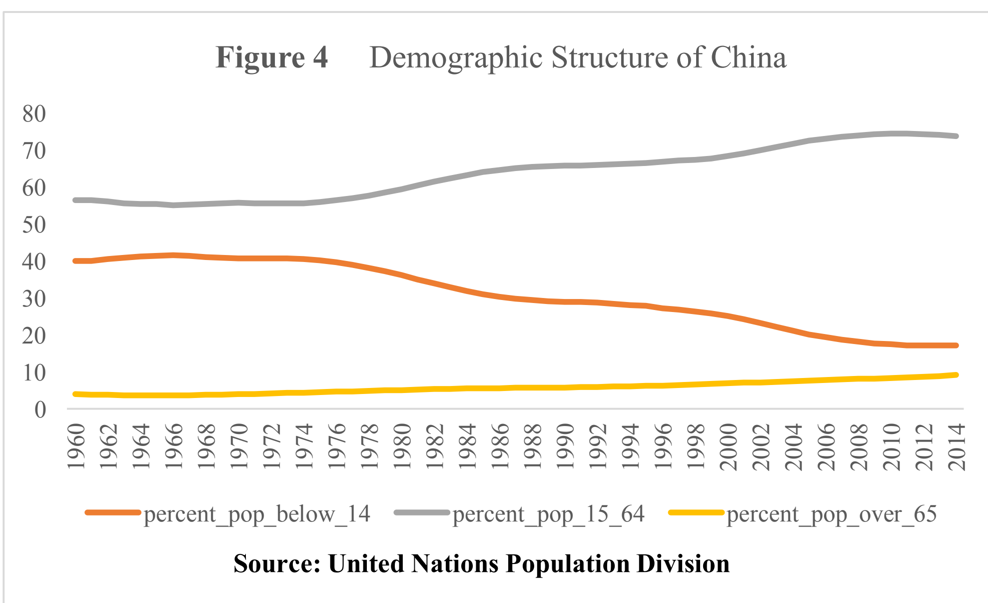

Figure 4 Demographic Structure of China
80
70
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1986
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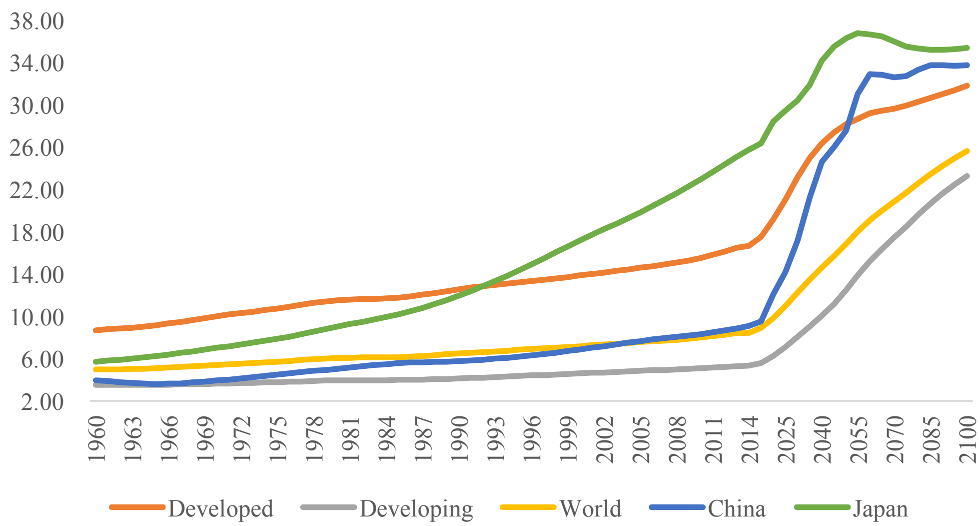
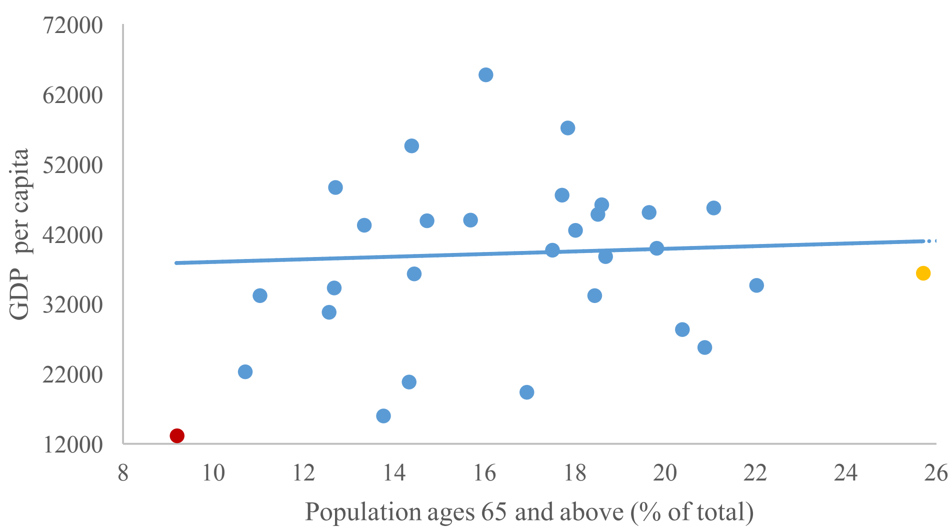
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
percent_pop_below_14
percent_pop_15_64
percent_pop_over_65
Source: United Nations Population Division

Figure 5 Share of Population of 65 and over



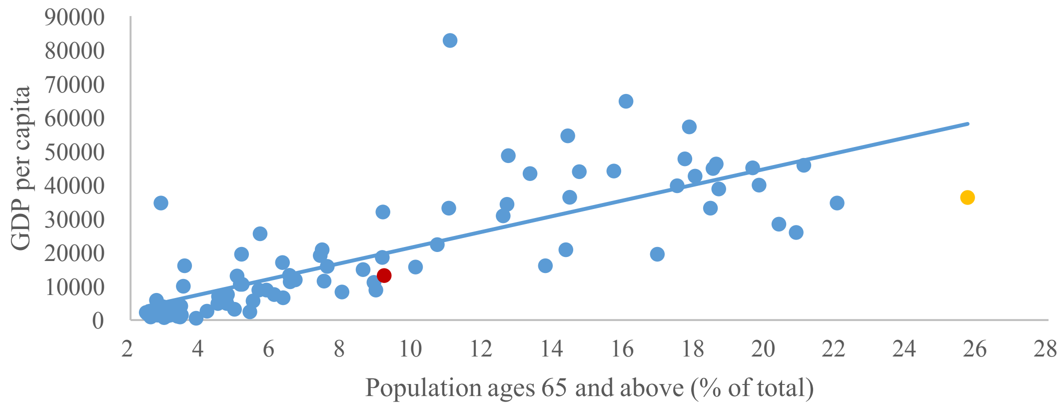
Source: World Bank estimation based on the data from the United Nations Population Division's World Population Prospects

Fiugre 6 Scatter plot of aged countries and China



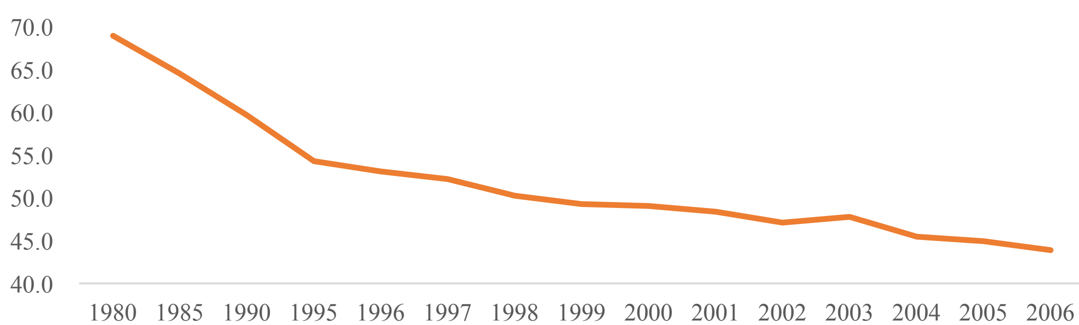
Source: the World Bank

Figure 7 Scatter plot of 97 sample countries



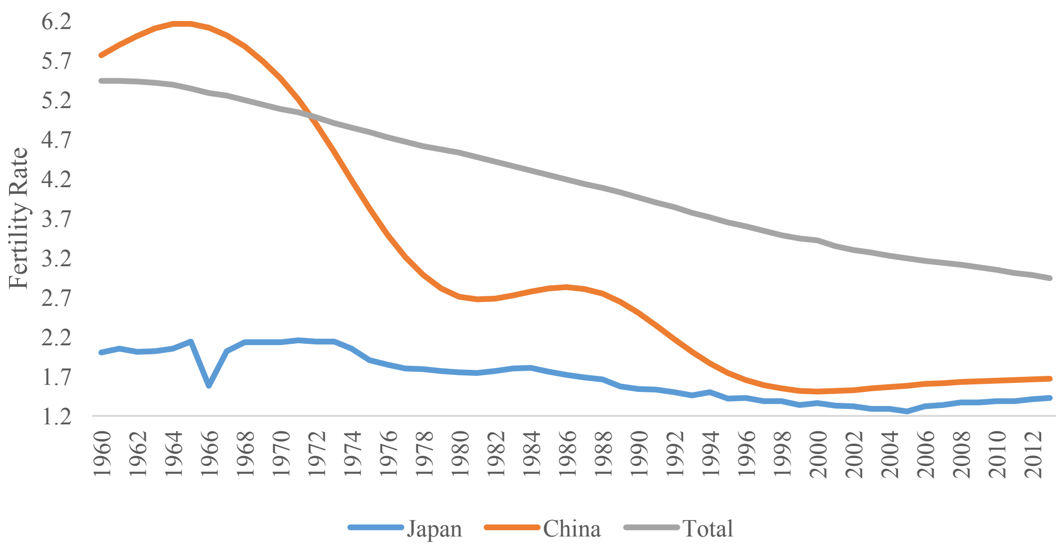
Source: the World Bank

Figure 8 Share of Persons Aged 65 and Over Living with Their Children : 1980-2006



Source: Statistics and Information Department, Ministry of Health, Labour and Welfare, Comprehensive Survey of the People on Health and Welfare.

Figure 9 Fertility Rate



Source: United Nations World Population Prospects

Table 1 Descriptions of variables

GDP	Real GDP from Expenditure-side atchained PPPs in millions in 2005 US dollars
GGDP	Annual growth rate of real GDP
POP	Number of population in millions
GPOP	Growth rate of number of population
EMP_RATIO	Employment rate=EMP/POP
GEMP_RATIO	Growth rate of employment ratio
FERTILITY_RATE	The total number of children that a woman would have in her life
TFP	Total factor productivity at constant national price (2005=1)
GTFP	Growth rate of TFP
DEPENDENCY_RATIO_OLD	The ratio of population over 64 years old to the working-age population from 15-64 years old. Data are shown as the proportion of dependents per 100 working-age population.
DEPENDENCY_RATIO_YOUNG	The ratio of population less than 15 years old to the working-age population from 15-64 years old. Data are shown as the proportion of dependents per 100 working-age population.
DEPENDENCY_RATIO_ALL	The ratio of population less than 15 years old and over 64 years old to the working-age population from 15-64 years old. Data are shown as the proportion of dependents per 100 working-age population.
BIRTHRATE	Number of live births occurring during the year, per 1,000 population estimated at midyear.
DEATHRATE	Number of deaths occurring during the year, per 1,000 population estimated at midyear
PERCENT_POP_OVER_65	Population ages 65 and above as a percentage of the total population
GPERCENT_POP_OVER_65	Growth rate of share of population ages 65 and above
PERCENT_POP_BELOW_14	Population ages 14 and below as a percentage of the total population
GPERCENT_POP_BELOW_14	Growth rate of percent of population ages 14 and below
URBAN POPULATION	The share of people living in urban areas to the whole country population
GURBANPOPULATION	Growth rate of share of people living in urban areas
TRADE_PERCENT	The share of the sum of exports and imports of goods and services to total GDP
GTRADE_PERCENT	Growth rate of trade percent
HUMAN CAPITAL	Index of human capital per person, based on years of schooling (Barro/Lee, 2012) and returns to education (Psacharopoulos, 1994)
GHUMANCAPITAL	Growth rate of human capital
TERTIARY ENROLLMENT RATE	Tertiary enrollment rate is the ratio of total enrollment of tertiary education, regardless of age, including both sexes. Data come from Barro's database.
GTERTIARY ENROLLMENT RATE	Growth rate of tertiary enrollment rate

Table 2 Country List

Africa		Asia	North America	South America	Oceania	Europe
Botswana	Madagascar	Bangladesh	Barbados	Argentina	Australia	Austria
Cameroon	Malawi	China	Canada	Bolivia	Fiji	Belgium
Cape Verde	Mali	India	Costa Rica	Brazil	New Zealand	Cyprus
Central African Republic	Mauritania	Indonesia	Dominican Republic	Chile		Denmark
Chad	Mauritius	Iran	El Salvador	Ecuador		Finland
Comoros	Morocco	Israel	Guatemala	Paraguay		France
Côte d'Ivoire	Mozambique	Japan	Honduras	Peru		Germany
Democratic Republic of the Congo	Namibia	Malaysia	Jamaica	Uruguay		Greece
Egypt	Niger	Nepal	Mexico	Venezuela		Iceland
Equatorial Guinea	Nigeria	Pakistan	Panama			Ireland
Ethiopia	Rwanda	Philippines	Trinidad and Tobago			Italy
Gabon	Senegal	Republic of Korea	United States			Malta
Gambia	Sierra Leone	Singapore				Netherlands
Ghana	South Africa	Sri Lanka				Norway
Guinea	Togo	Syrian Arab Republic				Portugal
Guinea-Bissau	Tunisia	Thailand				Romania
Kenya	Uganda	Turkey				Spain
Lesotho	Zambia					Sweden
						Switzerland
						United Kingdom

Table 3 Statistic Summary for 97 countries from 1960 to 2010 (yearly data)

Variable	Mean	SD	Min	Max	Variable	Mean	SD	Min	Max
grgdpe	4.32	7.54	-53.32	116.70	percent_pop_over_65	6.31	4.30	1.15	22.96
pop	42.60	138.89	0.18	1340.91	gpercent_pop_over_65	0.80	1.36	-5.06	11.63
gpop	1.84	1.19	-18.07	10.26	Urbanpopulation	47.58	25.23	2.60	100.00
emp_ratio	38.83	7.88	22.91	68.53	gUrbanpopulation	0.88	9.38	-95.51	227.53
gemp_ratio	0.33	1.92	-15.43	26.58	trade_percent	66.08	48.20	4.98	531.74
life_expentancy	62.19	12.40	26.76	82.93	gtrade_percent	1.97	15.08	-58.02	317.88
fertility_rate	4.24	2.03	1.08	8.45	humancapital	2.09	0.63	1.02	3.62
dependency_ratio_old	10.39	6.13	2.23	36.02	ghumancapital	0.94	0.68	-1.92	6.04
dependency_ratio_young	63.99	23.81	20.53	106.69	TFP	0.97	0.23	0.32	3.23
dependency_ratio_all	73.72	20.14	5.95	113.15	gTFP	0.48	4.04	-46.68	33.71
birthrate	30.56	13.36	8.10	56.66	gtertiary enrollment rate	9.68	34.05	-100.00	650.00
deathrate	11.72	5.73	3.38	39.97	TFP*pop_over_65	6.98	4.30	1.13	22.89
percent_pop_below_14	35.69	10.09	13.29	50.44	gTFP*gpop_over_65	1.00	7.65	-45.65	149.80
gpercent_pop_below_14	-0.62	1.02	-6.20	4.85					

Table 4 Statistic Summary for 97 countries from 1960 to 2010 (five-year)

Variable	Mean	SD	Min	Max	Variable	Mean	SD	Min	Max
grgdpe	25.1	35.73	-69.86	661.25	percent_pop_over_65	6.31	4.3	1.15	22.96
pop	42.68	139.47	0.18	1340.91	gpercent_pop_over_65	4.26	6.91	-18.43	55.49
gpop	2.4	2.89	-4.54	22.46	Urbanpopulation	47.58	25.23	2.6	100
emp_ratio	38.83	7.88	22.91	68.53	gUrbanpopulation	7.5	9.83	-17.3	104.06
gemp_ratio	1.71	5.59	-19.61	35.62	trade_percent	66.08	48.2	4.98	531.74
life_expentancy	62.19	12.4	26.76	82.93	gtrade_percent	4.82	3.56	-9.24	28.44
fertility_rate	4.24	2.03	1.08	8.45	humancapital	2.09	0.63	1.02	3.62
dependency_ratio_old	10.39	6.13	2.23	36.02	ghumancapital	0.94	0.68	-1.92	6.04
dependency_ratio_young	63.99	23.81	20.53	106.69	TFP	0.97	0.23	0.32	3.23
dependency_ratio_all	73.72	20.14	5.95	113.15	gTFP	0.98	4.97	-42.91	33.71
birthrate	30.56	13.36	8.1	56.66	gtertiary enrollment rate	28.85	51.67	-100	600
deathrate	11.72	5.73	3.38	39.97	TFP*pop_over_65	6.98	4.3	1.13	22.89
percent_pop_below_14	35.69	10.09	13.29	50.44	gTFP*gpop_over_65	7.25	36.94	-204.53	463.56
gpercent_pop_below_14	-2.96	4.73	-25.52	15.79					

Table 5 Unit root test

Variable	IPS	Variable	IPS	LLC
realGDP	✔	grealGDP	✗	
percent_pop_over_65	✔	gpercent_pop_over_65	✔	✗
TFP	✔	gTFP	✗	
emp_ratio	✔	gemp_ratio	✗	
trade_percent	✗	gtrade_percent	✗	
Urbanpopulation	✔	gUrbanpopulation	✗	
percent_pop_below_14	✔	gpercent_pop_below_14	✗	
pop	✔	gpop	✗	
human capital	✔	human capital	✗	
tietary enrollment ratio	✔	tietary enrollment ratio	✗	
popdensity	✗	gpopdensity	✗	

Table 6 No Fixed and Fixed effect in growths with yearly data

	No Fixed Effect with human capital in growth (1)	Fixed Effect with human capital in growth (2)		No Fixed Effect with Barro enrollment rate in growth (3)	Fixed Effect with Barro enrollment rate in growth (4)
gpercent_pop_over_65	-0.15	-0.13	**gpercent_pop_over_65**	-0.15	-0.14
	(0.08)*	(0.09)		(0.08)*	(0.09)
gTFP	0.90	0.85	**gTFP**	0.89	0.85
	(0.03)***	(0.03)***		(0.03)***	(0.03)***
gtrade_percent	0.00	-0.01	**gtrade_percent**	0.00	-0.01
	(0.01)	(0.01)		(0.01)	(0.01)
gpop	0.69	0.89	**gpop**	0.74	0.91
	(0.09)***	(0.13)***		(0.09)***	(0.13)***
gemp_ratio	0.48	0.42	**gemp_ratio**	0.48	0.42
	(0.05)***	(0.05)***		(0.05)***	(0.05)***
gpercent_pop_below_14	-0.27	-0.12	**gpercent_pop_below_14**	-0.31	-0.11
	(0.11)**	(0.13)		(0.11)***	(0.13)
ghumancapital	0.60	0.61	**g tertiary enrollment rate**	0.01	0.02
	(0.14)***	(0.17)***		(0.01)	(0.01)
gUrbanpopulation	0.12	0.12	**gUrbanpopulation**	0.13	0.12
	(0.06)**	(0.08)		(0.06)**	(0.08)
gpop_over_65*gTFP	0.06	0.05	**gpop_over_65*gTFP**	0.06	0.05
	(0.02)***	(0.02)***		(0.02)***	(0.02)***
_cons	1.84		**_cons**	2.14	
	(0.25)***			(0.24)***	
R-Squared	0.204	0.268	**R-Squared**	0.202	0.267
N	4,947	4,947	**N**	4,947	4,947
SER	6.73	6.55	**SER**	6.74	6.56

Table 7 Economic Significance for regression with yearly data

Economic Significance	Column (1)	Column (2)	Column (3)	Column (4)
Elasticity	-0.02	-0.02	-0.02	-0.03
Standardized coefficient	-0.02	-0.02	-0.02	-0.03
Semi-elasticity	-0.09	-0.08	-0.09	-0.09
Semi-standardized coefficient	-0.05	-0.04	-0.05	-0.05

Table 8 Unit root test of data with five-year intervals

Variable	IPS	Variable	IPS
realGDP	✔	grealGDP	✗
percent_pop_over_65	✔	gpercent_pop_over_65	✗
TFP	✔	gTFP	✗
emp_ratio	✔	gemp_ratio	✗
trade_percent	✗	gtrade_percent	✗
Urbanpopulation	✔	gUrbanpopulation	✗
percent_pop_below_14	✔	gpercent_pop_below_14	✗
pop	✔	gpop	✗
human capital	✔	human capital	✗
tietary enrollment ratio	✔	tietary enrollment ratio	✗
popdensity	✗	gpopdensity	✗

Table 9 Fixed and no fixed effect in growths with data at five-year intervals

	No Fixed Effect with human capital in growth (1)	Fixed Effect with human capital in growth (2)		No Fixed Effect with Barro enrollment rate in growth (3)	Fixed Effect with Barro enrollment rate in growth (4)
gpercent_pop_over_65	-0.07	-0.01	**gpercent_pop_over_65**	-0.07	-0.03
	(0.19)	(0.22)		(0.19)	(0.22)
gTFP	0.74	0.72	**gTFP**	0.70	0.70
	(0.33)**	(0.35)**		(0.33)**	(0.35)**
gtrade_percent	-0.04	-0.09	**gtrade_percent**	-0.05	-0.10
	(0.04)	(0.04)**		(0.04)	(0.04)**
gpop	4.34	7.47	**gpop**	4.48	7.41
	(1.21)***	(1.77)***		(1.20)***	(1.77)***
gemp_ratio	0.34	0.33	**gemp_ratio**	0.34	0.33
	(0.24)	(0.25)		(0.24)	(0.25)
gpercent_pop_below_14	-0.43	-0.26	**gpercent_pop_below_14**	-0.47	-0.25
	(0.31)	(0.35)		(0.31)	(0.35)
ghumancapital	0.34	0.56	**g tertiary enrollment rate**	0.14	0.20
	(0.32)	(0.39)		(0.20)	(0.22)
gUrbanpopulation	0.18	0.20	**gUrbanpopulation**	0.19	0.21
	(0.13)	(0.17)		(0.13)	(0.17)
gpop_over_65*gTFP	0.06	0.02	**gpop_over_65*gTFP**	0.06	0.02
	(0.04)	(0.04)		(0.04)	(0.04)
_cons	12.71		**_cons**	13.31	
	(3.22)***			(3.12)***	
R-Squared	0.034	0.199	**R-Squared**	0.033	0.198
N	969	969	**N**	969	969
SER	36.29	35.00	**SER**	36.30	35.02

Table 10 Economic Significance for regression with data at five-year intervals

Economic Significance	Column (1)	Column (2)	Column (3)	Column (4)
Elasticity	-0.02	-0.02	0.00	0.00
Standardized coefficient	-0.02	-0.02	-0.01	0.00
Semi-elasticity	-0.02	0.00	-0.02	-0.01
Semi-standardized coefficient	-0.01	0.00	-0.01	-0.01

Table 11 Fixed effect in growths for different continents with yearly data

	Africa	Asia	North America	South America	Oceania	Europe
gpercent_pop_over_65	-0.20	-0.06	-0.04	0.05	-1.29	0.03
	(0.20)	(0.21)	(0.20)	(0.40)	(0.78)	(0.08)
gTFP	0.88	0.79	0.61	0.68	0.53	1.07
	(0.07)***	(0.10)***	(0.06)***	(0.09)***	(0.27)*	(0.04)***
gtrade_percent	-0.00	-0.02	-0.02	-0.01	0.05	-0.10
	(0.01)	(0.01)	(0.02)	(0.02)	(0.06)	(0.01)***
gpop	0.77	1.19	1.00	1.80	1.22	1.02
	(0.23)***	(0.48)**	(0.53)*	(0.95)*	(0.99)	(0.11)***
gemp_ratio	-0.29	0.33	0.56	0.27	0.24	0.78
	(0.35)	(0.10)***	(0.07)***	(0.08)***	(0.22)	(0.05)***
gpercent_pop_below_14	0.49	-0.67	0.01	-0.85	-1.01	0.14
	(0.39)	(0.25)***	(0.27)	(0.62)	(0.96)	(0.09)*
ghumancapital	0.31	-0.02	0.97	0.72	-0.43	0.86
	(0.42)	(0.36)	(0.30)***	(0.36)**	(1.02)	(0.13)***
gUrbanpopulation	0.19	0.62	-0.48	-0.00	-1.74	0.40
	(0.13)	(0.23)***	(0.23)**	(0.60)	(1.83)	(0.14)***
gpop_over_65*TFP	-0.00	0.11	0.23	0.19	0.13	-0.01
	(0.04)	(0.04)**	(0.04)***	(0.07)***	(0.15)	(0.01)
R-Squared	0.203	0.354	0.464	0.606	0.583	0.756
N	1,836	765	612	459	153	1,020
SER	9.09	5.35	4.13	4.11	3.72	2.29

Table 12 Fixed and no fixed effect in growths with interaction with time for yearly data

	No Fixed Effect with human capital in growth (1)	Fixed Effect with human capital in growth (2)		No Fixed Effect with Barro enrollment rate in growth (3)	Fixed Effect with Barro enrollment rate in growth (4)
gpercent_pop_over_65	-0.03	0.27	**gpercent_pop_over_65**	-0.02	0.27
	-0.13	(0.15)*		-0.13	(0.15)*
gTFP	0.9	0.85	**gTFP**	0.89	0.85
	(0.03)***	(0.03)***		(0.03)***	(0.03)***
gtrade_percent	0	-0.01	**gtrade_percent**	0	-0.01
	-0.01	-0.01		-0.01	-0.01
gpop	0.69	0.86	**gpop**	0.74	0.88
	(0.09)***	(0.13)***		(0.09)***	(0.13)***
gemp_ratio	0.48	0.42	**gemp_ratio**	0.48	0.42
	(0.05)***	(0.05)***		(0.05)***	(0.05)***
gpercent_pop_below_14	-0.29	-0.12	**gpercent_pop_below_14**	-0.34	-0.11
	(0.11)**	-0.12		(0.11)***	-0.13
ghumancapital	0.6	0.59	**g tertiary enrollment rate**	0.01	0.02
	(0.14)***	(0.17)***		-0.01	-0.01
gUrbanpopulation	0.12	0.16	**gUrbanpopulation**	0.14	0.16
	(0.06)**	(0.08)**		(0.06)**	(0.08)**
gpop_over_65*TFP	0.06	0.04	**gpop_over_65*TFP**	0.06	0.04
	(0.02)***	(0.02)**		(0.02)***	(0.02)**
gpop_over_65*Time	-0.01	-0.02	**gpop_over_65*Time**	-0.01	-0.02
	0	(0.01)***		0	(0.01)***
_cons	1.85		**_cons**	2.14	
	(0.25)***			(0.24)***	
R-Squared	0.205	0.27	**R-Squared**	0.202	0.269
N	4947	4947	**N**	4947	4947
SER	6.73	6.55	**SER**	6.74	6.55

Table 13 Fixed and no fixed effect in growths with interaction with time for data at five-year intervals

	No Fixed Effect with human capital in growth (1)	Fixed Effect with human capital in growth (2)		No Fixed Effect with Barro enrollment rate in growth (3)	Fixed Effect with Barro enrollment rate in growth (4)
gpercent_pop_over_65	0.62	1.25	**gpercent_pop_over_65**	0.62	1.26
	(0.31)**	(0.37)***		(0.31)**	(0.37)***
gTFP	0.74	0.68	**gTFP**	0.70	0.66
	(0.33)**	(0.34)**		(0.33)**	(0.34)*
gtrade_percent	-0.05	-0.10	**gtrade_percent**	-0.05	-0.11
	(0.04)	(0.04)**		(0.04)	(0.04)**
gpop	4.27	6.96	**gpop**	4.41	6.89
	(1.20)***	(1.75)***		(1.20)***	(1.75)***
gemp_ratio	0.37	0.29	**gemp_ratio**	0.37	0.29
	(0.24)	(0.25)		(0.24)	(0.25)
gpercent_pop_below_14	-0.60	-0.29	**gpercent_pop_below_14**	-0.64	-0.29
	(0.32)*	(0.35)		(0.32)**	(0.35)
ghumancapital	0.34	0.47	**g tertiary enrollment rate**	0.13	0.22
	(0.32)	(0.39)		(0.20)	(0.21)
gUrbanpopulation	0.19	0.31	**gUrbanpopulation**	0.20	0.32
	(0.13)	(0.17)*		(0.13)	(0.17)*
gpop_over_65*TFP	0.05	0.01	**gpop_over_65*TFP**	0.06	0.01
	(0.04)	(0.04)		(0.04)	(0.04)
gpop_over_65*Time	-0.03	-0.05	**gpop_over_65*Time**	-0.03	-0.05
	(0.01)***	(0.01)***		(0.01)***	(0.01)***
_cons	12.83		**_cons**	13.48	
	(3.21)***			(3.11)***	
R-Squared	0.042	0.216	**R-Squared**	0.041	0.216
N	969	969	**N**	969	969
SER	36.15	34.66	**SER**	36.16	34.66

Table 14 Share of population of 65 and over from 1965 to 2095

Year	1965	1975	1985	1995	2005	2015	2025	2035	2045	2055	2065	2075	2085	2095
Developed Countries	9.19	10.75	11.78	13.24	14.6	17.51	21.05	24.96	27.37	28.67	29.48	29.96	30.66	31.42
Developing Countries	3.56	3.80	4.00	4.37	4.86	5.62	7.12	9.06	11.2	13.91	16.37	18.51	20.69	22.5
Total	5.12	5.73	6.17	6.84	7.57	8.93	11	13.48	15.7	18.02	20.02	21.69	23.47	24.98
China	3.62	4.50	5.58	6.20	7.67	9.55	14.18	21.25	26.03	31.02	32.86	32.71	33.79	33.68
Japan	6.27	7.88	10.20	14.39	19.85	26.34	29.43	31.9	35.54	36.78	36.46	35.51	35.23	35.29

Source: The Population Division of United Nations

Table 15 Labor force participation rate (% of ages 15-64) in 2014

	male	female	total
Developed Countries	68.31	68.43	80.21
Developing Countries	78.53	57.74	81.13
Japan	70.40	49.20	59.00
China	N/A	N/A	71.40
Total	75.66	60.75	80.87

Source: International Labor Organization, Key Indicators of the Labor Market database.

Table 16 China vs. Japan

Variables	China	Japan	China/Japan	Equivalent	Source
Area(sq km)	9596960	377915	25.39	N/A	World Bank
Population(millions)(2014)	1364	127	10.73	N/A	World Bank
Population growth(2014)	0.51%	-0.16%	-3.19	1985	World Bank
Age structure (2014)					World Bank
0-14	17.20	12.94	1.33	1992	World Bank
15-64	73.61	61.36	1.20	N/A	World Bank
>64	9.13	25.79	0.35	1981	World Bank
growth of share of elderly(%)(2014)	2.85	2.84	1.00	N/A	World Bank
Median age(2012)	35.12	45.53	0.77	N/A	World Bank
Birth rate(2013)	12.10	8.20	1.48	1984	World Bank
Death rate(2013)	7.20	10.10	0.71	1993	World Bank
Fertility rate(2013)	1.67	1.43	1.17	1988	World Bank
Life expectancy at birth(2013)	75.35	83.33	0.90	1976	World Bank
Dependency ratio(2014):					World Bank
Old	12.54	42.11	0.30	1978	World Bank
Young	23.37	21.09	1.11	1994	World Bank
Total	35.92	63.20	0.57	N/A	World Bank
Net migration	-1800000	350000	-5.14	N/A	World Bank
Ethnic groups	Han: 91.6%; Zhuang: 1.3%, others: 7.1%	Japanese: 98.5%, Koreans: 0.5%, Chinese: 0.4%, other: 0.6%	N/A	N/A	World factbook
Religions	Buddhist 18.2%, Christian 5.1%, Muslim 1.8%, folk religion 21.9%, unaffiliated 52.2% (2010)	Shintoism 79.2%, Buddhism 66.8%, Christianity 1.5%, other 7.1% (2012)	N/A	N/A	World factbook
Average years of schooling(2010)	7.95	11.60	0.69	1971	Barro Database
Urban population(%)(2014)	54.41	93.02	0.58	<1960	World Bank
GDP growth(%)(2011)	5.54	-1.11	-4.97	N/A	World Bank
GDP per capita (current US$)	7590	36194	0.21	1978	World Bank
Public health expenditure (%)(2013)	12.63	20.03	0.63	N/A	WHO

Source: The World Bank, the Penn World Tables, the United Nation

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