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Population Aging and Economic Growth: The Chinese Experience of Solow Model

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Abstract

The tradintional and mainstream viewpoint believe that aging is a disadvantage to growth. Mild population aging viewpoint indicates that reverse-U relationship may exist between aging and growth. This paper introduces old-age dependency ratio in a standard neoclassical Solow model and obtains a steady-state relation among old-age dependency ratio, savings rate and income per-capita. The model shows that population aging possibly has both positive and negative effects on economic growth. Through co-integration test of GDP per-capita, national savings ratio and old-age dependency ratio in China (1978-2012), it is found that, in the long-run, national savings rate and population aging have positive effects on the increase of per-capita income, and the influence of aging on economic growth exceeds that of national savings rate.

Keywords: population aging, Solow model, economic growth, co-integration analysis, error correction model

1. Introduction

Population aging has become a global consensus and will impose far-reaching influence on social and economic development. Economists have carried out wide relevant researches. Mainstream life cycle theory considers on the one hand, population aging gives rise to labor shortage and then results in productivity growth slowdown; on the other hand, it leads to total savings rate decrease and slows down capital accumulation, thus causing economic growth slowdown. Most Chinese scholars tend to negative effects of population aging on economic growth. For example, Wang et al. (2004) show if dependency ratio increases 1%, economic growth rate will reduce about 0.115%. Hu et al. (2012), Sun and Liu (2014) introduce human capital in Solow model, and they combine provincial panel data test to show the rise in dependency ratio imposes adverse effects on economic growth rate. Mixed OLS estimation result is that 1% rise in old-age dependency ratio will result in 1.5% or 5.59% decline of economic growth rate.

In fact, a large number of studies find that there is no exact conclusion on the influence of population aging on economic growth through two approaches (savings rate and labor supply) (cf. Li, 2010). For the influence of population aging on savings rate, Loayza et al. (2000) apply GMM for estimation and find if old-age dependency ratio increases 1%, private savings rate and total savings rate will decrease 0.7% and 0.8% respectively. Bosworth and Chodorow-Reich (2006) discover 1% rise in old-age dependency ratio will result in 0.54% decline of national savings rate. Loumrhari (2014) uses annual data from 1980 to 2010 in Morocco to testify an overlapping generations model (OLG), showing that population aging has negative effects on the growth rate of savings. Wang et al. (2004) apply the Chinese data in 1982-2002 for OLS regression and show 1% rise in old-age dependency ratio gives rise to 0.216% drop of national savings rate.

However, some evidences shows people will continue to save money as their age increases (Burbidge & Davies, 1994; Lin, 1997), and that longer life expectancies will also improve savings rate, because it will enhance investment in human capital and the motivation of saving for retirement. Family survey of Auerbach et al. (1991), Canari (1994) and Borsch-Supan (1996) shows dependency ratio has weak and even positive influences on private saving. Aisa and Pueyo (2013) argue when considered that availability of capital is endogenously determined by domestic saving, a new “capital accumulation effect” appeares, and population aging probably fosters economic growth. With a two-sector OLG model, Kim and Hewings (2013) show that endogenous investment in human capital can offset the negative effects of the population aging on the regional economy (Illinois). Kraay (2000) utilizes urban and rural panel data in China (1978-1989) and considers the effect of dependency ratio on savings rate is not significant statistically. Yuan and Song (2000) utilize overlapping generations model to analyze China's old-age insurance system and hold that the rise in old-age dependency ratio caused by family planning may be the cause of the increase in household savings rate. Chamon and Prasad (2008) study savings rate of Chinese urban population and find the household savings rate of the youngest and the oldest heads of households is the highest in the samples. Li et al. (2012) use provincial panel data and find the savings and investment rates of aging population is increasing in current China.

For the effects of population aging on labor supply, although total amount of labor supply may drop, aging will stimulate the society to resist the decrease in the quantity of labor through boosting labor quantity. So, aging will not inevitably result in the decline of gross productivity. For instance, the expectation of extending the retirement age will enhance individual physical capital investment incentive. The expectation of future labor scarcity will strengthen individual human capital investment incentive. Fallick and Pingle (2007) argue aging has lowered aggregate U.S. labor force participation from 2002 to 2006. Cutler et al. (1990) found the decline of living standards caused by the rise in population aging could be completely counteracted through improving 0.15% of annual productivity growth rate during cross-sectional studies of a large number of countries in 1960-1985. Xiao (2014) considers both the influence of population aging on the quantity of labor force and its negative effects on labor productivity in China are very limited. Mason and Lee (2013) show longer life results in greater lifetime consumption and has few effects on lifetime labor supply, but there is an exception in low income, high mortality countries, where the old still increase their labor supply.

The above studies show that equivocal influence exists between population aging and economic growth. This paper introduces dependency ratio of population in neoclassical Solow model and obtains a steady-state relationship among old-age dependency ratio, savings rate and income per-capita. On this basis, Chinese actual economic data in 1978-2012 are used for co-integration analysis and error correction model is established. Our results are as follows: firstly, long-term equilibrium relationship exists among old-age dependency ratio, savings rate and income per-capita; secondly, in a long run, population aging will promote the increase in income per-capita; in a short term, the promotion of old-age dependency ratio and national savings rate impose adverse impacts on the rise in income per-capita.

The contributions of this paper lie in that we indicate population aging possibly has both positive and negative effects on economic growth in a theoretical model, and utilize Chinese statistical data to carry out empirical test of this result. This expands neoclassical mainstream growth theory and life cycle theory, instead of denying them. The mainstream theory fails to take into account of labor participation rate and savings of the old. Thus, negative effect of population aging on economic growth will certainly be gained. Once these circumstances are considered, the results are completely different.

2. Introduction of Solow Model about Population Aging

Assuming total population (the quantity is expressed with N) in an economic entity is simply classified into young people (the quantity is expressed with N_y) and old people (the quantity is expressed with N_o), N=N_y+N.

Assuming old people participate in labor supply at an exogenous proportion β, and all young people participate in labor supply, total labor supply in economy is $L= N_y+\beta N_o$.

Population aging index we adopt is old-age dependency ratio d=No/Ny. Then, $N_y = \frac{1}{1+d}N$, $N_o = \frac{d}{1+d}N$.

Total labor supply is $L = \frac{1+\beta d}{1+d}N$.

Assuming growth rate of population n is a constant, the growth rate of total labor supply is

$$\frac{\dot{L}}{L} = (\beta - 1)\mu \frac{d}{(1+\beta d)(1+d)} + n \quad (1)$$

Where, $\mu = \dot{d}/d$ refers to the growth rate of old-age dependency ratio. To simplify the analysis, we assume it is an exogenous variable. Formula (1) is the amendment of population aging on the growth rate of labor supply. Without regard to aging, for example, μ = 0 in standard Solow model. Then, the growth rate of labor supply is consistent with that of population. After aging is considered, since μ can be positive and negative, β <1, aging may reduce or increase labor supply.

In accordance with the standard Solow model, we assume a Cobb–Douglas production function with constant returns to scale:

$$Y = AK^{\alpha} L^{1-\alpha},\ A>0,\ 0<\alpha<1$$

Where, Y and K are (actual) gross economic output and total capital stock.

Without regard to technical progress and capital depreciation, capital accumulation equation is $\dot{K} = I$, where I refers to total investment. Total investment is from social saving accumulation, including both young people's saving and old people's saving. Assuming social savings rate is exogenous parameter s, macro-economic equilibrium condition is utilized to gain the following:

$$\dot{K} = sY \quad (2)$$

Define capital-labor ratio as $\bar{k} = K/L$ and income-labor ratio as $\bar{y} = Y/L$. Formula (2) as an intensive formula:

$$\dot{\bar{k}} = sA\bar{k}^{\alpha} - [\frac{(\beta-1)\mu}{(1+\beta d)(1+d)} d + n]\bar{k} \quad (3)$$

It can be seen there is a unique steady state. The value is:

$$\bar{k}^* = (\frac{sA}{\eta})^{\frac{1}{1-\alpha}},\ \ \eta \equiv (\beta-1)\mu\frac{d}{(1+\beta d)(1+d)} + n\ >\ 0 \quad (4)$$

We concern about effects of population aging on economic growth. Thus, define capital per-capita as $k = \frac{K}{N} = \frac{1+\beta d}{1+d}\bar{k}$ and income per-capita as $y = \frac{Y}{N} = \frac{1+\beta d}{1+d}\bar{y}$. Their steady-state values are:

$$k^* = \frac{1+\beta d}{1+d}(\frac{sA}{\eta})^{\frac{1}{1-\alpha}},\ \ y^* = A\frac{1+\beta d}{1+d}(\frac{sA}{\eta})^{\frac{\alpha}{1-\alpha}} \quad (5)$$

This indicates steady-state income per-capita depends on labor supply ratio of the old β, social savings rate s, d and its growth rate μ as well as population growth rate n.

We can get:

$$\frac{\partial y^*}{\partial s} = A\frac{1+\beta d}{1+d}(\frac{A}{\eta})^{\frac{\alpha}{1-\alpha}}\frac{\alpha}{1-\alpha}s^{\frac{\alpha-1}{1-\alpha}} > 0 \quad (6)$$

$$\frac{\partial y^*}{\partial d} = A(\frac{sA}{\eta})^{\frac{\alpha}{1-\alpha}}\frac{\beta-1}{(1+d)^2} + A(sA)^{\frac{\alpha}{1-\alpha}}\alpha\frac{\beta-1}{\alpha-1}\eta^{\frac{\alpha}{\alpha-1}-1}\frac{1-\beta d^2}{(1+\beta d)(1+d)^3}\mu \quad (7)$$

From formula (6), it can be seen that long-term effect of savings rate on steady-state income per-capita is positive.

The first term of formula (7) is negative. The sign of the second term depends on aging rate μ. If $\mu<0$, $\partial y^*/\partial d < 0$. This indicates that when population aging is very slow, margin contribution of old-age dependency ratio to steady-state income per-capita is negative. If $\mu>0$, the sign of $\partial y^*/\partial d$ is uncertain. If aging speed is very fast, $\partial y^*/\partial d > 0$. This shows margin contribution of old-age dependency ratio to steady-state income per-capita is positive. This result obviously depends on the hypothesis that the old also join in labor supply and have savings. As mentioned above, this is proved in empirical research.

According to the above model, the following can be speculated: income per-capita, social savings rate and old-age dependency ratio have long-term equilibrium relationship. Income per-capita is positively correlated to social savings rate, and its relationship with old-age dependency ratio is uncertain.

We can set up the following semi-logarithm econometric model to test long-term relationship among the three:

$$\ln y = \gamma_0 + \gamma_1 s + \gamma_2 d$$

3. Empirical Test Based on Chinese Data

The sample investigation period is from 1978 to 2012 in China. According to theoretical model, the following variables are selected:

ln$y$, logarithm of GDP per-capita. GDP per-capita is gained through actual GDP/total population. Retrenchment treatment of actual GDP with nominal GDP through GDP conversion index in 1978 to get rid of price change factor.

s, social savings rate (%), gained through 1-final consumption rate.

The above data come from previous Chinese statistical yearbooks.

d is old-age dependency ratio. It refers to the specific value between the population at the age of 65 and above and the population at the age of 15-64. The data between 1989 and 2012 come from Chinese statistical yearbooks. The data between 1978 and 1988 come from the research of Tian et al. (2006).

Our empirical study can be achieved through co-integration test. But the precondition of co-integration test is that time series is a stationary process. If it is non-stationary, spurious regression phenomenon may appear easily. Even if variables have no relevance, they will present certain relationship due to trend term of non-stationary series. Thus, the conclusion may be wrong. Therefore, before co-integration test, ADF unit root test should be first made to confirm whether the time series is stationary. Finally, error correction model (ECM) is used to discuss the relationship of variables between short-term fluctuations and long-term equilibrium. On this basis, long-term equilibrium relationship among ln *y*, *s* and *d* is gained.

The following measurement is achieved through Eviews7.0.

3.1 Stationary Test

ADF unit root test is adopted to confirm integration order of each variable. See Table 1 for unit root test results.

Table 1. Unit root test results of each series

Variable	Test form (CTK)	ADF Test value	Critical value		Conclusion	Variable	Test form (CTK)	ADF Test value	Critical value		Conclusion
ln*y*	(CT1)	–4.04	1%	-4.26	Non-station	△ln*y*	(C05)	–3.45*	1%	–3.69	Stationary
			5%	-3.55	ary			*	5%	–2.97	
			10%	-3.21					10%	–2.63	
s	(CT1)	–2.57	1%	-4.26	Non-station	△ln*s*	(C01)	–2.95*	1%	–3.65	Stationary
			5%	-3.55	ary			**	5%	–2.96	
			10%	-3.21					10%	–2.62	
d	(CT1)	–2.67	1%	-4.26	Non-station	△ln*d*	(C01)	–4.25*	1%	–3.65	Stationary
			5%	-3.55	ary				5%	–2.96	
			10%	-3.21					10%	–2.62	

Note. C, T and K in test form (CTK) means constant term, time trend and the number of lag terms respectively included in unit root test equation. K is confirmed according to the principle of minimum AIC and SC. △ means difference operator. *, ** and *** means refusal of null hypothesis at the significance levels of 1%, 5% and 10%.

The results show ln*y*, *s* and *d* are non-stationary at the significance level of 10%, but their one-order difference sequence is stationary. It thus can be seen that they are one-order integration series. Engel ad Granger (1987) point out that the linear combination of two or more non-stationary series may be stationary. In other words, they have co-integration relationship. So, co-integration analysis can be carried out for them, and error correction model can be established.

3.2 Johansen Co-Integration Test

To obtain co-integration vector, we use the test based on VAR co-integration system which is put forward by Johansen and Juselius. Time series does not confirm, the trend, and co-integration equation has intercept.

Prior to Johansen co-integration test, the optimal lag order k of VAR model should be first confirmed. There are multiple judging criteria for selection of lag order, including LR statistical magnitude, AIC and SC. This paper adopts AIC. Through multiple tests, the results show the optimal lag order is 7.

Because co-integration test mode actually carries out co-integration constraint of unconfined VAR model, the lag order is the lag order of first difference viable of unconfined VAR model. In other words, the lag order selected for co-integration test should be equal to the optimal lag order of unconfined VAR model minus 1. It thus can be seen that the optimal lag order of co-integration test in this paper is 6.

Table 2 shows Johansen co-integration test results. The table provides trace statistics and likelihood ratio statistics of maximum eigenvalue.

Table 2. Johansen co-integration test results

H0	Eigenvalue	Trace statistics	Critical value (5% significance level)	p value **	Conclusion
r=0*	0.790577	80.53648	29.79707	0.0000	Refusal
r ≤1*	0.684491	36.76131	15.49471	0.0000	Refusal
r ≤2*	0.147291	4.461437	3.841466	0.0347	Refusal

Note. * means refusal of null hypothesis at the significance level of 5%; ** means MacKinnon p value; r means the number of co-integration relationship.

The above table indicates at the significance level of 5%, a linear combination which reflects their long-term stable proportional relation exists among ln*y*, *s* and *d*, i.e. co-integration relationship. Standard co-integration equation which complies with economic significance is (numerical value in the bracket is standard deviation):

$$\ln y = 0.04s + 0.39d$$
$$(0.008) \quad (0.021)$$

3.3 ECM

We establish the following ECM:

$$\Delta \ln y = \beta_0 + \beta_1 \Delta s + \beta_2 \Delta d + \lambda ec + \mu$$

Where, *ec* is error correction term which reflects deviation of income per-capita from long-term equilibrium relationship.

VEC model is actually constrained VAR model. The lag divisor setting should be consistent with lag order setting of Johansen co-integration test. We list error correction model which is related to the study and gets rid of non-significant variances (numerical values in brackets are standard deviation and t value):

$$\Delta \ln y_t = 0.30 - 0.81\Delta \ln y_{t-2} - 0.35\Delta \ln y_{t-3} - 0.28\Delta \ln y_{t-4} - 0.51\Delta \ln y_{t-5} - 0.51\Delta \ln y_{t-6} - 0.01\Delta s_{t-2}$$
$$(0.05) \quad (0.14) \quad (0.21) \quad (0.16) \quad (0.16) \quad (0.19) \quad (0.002)$$
$$(5.99) \quad (-5.72) \quad (-1.63) \quad (-1.77) \quad (-3.21) \quad (-2.70) \quad (-3.08)$$
$$+ 0.01\Delta s_{t-4} + 0.006\Delta s_{t-6} - 0.03\Delta d_{t-1} - 0.04\Delta d_{t-2} - 0.04\Delta d_{t-3} - 0.03\Delta d_{t-4} - 0.04\Delta d_{t-5} - 0.12\, ec_{t-1}$$
$$(0.003) \quad (0.002) \quad (0.01) \quad (0.01) \quad (0.01) \quad (0.01) \quad (0.01) \quad (0.03)$$
$$(3.99) \quad (3.02) \quad (-2.77) \quad (-4.68) \quad (-4.22) \quad (-4.09) \quad (-3.87) \quad (-3.89)$$

According to error correction term $ec_t = \ln y_t - 0.04s_t - 0.39d_t - 2.05$, long-term equilibrium relationship (co-integration equation) can be gained.

$$\ln y = 2.05 + 0.04s + 0.39d$$
$$(0.01) \quad (0.02)$$
$$(-5.35) \quad (-18.49)$$

The co-integration relationship indicates that, in the long-run, income per-capita rise is positively correlated to national savings rate and population aging. If other conditions remain unchanged,when national savings rate increases 1%, income per-capita will boost 0.04%. With other conditions unchanged, old-age dependency ratio increases 1%, income per-capita will boost 0.39%. The relationship also shows the statistic value of coefficient t of aging variable *d* is large. This means in a long term, old-age dependency ratio influences GDP at a higher confidence level, and that the promotion effect on GDP is great. On the whole, the influence of population aging on economic growth exceeds that of national savings rate.

In the model, the coefficient of error correction term indicates the adjustment speed from short-term disequilibrium state to long-term equilibrium state. The difference term of each variable reflects short-term adjustment relationship among variables. Our estimation shows error correction term reversely corrects income per-capita in next period with the proportion of 12% of error between current income per-capita and long-term equilibrium so as to make it approach long-term equilibrium. This indicates the adjustment speed from disequilibrium to long-term equilibrium is fast. The function of error correction mechanism is obvious. The coefficient is negative and significant. This indicates VEC model is very successful.

In accordance with error correction model which reflects short-term fluctuations, the lagged value of per-capita income, per-capita saving and old-age dependency ratio have significance effects on fluctuations of per-capita income. In addition, such effects have a 5-order or 6-order lag phase. National savings rate in 2 lag periods, per-capita output in 2 or more lag periods and old-age dependency ratio in each lag period have negative effects on per-capita output growth; but national savings rate in 4 and 6 lag periods have positive effects on per-capita output. This indicates short-term rise in national savings rate and population aging degree will make output per-capita decline.

Seeing from overall model evaluation criteria, AIC=-3.386981 and SC=-0.389521. This means the model is good.

The results also show regardless of short term or long term, effects of population aging on economic growth exceed effects of national savings rate. In a short term, saving and aging have negative effects on growth, while the long-term effects are positive. Economic theory shows the influence of saving and aging on capital stock and labor supply is a long-term process. In a short term, saving makes effective economic demand drops, and aging makes labor supply reduces.

For current data in China, population aging presents long-term positive effects on output. This is because:

Firstly, at present, China's aging degree is not deep. Usually, it will take about 20 years for China to reach 20% level of currently developed countries. In the initial stage of aged society, aging often has positive relationship with economic growth.

Secondly, old people also have savings. For example, Tian et al. (2005) show 1% rise in old-age dependency ratio will result in 0.37% increase in savings rate. Besides, underdevelopment of aging industry causes potential consumption of old people cannot be achieved, but transform to "forced saving". Aging will not always reduce savings.

Thirdly, aging can improve productivity. When aging results in slowdown of labor force growth, technological changes will occur to economy. Thus, productivity growth rate will continue to rise. There are three reasons. 1) Physical capital investment incentive enhances. Since expected working time is longer, individual savings will be more. Even so, it is still not stable enough to offset the drop of labor supply through higher capital intensity. 2) Aging can shorten investment time of human capital and generate very strong human capital investment incentive, i.e. carry out more education and training for the next generation. With population aging, if expected labor becomes relatively scarce input element, the income from predictable human capital investment will rise. 3) Aging makes workers' pre-tax income rise. In accordance with efficiency wage theory, productivity will improve.

Fourthly, in China, the old in rural areas account for a large part of nationwide aging population. Influenced by retirement pension system and work nature, the old in rural areas will participate in agricultural production as long as they have the ability. So, labor participation rate is high. In 2000, population census data showed labor participation rate of the old with the age of above 65 in rural areas was 32.9%, much higher that that in urban areas (9.4%).

4. Conclusions and Policy Implication

Recent research literatures about the relationship between population aging and economic growth show population aging will reduce labor supply, but will not always result in the decline of savings rate as predicted by life cycle hypothesis. The behavior which decides savings is a social process, which cannot be predicted only by demographic transition. So, capital accumulation will not certainly reduce during population aging. A mild population aging view indicates reserve-U relationship may exist between population aging and growth.

We conduct co-integration analysis of China's GDP per-capita, national savings rate and old-age dependency ratio in 1978-2012. The results show economic growth, savings rate and population aging have long-term stable equilibrium relationship. In a long run, saving and aging are positively correlated to economic growth. But, the influence of population aging exceeds that of saving. This indicates the efficiency of saving-investment transformation mechanism is low.

Based on the above research, this paper gains the following significant results:

1) In a short term, the rise in national savings rate and old-age dependency ratio will result in the decrease in come. This is because they lead to the decline of short-term effective economic demand (i.e. consumption) and labor supply.

2) In accordance with current China' data, in a long term, income per-capita has positive correlation with old-age dependency ratio. This conclusion is different from most people's opinion. They consider aging will hinder economic growth. Wang et al. (2004), Hu et al. (2012), Sun and Liu (2014) hold that population aging will

reduce economic growth rate. In view of different indexes used, the decline of economic growth rate does not conflict with income per-capita increase. Besides, our conclusions do not conflict with their conclusions, either. In numerical simulation of Liu and Lu (2008), the rise in the degree of aging gives rise to the drop of savings rate and the rise in education investment, while economic growth rate does not always drop. This proved aging generates upward pressure on productivity.

3) Considering the basis trend of old-age dependency ratio from decline to rise around 1985 and significant negative effect of high aging economic aging, we conjecture M-shaped relationship may exist between aging and economic growth: aging first promotes growth and then hinders growth (this trend comes from effects of the drop of old-age dependency ratio and short-term aging on saving and labor supply), then facilitates growth from hindering growth (this trend comes from upward pressure on productivity generated by aging) and finally hinders growth. At present, China is in the left half state of M-shaped relationship.

We also conduct Granger causality and find GDP per-capita, national savings rate and old-age dependency ratio have no explicit Granger causality. This can promote people to cognize and treat population aging in a more rational way. The rise in old-age dependency ratio will not always bring about the decrease in income per-capita. We can enhance promotion effects of aging on economic growth with the help of policy guidance and cope with future population aging through structural reform of tax revenue and social security system, making the best of human resources, actively developing old talent resources (such as retirement delay), more education and training and accumulating more human capital.

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