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Analysis of Influence of Population Aging on Urban Economic Growth

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Abstract: Population aging is an irreversible changing tendency of urban population age structure at present and for a long time in the future, and this tendency inevitably has significant and continuous influence on urban economy in future. Therefore, it is necessary and important to make clear the action mechanism and the influential effect of population aging for urban economic growth. On the basis of previous researches as well as intermediate and microcosmic data, Shanghai is taken as an example in the article to discuss and analyze the influence of population aging on urban economic growth by virtue of Solow growth model from the new view angle of closed city and open city. Meanwhile, the article focuses on disclosing the aging dilution effect generated by the labour mobility under open city system, the restraint effect on the negative influence generated by continuous high R&D investment to population aging, *etc*.

Keywords: Influential effect, population aging, urban economy.

1. INTRODUCTION

Generally speaking, if the population of 60 years old or above in a country or a region occupies 10% of the total population and the population of 65 years old or above occupies as high as 7%, then the country or the region is judged to enter population aging society. Based on the above standard, China has entered aging society ever since 2000. As of February 2014, there were more than 200 million old people above 60 years old in China, occupying 14.9% of the total population. For example, Shanghai Municipal as the first largest city in China entered aging society in 1982, the aging average of the whole country at that time was about 5% but the aging level of Shanghai Municipal had exceeded 11%. Till the end of 2013, there were 14.3234 million registered people in Shanghai Municipal, including 3.8762 million old people of 60 years old or above, namely 27.19% of the total population; obviously, the aging level thereof was two times of that of the whole country. According to the Forecast of China's Population Aging Development Tendency, the population aging degree in China will be about 18% in 2020 and will be promoted to above 30% in 2050.

The increase of the aging degree of a city essentially reflects the change of the population age structure of the city, and the change of the urban population age structure directly reflects the change of urban labour force or employment age structure. Viewed from Solow economic growth mode (also called new classical economic growth model), the three factors, namely invested capital, labour resource and production technology, are the source power for driving urban economic growth.

The population aging is transferred to and accordingly influences urban economic growth through influencing the above three factors.

2. RESEARCH SUMMARY OF THE INFLUENCE OF THE POPULATION AGING IN CHINA ON ECONOMIC GROWTH

Scholar Tian Xueyuan [1] in China is one of the scholars who all along pay close attention to the relationship between population aging and economic development for a very long time. Tian Xueyuan, *et al.* [2] believed that the direct influence of population aging on economic development was presented in the population change of different age groups; since the proportion of the dependent population of the society and the labor supply depended on the change of the adult population, thus the change of the adult population would directly act on economic growth; additionally, Tian Xueyuan, *et al.* also proposed the opinions that population aging negatively influenced scientific and technological progress, caused talents' knowledge aging and was unfavorable for scientific and technological progress, *etc*. Yu Xuejun [3] gave the quantitative research on the influence of the population aging in China on economic growth. Jiang Xiangqun and Du Peng [4, 5] analyzed the influence of population aging on such economic aspects as labor dependency ratio, labor resource supply, pensions and social consumption quantity according to the sample survey of the population covering 1% of the total population in 1995 and the survey data since 1990. Zhao Jinwen [6] established econometric model to empirically analyze the internal relation between population variable and economic variable during the period of 1952~2001. Peng Xiujian [7] adopted People's Republic of China's Computable General Equilibrium Model to quantitatively analyze the macroeconomic consequence of the population aging in China. Wang Jinying, *et al.* [8] established multiple regression model to analyze that the change of the population age structure in China gradually reduced the labor burden and had obvious promotion effect on the increase of saving level and the improvement of labor input efficiency. On the basis of the population forecast data issued by the

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United Nations in 2008, Qi Chuanjun [9] respectively investigated the influence of the population aging in different countries on the three factors, namely labor supply, capital formation and all-factor productivity. The author believed that the negative influence of population aging on economic growth was mainly presented in the following three aspects: firstly, the aging of labor age structure and the contraction of labor resource would cause the reduction of labor supply; secondly, the international mobility of capitals and the reduction of saving ratio would cause the reduction of the capital formation in the region suffering from severe aging; thirdly, population aging would damage institutional innovation and technological progress and would be unfavorable for improving all-factor productivity. On the basis of Solow growth theory, Hu Angang, *et al.* [10] adopted Cobb-Douglas production function containing human capital to analyze the influence of population aging and population growth rate on economic influence and accordingly obtain several conclusions: firstly, the increase of human capital investment and the improvement of labor efficiency could more or less relieve the impact brought by population aging; secondly, the low saving ratio under aging tendency could cause economic downturn.

In conclusion, viewed from the time sequence, since the aging level did not significantly influence economy in the early period, the researchers were usually focused on the quantitative judgment based on population forecast result, the researches in middle and later periods were focused on the significant influence of population aging on various economic factors through econometric models, multiple regression analysis and other technical measures. Viewed from the data, most data were the closed data of the countries or the data hierarchy was too macroscopic to cause the formation of relatively closed data (*e.g.*, Qi Chuanjun [11] adopted extensively multinational data), and the aging dilution effect generated by population mobility was not considered in intermediate and microscopic hierarchy (*e.g.* city). Viewed from the research details, the research data of Zhao Jinwen [12] and Wang Jinying [13] were mainly focused on structural comparison or rough regression analysis, and the research content was not detailed enough. Although Qi Chuanjun [14] established model through Solow equation, the data was too macroscopic to lack of details. Through comparison, Hu Angang, *et al.* [15-17] researched the details, especially researching the interaction between aging and human capital investment and the interaction between saving ratio and labor participation rate trough Solow growth model and transmission mechanism.

Therefore, on the basis of above mentioned researches as well as intermediate and microcosmic data, Shanghai is taken as an example in the article to discuss and analyze the influence of population aging on urban economic growth by virtue of Solow growth model from the new view angle of closed city and open city. Meanwhile, the article focuses on disclosing the aging dilution effect generated by the labor mobility under open city system, the restraint effect on the negative influence generated by continuous high R&D investment to population aging, *etc*.

3. ACTION MECHANISM OF THE INFLUENCE OF POPULATION AGING ON URBAN ECONOMIC GROWTH

Population aging is not only a static concept but also a dynamic concept. Statically, population aging means that the proportion of the old people in the total social population in a country or a region has reached or already exceeded the internationally specified population aging standards and the whole society is in aging state. Dynamically, population aging means a process that the number of the old people in a country or a region is relatively increased and the proportion of the old people in the total population is continuously increased, and population aging actually reflects the relative change caused by the population age structure of the whole society in the number of different age populations. The population aging emphasizes the aging of the population structure of the whole society rather than the aging of individuals.

By virtue of Solow economic growth model, the population aging is transferred to and accordingly influences urban economic growth through influencing the three factors, namely invested capital, labor resource and production technology. The details are as follows:

Influence of population aging on capital input: capital input is one of the source powers for social economic growth, and along with the deepening of the aging degree of the whole society, the continuously increased pension expenditures will certainly cause the reduction of the capital input of the society for production and undoubtedly influence economic growth.

Influence of population aging on labor source: aging means the reduction of adult labor resource percentage; under the condition that child-bearing concept and the total population of the region are relatively stable, the reduction of adult labor resource percentage means the insufficiency and shortage of labor resource available for the whole society which will certainly influence urban economic growth.

Influence of population aging on production technology: aging may generate two distinct influence effects on production and accordingly influences production technology progress: firstly, aging may cause the reduction of the new knowledge absorption efficiency of the whole society and further cause the reduction of innovation capability as well as influence social production efficiency and technological progress; secondly, under social aging state, the relative shortage of labor resource will oppositely stimulate the whole society to realize production efficiency improvement and technological progress through technical innovation.

In conclusion, the action mechanism of the influence of population aging on urban economic growth can be expresssed in the following figure (Fig. **1**).

4. MODELING ANALYSIS OF INFLUENCE OF POPULATION AGING ON URBAN ECONOMIC GROWTH

According to the analysis of the influence of population aging on the three aspects, namely capital input, labor resource and production efficiency & technological progress, in the second part, the action factors of population aging for

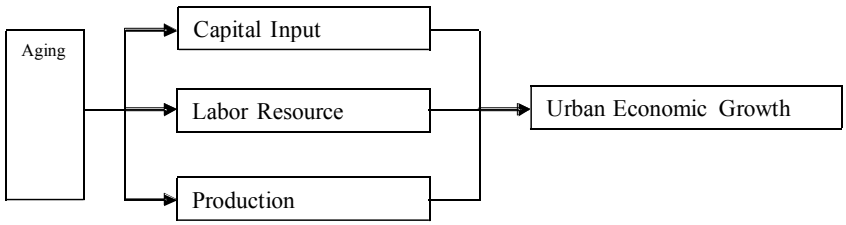

Fig. (1). Schematic diagram for influence of population aging on urban economic growth.

labor resource, capital input and production efficiency & technological progress will be put into Solow economic growth model in the following paragraph in order to research the aging action effect on economic growth through model deduction. Establish the models needed in the article on the basis of Solow growth model

Solow growth model as a standard economic growth mode in economics is actually the basic model for establishing and discussing economic growth. According to the model, economic growth is determined by three factors, namely capital input, labor resource and production efficiency & technological progress.

Under the precondition of constant returns to scale and progressively decreased marginal output as well as replaceable capital and labor, the general function is given as follows:

$$Y(t) = F[K(t) \quad E(t)L(t)] \tag{1}$$

Therein, $Y(t)$ denotes the gross output of the whole society; $K(t)$ denotes capital input quantity; $L(t)$ denotes labor input quantity; $E(t)$ denotes production efficiency & technological progress situation.

1. The net input quantity of the newly increased capital is recorded as $\dot{K}(t)$

$$\dot{K}(t) = sY(t) - \sigma K(t) \tag{2}$$

Therein, $\dot{K}(t)$ denotes the net input quantity of the newly increased capital; s denotes the proportion of output for reinvestment, σ denotes asset depreciation rate, s and σ are exogenous variable.

2. The changes of labor resource and production efficiency & technological progress are respectively recorded as $\dot{L}(t)$ and $\dot{E}(t)$

$$\dot{L}(t) = \gamma L(t) \tag{3}$$

$$\dot{E}(t) = gE(t) \tag{4}$$

Therein, γ denotes labor growth rate; g denotes the growth rate of production efficiency & technological progress.

3. Under the condition of constant returns to scale, formula (1) is converted into following formula:

$$\frac{Y(t)}{E(t)L(t)} = F\left[\frac{K(t)}{E(t)L(t)}\right] \tag{5}$$

Therein, $\frac{Y(t)}{E(t)L(t)}$ denotes per capita output; $\frac{K(t)}{E(t)L(t)}$ denotes per capita capital.

4. Per capita capital and per capita output are respectively recorded as $k(t)$ and $y(t)$.

$$k(t) = \frac{Y(t)}{E(t)L(t)} \tag{6}$$

$$y(t) = \frac{K(t)}{E(t)L(t)} \tag{7}$$

5. Carry out derivation for formula (6) to obtain:

$$\dot{k}(t) = \frac{\dot{K}(t)}{E(t)L(t)} - \frac{K(t)}{E(t)L(t)} \times \frac{\dot{L}(t)}{L(t)} - \frac{K(t)}{E(t)L(t)} \times \frac{\dot{E}(t)}{E(t)} \tag{8}$$

6. Put formulae (2), (3) and (4) in formula (8) to obtain:

$$\dot{k}(t) = sy(t) - k(t)(\sigma + \gamma + g) \tag{9}$$

Introduce the aging influence on capital input into the above model

Aging influence on capital input is mainly presented in the substitution effect of the output part used for pension security on the capital reinvestment along with the deepening of aging degree.

1. L is assumed as the total population of the aging population and the non-aging population, wherein L_r denotes the number of the old people and ρ denotes aging degree. Then, the following formula is available:

$$\rho = \frac{L_r}{L} \tag{10}$$

2. β is assumed as pension expenditure coefficient and denotes the distribution proportion of the output for the pension expenditure of the old people, and it is also the function of aging degree ρ_t at t period. The expression formula is as follows:

$$\beta = f(\rho_t) \tag{11}$$

Therein, β is the function increasing along with the increase of variable ρ.

3. $Y_r(t)$ is assumed as pension expenditure, then

$$Y_r(t) = \beta Y(t) = f(\rho_t)Y(t) \quad (12)$$

4. Along with the deepening of the aging degree of the whole society, more outputs will be used for pension security and the continuously increase pension expenditure proportion will certainly cause the proportion reduction of the social capital input for reproduction. Put formula (12) into formula (2) reflecting capital change, then:

$$\dot{K}(t) = s(1 - f(\rho_t))Y(t) - \sigma K(t) \quad (13)$$

Introduce aging influence on the labor resource of the whole society into the model

1. Along with aging deepening, the aging degree rises from ρ_{t1} to ρ_{t2}, then $\rho_{t2} - \rho_{t1}$ denotes the labor shortage rate of the whole society during the period and is recoded as $\Delta\rho$, namely $\Delta\rho = \rho_{t2} - \rho_{t1}$; meanwhile, ψ is assumed as the immigration rate of migrant labor. Obviously, the difference between the above two is namely the net urban labor growth rate:

$$\gamma = \psi - \Delta\rho \quad (14)$$

2. Viewed from the labor resource supply of the whole society, the labor supply of the whole society will be changed along with the change in population structure. Therein, the change caused by aging in the population structure leads to the relative labor resource insufficiency and shortage in the whole society. Put such change in formula (3) to obtain:

$$\dot{L}(t) = (\psi - \Delta\rho)L(t) \quad (15)$$

For the aging influence on production efficiency & technological progress, according to the analysis in above paragraphs, the aging influence on future production efficiency & technological progress has not been clearly defined, so it is temporarily assumed to be neutral.

For the aging action effect on economic growth, it is necessary to put the aging action effect regarding capital input, labor resource and production efficiency & technological progress in formulae (2), (3) and (4) into the economic growth model as shown in formula (9) to obtain:

$$\dot{k}(t) = s(1 - f(\rho_t))y(t) - (\sigma + g + \psi - \Delta\rho)\, k(t) \quad (16)$$

Analysis of aging influence on economic growth efficiency

According to the analysis in the above paragraphs, the population aging theoretically negatively influences capital input and labor resource and has caused the continuous reduction of per capita capital input $\dot{k}(t)$. In other words, formula (16) tends to zero and even negative value.

The critical point thereof is:

$$\dot{k}^*(t) = s(1 - f(\rho_t))y^*(t) - (\sigma + g + \psi - \Delta\rho)\, k^*(t) = 0 \quad (17)$$

Under the precondition of s and δ as exogenous variables, the critical point is namely the economic balance growth point.

Then, formula (17) is further converted as:

$$\frac{y^*(t)}{k^*(t)} = \frac{\sigma + g + \psi - \Delta\rho}{s(1 - f(\alpha_t))} \quad (18)$$

Therein, $\frac{y^*(t)}{k^*(t)}$ denotes capital input and output efficiency under economic balance growth state.

In case of a closed city system in which migration rate ψ of the external population is 0, and production efficiency & technological progress is neutral (g=0), σ and s are exogenous variables, namely:

ψ=0, g=0, σ and s are unchanged. (19)

Under such state, $\Delta\rho$ is gradually increased along with the continuous depending of the population aging of the city, then:

$$\sigma + g + \psi - \Delta\rho \to 0 \quad < 0 \quad (20)$$

In other words, in a closed city system, the urban economic recession gradually becomes severe along with the continuous deepening of the population aging of the city.

5. EXAMPLE ANALYSIS BASED ON THE ABOVE MODEL: TAKE SHANGHAI AS AN EXAMPLE

Shanghai entered aging society in 1982, with the aging level thereof exceeding 11%, but the aging average of the whole country was about 5% at that time. After 90s, along with the further reduction of birth rate in Shanghai Municipal, the proportion of the old people above 60 years old in both the total registered people and in the total population has exceeded 14% and accordingly approached to or even exceeded the aging level of some developed countries. Meanwhile, along with the formation of the Yangtse river delta economic area and the economic promotion of Pudong new area development as well as the population migration policy change, the number of the population in Shanghai Municipal was sharply increased due to school graduates' move-back and the immigration of external population, thus significantly changing the population structure of Shanghai Municipal; therein, the huge immigration of external population increased the total number of registered populations and accordingly diluted the proportion of the old people in the total population, which is reason for the slight change in the proportion of the old people in the total populations as shown in the 4th (1990) and 5th (2000) population censuses. Although the external population has diluted the proportion of the old people in the total populations, the extremely low

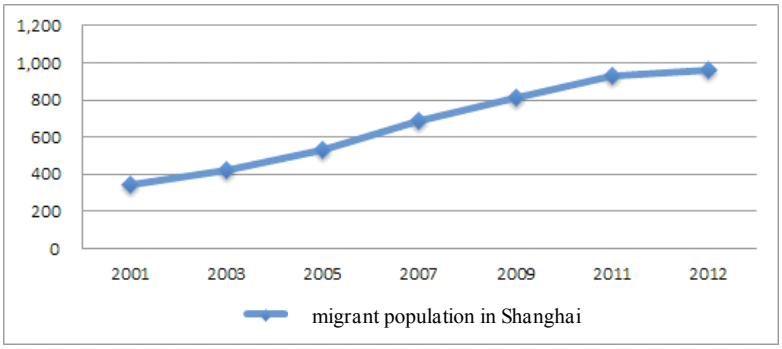

Fig.(2). Number of external permanent resident population of shanghai municipal in main years.

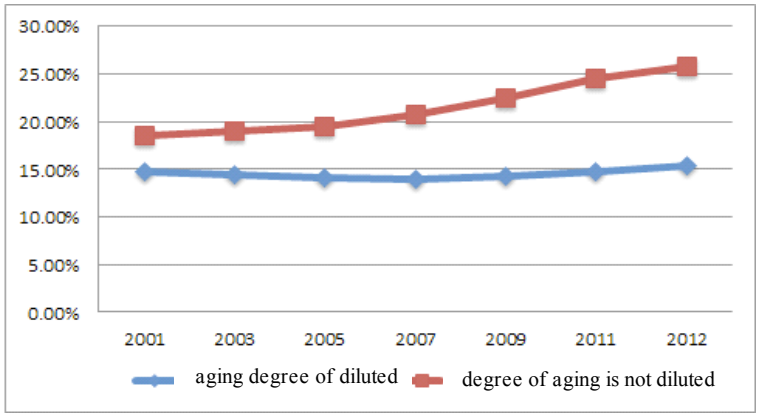

Fig. (3). Dilution effect of external labor resource to aging degree of shanghai.

growth range of the registered population during the ten years (average annual growth rate of the registered population during the ten years was only 0.3%) and the relatively large growth range of the old people (average annual growth rate reached 2.67%) have finally caused the significant increase of the old people in the registered populations. Till the 5th population census (2000), the proportion of the registered old people above 60 years old in the total populations in Shanghai Municipal has reached 18.60%, and this indicated that the aging level of Shanghai Municipal had exceeded that (15%) of the developed countries in the world by about 4%. Till the 6th population census (2010), the proportion of the registered old people above 60 years old in the total registered populations in Shanghai Municipal reached 23.4%, namely 10% higher than the national aging level. It is predicted that the proportion of the aging population will reach 29% in 2005 and 40% in 2030.

However, in substantial economy, the urban economic growth does not tend to reduce along with population aging, and the present economic development situation of Shanghai Municipal during the aging stage has at least verified this. The reasons mainly lie in the following three aspects:

Firstly, ψ in $\sigma + g + \psi - \Delta\rho$ is positive value, indicating the continuous immigration of external labor resource which has supplemented the labor shortage caused by population aging in Shanghai Municipal in recent years, as shown in Fig. (**2**).

Data source: collated and obtained from relevant data of 2013 Shanghai Statistic Yearbook (similarly hereinafter)

Secondly, $\Delta\rho$ value in $\sigma + g + \psi - \Delta\rho$ is diluted: in recent years, Shanghai has relatively strong economic comparison advantage and urban employment capacity and accordingly attracts lots of external high-quality labor resources, so the introduction of the large amount of external labor resources has substantially diluted the urban aging level calculated on the basis of registered population. Actually, such dilution effect can be easily understood through the following figure (Fig. **3**).

Thirdly, g value in $\sigma + g + \psi - \Delta\rho$ is continuously increased: in recent years, R & D investment is continuously increased in Shanghai, thus to effectively promote technical innovation and improve social production efficiency. As a result, the specific value of R & D investment in the gross production output is increased year by year, as shown in the following figure (Fig. **4**).

Fourthly, σ value in $\sigma + g + \psi - \Delta\rho$ is increased: in recent years, Shanghai Municipal has focused on energetically promoting industrial upgrading and has accordingly accelerated the elimination of obsolete equipment and redundant production machinery, namely the acceleration of asset depreciation rate σ.

However, along with the continuous aging depending, due to the gradually increased $\Delta\rho$ and the saturation condition of urban population introduction, only technical innovation and industrial upgrading can be relied to improve output

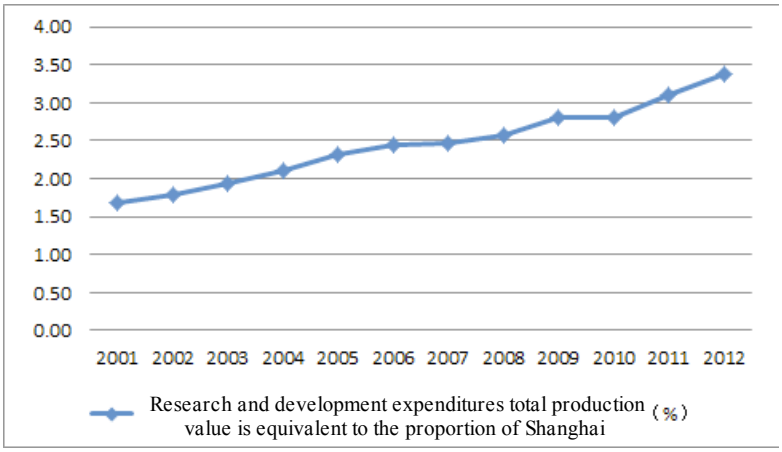

Fig. (4). Specific value of R & D investment of shanghai municipal in gross production output during 2001~2011.

level especially in the old aging stage; if continuous technical innovation cannot be realized, then $0 \geq \sigma + g + \psi - \Delta\rho$ may appear. In other words, the critical point of economic balance growth is broken and then economic recession and welfare reduction will take place.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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