Korea and the World Economy, Vol. 20, No. 3 (December 2019) 259-283

Effects of Population Age Structure on Economic Growth in China*

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It is widely believed that age structure change is one of the reasons for China's rapid economic growth. While most of the studies have concentrated on the linear relationship between age structure changes and economic growth, this paper investigates the non-linear relationship by incorporating quadratic terms of child dependency ratio and aged dependency ratio involved through "Cobb-Douglas" production function. The results of empirical analysis on Chinese panel data of 31 provinces from1990 to 2015 reveal that age structure has significant non-linear effects on economic growth: child dependency ratio has a "U-shape" relationship with economic growth; aged dependency ratio has an "inverted U-shape" relationship with economic growth.

JEL Classification: J1, O5

Keywords: child dependency ratio, aged dependency ratio, economic growth, population age structure

* Received November 14, 2019. Revised December 22, 2019. Accepted December 27, 2019. The earlier version of the paper was presented at the 2018 International Conference of the Korea and the World Economy XVII in Jeju. We would like to thank participants of the Conference and two anonymous referees for useful comments.

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1. INTRODUCTION

The history of economic development around the world reveals that change in the population age structure is an important factor of economic growth. Hatton and Williamson (1998) analyzed the data on population age structure and economic growth of 17 countries in the West from 1870-1913 and found that the per capita GDP of the New World is higher than that of the Old Word by nearly 0.5%p. Most of this difference was due to the New World's advantage in the population age structure. Using related data of some East Asian countries over the period of 1971 and 2004, Bloom and Williamson (1998) revealed that in the rapid economic growth of East Asia, the contribution of demographic transition exceeded 25%. At present, developed countries such as France, Germany, Japan and Korea are experiencing economic weakness and population aging which is considered to be one of the important reasons behind their restrained economic growth.

The process of population age structure transformation in China is similar to that in Japan. In the early years of the People's Republic of China, the birth rate and death rate in China were at a relatively high level and the natural growth rate was low. In the 1960s and 1970s, the Chinese population was characterized by high birth rates, low death rates, and high natural growth rates. Since the 1970s, with the full implementation of the one child policy and rapid economic growth, the birth rate, death rate and natural growth rate have rapidly declined. In the nearly 40 years since the 1970s, the Chinese population has completed three phases of transformation, and the population age structure has also undergone tremendous changes.

The majority of existing research concentrates on the linear relationship between population age and economic growth. Some of the previous studies, however, suggest that in a moderate range, the increase in child or aged dependency ratio can promote economic growth, but beyond a certain value, it may hinder economic growth. In order to capture the possible threshold effects, the paper tries to investigate the non-linear relationship by incorporating quadratic terms of child dependency ratio and aged dependency

ratio into “Cobb-Douglas” production function.

The existing literature rarely touches on the long-term impacts of population age structure on economic growth. Using panel Autoregressive Distributed Lag (ARDL) cointegration model, this paper reveals the effects of the child dependency ratio and aged dependency ratio on economic growth in the long-term. This paper also separately calculates the contributions of the changes in the child dependency ratio and aged dependency ratio toward economic growth and analyzes the reasons.

2. LITERATURE REVIEW

2.1. Theoretical Study

There have been a lot of studies on the relationship between population and economic growth. Much attention has been paid to the effects of the size, quality and structure of population on economy. Classical studies tend to focus on population size. There are two main views on the impact of population size on economic growth. Optimists believe that the increase in the size of population is a necessary condition for economic growth (Petty, 1662; Quesnay, 1759; Smith, 1776). On the contrary, pessimists believe that the population growth will eventually lead to economic stagnation or catastrophic consequences (Malthus, 1798; Ricardo, 1817). Keynes shifted from pessimism to optimism in regard to the impact of population growth on economic growth. Keynes (1922) was concerned about the negative impact of excessive population on economic growth, but in Monetary Theory (Keynes, 1930), he stated that slow population growth is the main reason of economic stagnation and lack of investment.

Some research pays attention to the impact of population quality on economic growth. Adam Smith (1776) believed that “the improvement of labor quality is one of the sources of wealth growth”. Mill *el at*. (1848) proposed that increased investment in education promotes economic growth.

Schultz (1961, 1982) put forward a systematic human capital theory, discussed the reasons for the formation of differences in population quality, and studied the impact of differences in population quality on economic growth.

More recently, there is research investigating the relationship between population structure and economic growth. The population structure includes the regional structure, industry distribution, gender ratio and age structure. The dual economic structure model put forward by Lewis (1954) has drawn attention to the impact of population structure on a country's economy. Lewis conducted an in-depth study of the process of the urbanization of developing countries, in which the surplus rural labor force continuously flows into urban industrial manufacturing. Ranis and Fei (1963) have perfected the dual economic structure model. Lewis-Ranis-Fei dualistic economic structure model not only describes the spatial shift of rural populations from rural to urban areas in developing countries, but also describes the process of labor force allocation and distribution that shifts labor from agriculture to industrial manufacturing. Petty-Clark theorem in turn describes the impact of economic growth on the distribution of population across industries. Until the 1990s, David Bloom, an American scholar, examined the effects of changes in the population age structure on economic growth based on demographic transition theory and population structure theory (Bloom *et al.*, 1998).

2.2. Mechanism Study

Population age structure can affect the economy through labor supply, savings, human capital, and public expenditure.

2.2.1. Affecting economic growth through labor supply

On the one hand, when the birth rate of the population is reduced, more women are freed from the burden of childbearing, and women's labor participation rate increases. Studies have shown that the birth of a baby can reduce the labor supply of a female worker by an average of two years. The

decrease in fertility rate increases the female labor participation rate (Bloom *et al*., 2009).

On the other hand, with the total population maintaining an upward trend, the increase in the proportion of working-age population leads to an increase in labor supply, facilitating the division of labor in society and promoting economic growth. Mason (1997) showed that the change in population age structure in East Asia has brought about a rapid increase in the number of working-age people, providing the impetus for economic growth. When the World Bank measured the contribution of various factors in China's economic growth in 1998, it found that the increase in the number of laborers contributed to the economic growth of China by as much as 17%. Bloom *et al*. (1999) found that the growth rate of the working-age population in East Asian countries from 1965 to 1990 was about five times that of the children population and the elderly population. The increase in labor supply that is brought about by the population structure transition reduces social production costs and contributes to economic growth. Andersson (2001) revealed that changes in population age structure during the period 1950 and 1992 in Sweden, Norway, and other countries resulted in a rapid increase in the proportion of working-age population, which is conducive to economic growth.

2.2.2. Affecting economic growth through savings

A population structure with a lighter dependency burden will increase the savings rate and promote economic growth. At the micro level, a family's support burden is lighter, its disposable income increases and marginal savings tend to increase, which is conducive to raising the level of savings. On the other hand, people consider that their children's overburdened parents will tend to increase their savings during the working age. At the macro level, when the entire society has a large proportion of the working-age population belonging to the life stage where most savings occur, it contributes to increasing the overall savings level. When retirement age remains fixed despite increase in life expectancy from improved health, people will save more in their working age to prepare for the old age. Many scholars have

conducted relevant empirical studies on the effect of dependency ratio on savings. Leff (1969) using 47 underdeveloped, 20 developed and 7 communist countries' data, argued that with high birth rates it is not possible to achieve higher savings for underdeveloped countries. Cansin *et al*. (2016) investigated how demographic determinants are effective on saving ratios using panel data analysis between 1993 and 2003 on 20 transition economies. They found that dependency ratio in fixed effect model is satisfied with negative correlation to savings. Loayza *et al*. (2000) used panel data to analyze the effects of child dependency ratios and old-age dependency ratios on savings rates. They found that both had a significant effect on savings rates, while elderly dependency ratios had a greater effect on savings rates.

2.2.3. Affecting economic growth through human capital

The population age structure of a country is the result of the combined effect of the birth rate, death rate, and life expectancy. The birth rate of the population is directly related to the number of children born to women. So, the change in the population age structure is accompanied by a change in the number of children born to women. Joshi and Schultz (2007) pointed out that the impact of female childbearing on human capital mainly has the following two aspects: first, the reduction in the number of children born to women will help improve women's physical health; second, the reduction in the number of childbearing is conducive to the promotion of the increase in women's labor participation rate, which in turn increases women's social status and independence. That is beneficial to both the family and society. From the family level, the decrease in the number of children can ease the economic pressure of parents in raising children. On the other hand, it also makes parents pay more attention to the development of children's quality. The children can get better food and better education during their growth.

2.2.4. Affecting economic growth through public expenditure

Bloom *et al*. (2007) proposed that the population age structure affects the funding sources of public expenditure, and influences the structure of public

expenditure and thereby economic growth. Ruggeri and Zou (2007) proved that the effect of child dependency ratio and aged dependency ratio on public expenditure in population age structure did exist through empirical analysis and suggested that there was a difference in the marginal impact of the child dependency ratio and aged dependency ratio on public expenditure. The marginal effect of aged dependency ratio on public expenditure is 2.5 times that of child dependency ratio.

The impact of population age structure on economic growth is usually not achieved through only one of the above approaches. It is generally a combination of two or more approaches. For example, the increase in labor supply has reduced the cost of labor and the increase in the savings rate has reduced the cost of financing, attracting more foreign capital to enter China and promoting economic growth.

2.3. Empirical Study

Bloom and Williamson (1998) explored the impact of demographic transition on economic growth in East Asia during the period 1965-1990 by integrating demographic variables into an economic growth model. They concluded that East Asia's miracle occurred in part because East Asia's demographic transition resulted in its working age population growing at a much faster rate than its dependent population, thereby expanding the per capita productive capacity of East Asian economies. Their finding suggests that if the dependent population (age 15 below and 65 and above) is growing faster than the workforce, economic growth will be slow down.

Bloom and Canning (2004) argue that transitions from high mortality and fertility to low mortality and fertility can be beneficial to economies as large baby boom cohorts enter the workforce and save for retirement, while rising longevity has perhaps increased both the incentive to invest in education and to save for retirement. They showed that Ireland benefited from lower fertility in the form of higher labor supply per capita and that Taiwan also benefited through increased savings rates.

Lindh and Malmberg (1999) took the population age structure into Solow growth model to study its effects on economic growth in the OECD countries from 1950 to 1990. They showed that the 50-64 age group has a positive influence, and the group above 65 contributes negatively, while younger age groups have ambiguous effects on economic development.

In 1998, the term "demographic dividend" appeared for the first time in the UN's report on the status of the world's population. Mason (1997, 2001) and Bloom *et al*. (2003) have successively used the term "demographic dividend" in their works to explain the "big in the middle, small at both ends" features that have emerged during transition process of population age structure. Bloom *et al*. (2010) studied the effects of changes in population and population age structure on economic growth in China and India. They showed that the growth of total population and working-age population contributed 26% to China's economic growth in the last 40 years. With the impressive economic development in China, the influence of the population age structure on China's economic growth has also attracted the attention of the academic community.

3. POPULATION DEPENDENCY RATIO

The population age structure in this paper refers to the proportion of children's population (0-14 years old), the working-age population (15-64 years) and the elderly population (65 years and over) in the total population. The academic community usually uses the index of dependency ratio to reflect the burden of population support.

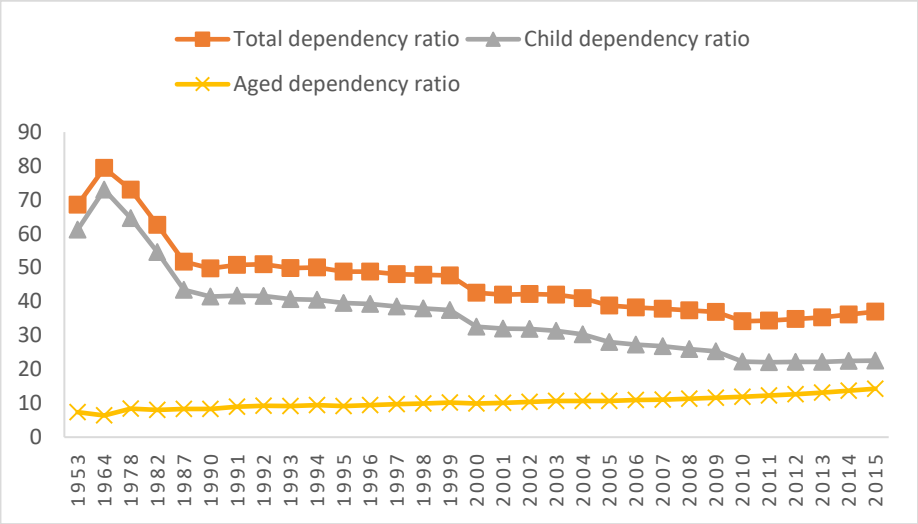
Total dependency ratio, also known as the total burden coefficient, is an age-population ratio of those typically not in the labor force (the dependent part ages 0 to 14 and 65+) to those typically in the labor force (the productive part ages 15 to 64). It is used to measure the pressure on productive population;

$$\begin{aligned} &total\ dependency\ ratio\ (TD) \\ &\quad = child\ \ dependency\ \ ratio + aged\ \ dependency\ \ ratio, \end{aligned}$$

$$child\ dependency\ ratio\ (CD) = \frac{number\ of\ \ people\ aged\ 0\text{-}14}{mumber\ of\ \ people\ aged\ \ 15\text{-}64} \times 100\%,$$

$$aged\ dependency\ ratio\ (AD) = \frac{number\ of\ \ people\ aged\ 65\ and\ \ over}{mumber\ of\ \ people\ aged\ \ 15-64} \times 100\%.$$

Figure 1 Dependency Ratio Changes from 1953 to 2015 in China



Source: China Statistical Yearbook.

Figure 1 and table 1 show dependency ratios of China. From 1953 to 1964, the child dependency ratio rose from 61.2% to 73%, aged dependency ratio fluctuates about 10%, and total dependency ratio rose from 68.6% to 79.4%. Since 1964, the dependency ratio of children has been declining from 73% in 1965 to 22.6% in 2015 and the aged dependency ratio has risen from 6.4% to 14.4%. As the increase in aged dependency ratio is smaller than the decline in the child dependency ratio, the total dependency ratio is declining from 79.4% to 37%. At present, the downward trend in the child dependency

Table 1 Dependency Ratio Changes of China from 1953 to 2015

Unit: %

Year	Total dependency ratio	Child dependency ratio	Aged dependency ratio
1953	68.6	61.2	7.4
1964	79.4	73.0	6.4
1978	73.0	64.6	8.4
1982	62.6	54.6	8.0
1987	51.8	43.5	8.3
1990	49.8	41.5	8.3
1991	50.8	41.8	9.0
1992	51.0	41.7	9.3
1993	49.9	40.7	9.2
1994	50.1	40.5	9.5
1995	48.8	39.6	9.2
1996	48.8	39.3	9.5
1997	48.1	38.5	9.7
1998	47.9	38.0	9.9
1999	47.7	37.5	10.2
2000	42.6	32.6	9.9
2001	42.0	32.0	10.1
2002	42.2	31.9	10.4
2003	42.2	31.4	10.7
2004	41.0	30.3	10.7
2005	38.8	28.1	10.7
2006	38.3	27.3	11.0
2007	37.9	26.8	11.1
2008	37.4	26.0	11.3
2009	36.9	25.3	11.6
2010	34.2	22.3	11.9
2011	34.4	22.1	12.3
2012	34.9	22.2	12.7
2013	35.3	22.2	13.1
2014	36.2	22.5	13.7
2015	37.0	22.6	14.4

Source: China Statistical Yearbook.

ratio has slowed down, and the increase in the ratio of aged dependency has strengthened. Since 2011, the total dependency ratio has begun to show a slow increase.

4. EMPIRICAL STUDY

4.1. Theoretical Models and Hypotheses

In the theoretical analysis, this paper quotes the Cobb-Douglas production function:

$$Y = AK^{\alpha}L^{\beta}. \tag{1}$$

In the formula, Y represents output, K represents capital input, L represents the number of laborers participating in production, and A represents economic growth factors other than capital and labor input, such as technological level and production factor allocation. α and β are the output elasticity of capital and labor respectively, as $\alpha > 0,\ \beta > 0,\ \alpha + \beta = 1$. In order to study the impact of population age structure on output, the total population that is denoted by P was introduced into the Cobb-Douglas production function. Dividing the two sides of the production function by the total population P to obtain the expression of per capita output y.

$$y = \frac{Y}{P} = \frac{AK^{\alpha}L^{\beta}}{P} = A \cdot K^{\alpha} \cdot (\frac{L}{P})^{\beta} \cdot P^{\beta-1}. \tag{2}$$

Based on (2), this paper assumes that the population of working ages is all involved in production and the population of non-working ages does not participate in production. That is, the number of working-age population is equal to the number of laborers engaged in production (L) and the proportion of working-age population to the total population is L / P. By using CD and AD to represent child dependency ratio and aged dependency ratio, the following formula (3) can be obtained:

$$L / P = 1/(1 + CD + AD). \tag{3}$$

Taking formula (3) into (2) and taking logarithms on both sides to get (4):

$$\ln y = \ln A + \alpha \ln K - \beta \ln(1 + CD + AD) + (\beta - 1)\ln P. \tag{4}$$

From the McLaughlin formula with Peano's remainder, it can be seen that when the function $f(x) = \ln(1+x)$ has a third-order derivative in the open interval (-1, $+\infty$) containing $x = 0$, it has the following formula for any x; $f(x) = f(0) + f'(0)x + \frac{f''(0)}{2!}x^2 + o(x^2)$, therefore $\ln(1+x) = x - \frac{1}{2}x^2 + o(x^2)$. Total dependency ratio (TD=CD+AD) of the Chinese demography continues to decline and tends to zero, and $TD \subset (-1, +\infty)$, so $\ln(1+TD) = TD - \frac{1}{2}TD^2 + o(TD^2)$. We can get the formula (5);

$$\ln(1 + CD + AD) \approx (CD + AD) - \frac{1}{2}\cdot(CD + AD)^2. \tag{5}$$

Taking formula (5) into formula (4) to get (6):

$$\begin{aligned} \ln y = {} & \frac{1}{2}\beta \cdot CD^2 - \beta \cdot CD + \frac{1}{2}\beta \cdot AD^2 - \beta \cdot AD + \ln A + \alpha \cdot \ln K \\ & + \beta \cdot CD \cdot AD + (\beta - 1)\ln P. \end{aligned} \tag{6}$$

Since the output elasticity of labor is $\beta > 0$, the coefficients of AD^2 and CD^2 are positive. Based on this, this paper proposes the following hypothesis:

Hypothesis 1: there is a U-shaped relationship between child dependency ratio and economic growth.

Hypothesis 2: there is a U-shaped relationship between Aged dependency ratio and economic growth.

4.2. Empirical Model

According to the theoretical model, the child dependency ratio and aged dependency ratio are important factors affecting economic growth. In order to test Hypothesis 1 and Hypothesis 2, child dependency ratio and its quadratic item and aged dependency ratio and its quadratic item are added to the model, which is the important independent variable that this paper focuses on. In addition, with reference to the research of other scholars, other factors affecting economic growth (RGDP, real GDP per capita) are selected as control variables. Based on the studies of Radelet *et al*. (1997) and Bloom *et al*. (1999), this article selects fixed-asset investment (I), trade openness (TO), government spending (GS), urbanization rate (UR) and industrial structure of employed population (TIR) as control variables.

In order to analyze the long-term relationship between population age structure and economic growth, this paper selects the panel Autoregressive Distributed Lag (ARDL) cointegration model for empirical analysis. ARDL models have gained popularity in recent years as a method of examining long-run cointegrating relationships between variables (Pesaran and Shin, 1999).

In panel settings with individual effects, standard regression estimation of ARDL models is problematic due to bias caused by correlation between the mean-differenced regressors and the error term. A popular alternative is the Pooled Mean Group (PMG) estimator of Pesaran, Shin and Smith (PSS, 1999). The PGM model for a panel setting allows short-run coefficients, including the intercepts, the speed of adjustment to the long run equilibrium values, and error variances to be heterogeneous province by province while the long-run slop coefficients are restricted to be homogeneous across provinces. If the model is heterogeneous, the PMG estimates are inconsistent; the mean group (MG) estimates are consistent in either case. For our purposes under the assumption of long-run slope homogeneity, the PMG estimator offers an increase in the efficiency of the estimates with respect to mean group estimators (PSS, 1999). This is because a homogeneous nature exists in studied provinces in terms of economic growth and population age structure in

China. We therefore, assume that the long-term relationship between economic growth and economic development would be homogenous across the provinces. However, short-run impacts of age population structure on economic activity are affected by local laws, regulations, and over lending; hence, it is reasonable to argue that province heterogeneity is relevant in the short-run. Moreover, as the time span in this study is only 26 years, the MG estimator has no enough degrees of freedom. Therefore, PMG estimations are more relevant for our analysis. The PGM model is written as follows:

$$\begin{aligned}\Delta \ln RGDP_{i,t} = & \sum^{q} \Delta CD_{i,t-j}\beta_{1i,j} + \sum^{q} \Delta CD^{2}_{i,t-j}\beta_{2i,j} + \sum^{q} \Delta AD_{i,t-j}\beta_{3i,j} \\ & + \sum^{q} \Delta AD^{2}_{i,t-j}\beta_{4i,j} + \sum^{q} \Delta \ln I_{i,t-j}\beta_{5i,j} \\ & + \sum^{q} \Delta \ln GS_{i,t-j}\beta_{6i,j} + \sum^{q} \Delta \ln FDI_{i,t-j}\beta_{7i,j} \\ & + \sum^{q} \Delta TIR_{i,t-j}\beta_{8i,j} + \sum^{q} \Delta UR_{i,t-j}\beta_{9i,j} \\ & + \sum^{q} \Delta TO_{i,t-j}\beta_{10i,j} + \sum^{p} \Delta \ln RGDP_{i,t-j}\lambda_{i,j} \\ & + \phi_i EC_{i,t-1} + \varepsilon_{i,t},\end{aligned} \tag{7}$$

where,

$$\begin{aligned}EC_{i,t-1} = & \ln RGDP_{i,t-1} - CD_{i,t-1}\theta_1 - CD^{2}_{i,t-1}\theta_2 \\ & - AD_{i,t-1}\theta_3 - AD^{2}_{i,t-1}\theta_4 - \ln I_{i,t-1}\theta_5 \\ & - \ln GS_{i,t-1}\theta_6 - \ln FDI_{i,t-1}\theta_7 - TIR_{i,t-1}\theta_8 \\ & - UR_{i,t-1}\theta_9 - TO_{i,t-1}\theta_{10}.\end{aligned} \tag{8}$$

In the model, i represents the observation area and t represents the observation time in each area. $\varepsilon_{i,t}$ is a random disturbance term, λ's and β's represent short-run coefficients of dependent and independent variables

Table 2 Statistical Description of All Variables

Variables	Label	Max.	Min.	Mean	Std. Dev.
ln*RGDP*	Logarithm of real GDP per capita	10.868	6.0298	7.9184	0.8552
CD	Child dependency ratio (%)	59.26	9.6	31.251	10.6438
CD^2	Square of CD	3,512	92.16	1,089.8	698.7026
AD	Aged dependency ratio (%)	21.9	4.97	11.118	2.7309
AD^2	Square of AD	479.61	24.701	131.06	65.6337
ln*I*	Logarithm of real fixed investment	25.796	19.414	23.364	1.1525
ln*FDI*	Logarithm of real FDI	23.607	9.9888	20.149	1.8508
TO	Total export+import value/GDP (%)	280.63	3.1666	30.919	42.2027
ln*GS*	Logarithm of gov't spending	24.468	19.874	22.307	0.9099
TIR	Proportion of employees in tertiary industry (%)	78.8	10.41	29.782	10.4515
UR	Urbanization rate (%)	89.6	12.26	40.647	17.8880

respectively, θ is long-term coefficient, ϕ is the speed of adjustment parameter, and *EC* is the error terms.

This paper selects 31 provincial panel data in China from 1990 to 2015 as the sample. The statistical description of each variable is shown in table 2. The data used in this paper come from ″Statistical yearbook of china″, the website of the National Bureau of Statistics of China, New China in 65 years of statistics compilation and the Statistical Yearbooks of various regions.

4.3. Empirical Analysis

In order to study the long-term relationship between population age structure and economic growth, this paper selects the ARDL model for empirical analysis. The results of regression are shown in table 3.

In model 1, the variable ln*FDI* is not significant, so we remove this variable to estimate model 2. The coefficient of $EC_{i,t-1}$ is negative and significant, so there is a long-term relationship between the population age structure and economic growth.

First, the child dependency ratio is "U-shape" in relation to economic

Table 3 The Results of ARDL Model

Independent Variable	Model 1	Model 2
CD	−0.068770*** (−10.64)	−0.039688*** (−10.41)
CD^2	0.000596*** (7.12)	0.000292*** (6.38)
AD	0.257995*** (8.03)	0.068518*** (4.81)
AD^2	−0.008627*** (−6.96)	−0.00206*** (−4.00)
ln*I*	0.490144*** (13.06)	0.303325*** (16.80)
ln*GS*	−0.532960*** (−7.70)	−0.159978** (−5.48)
ln*FDI*	−0.014985 (−1.51)	–
TIR	0.005248* (1.72)	0.042018*** (19.10)
UR	0.016832*** (7.68139)	0.004291*** (4.61)
TO	0.017123*** (10.06)	0.003227*** (7.87)
$EC_{i,t\text{-}1}$	−0.061381*** (−7.84)	−0.082927*** (−6.20)
Observations	764	

Notes: The lag length in (7) is selected as p=1 and q=1, based on Akaike information criterion. ***, **, * indicate statically significance at 1%, 5%, 10% level. ( ) is t value.

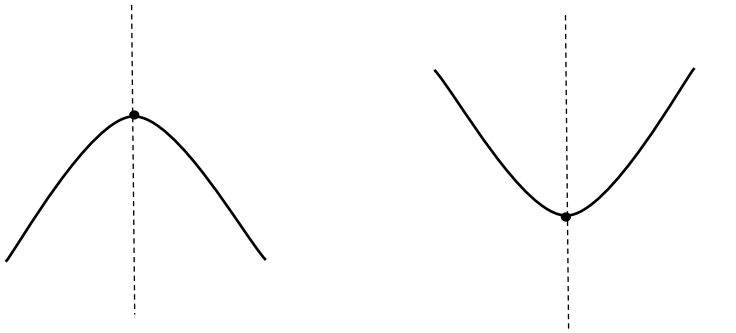
growth, which is consistent with the expectation of hypothesis 1. The turning point in the effect of child dependency ratio on economic growth appears to be 67.96% (Model 2). Combined with the actual situation, the impact of child dependency ratios on economic growth in all provincial units in China appears

on the left side of the "U-shape", indicating that the decline in child dependency ratio has a positive impact on per capita output and promotes China's economic growth. Possible explanations: (1) the decline in the dependency ratio of children can increase the savings rate and promote economic growth. At the micro level, the decline in child dependency ratio means that the burden of family support is reduced, consumption for raising children is reduced and household savings are relatively increased. At the macro level, the decline in child dependency ratio means that the proportion of working-age population in society has risen relatively. According to the Modigliani (1954) life cycle theory, the increase in the proportion of working-age population will increase the overall social savings rate to some degree; (2) the decline in child dependency ratio will increase labor supply to a certain extent. The population structure with a relatively low child dependency ratio and a large proportion of working-age population results from the process of fertility rate from high to low. In the process, more labor will be released from the burden of childbearing and raising children; (3) the reduction in the number of children has prompted parents to be more energetic and able to value the quality of their children, which increase investment in human capital and promote technological progress.

Second, the aged dependency ratio is "inverted U-shape" in relation to economic growth, which is contrary to the expectation of hypothesis 2. It shows that in a moderate range, the increase in aged dependency ratio can promote economic growth, but beyond a certain value, the continued increase in aged dependency ratio will hinder economic growth. The possible reasons are as follows: (1) although the increase in aged dependency ratio means that part of labor force is aging, the working-age population spends more time on supporting the elderly, and many elderly people aged over 65 in rural areas of China still participate in production activities. It has become common for elderly people in urban and rural areas to help their children with housework and child raising. To a certain extent, they release a large number of working-age population. Therefore, the increase in aged dependency ratio does not significantly weaken the effective supply of labor; (2) according to

Modigliani's (1954) life cycle theory, the elderly population is a purely consuming population. The increase in the elderly population in society will increase the level of immediate consumption, promoting economic growth; (3) the increase in aged dependency ratio reflects the increase in the accumulation of China's human capital stock. The elderly population is the working-age population with rich experience before retiring and its rich labor experience can help to promote technology progress and promote economic growth. But as the elderly population continues to rise, the negative effects on the economy begin to show. Aged dependency ratios have led to a heavier burden of support than that of the general assembly, which has reduced the level of social labor supply and savings. The turning point in the effect of aged dependency ratio on economic growth appears at 16.63% (Model 2). Combined with the actual situation in each region, except for Liaoning, Chongqing and Sichuan province, aged dependency ratio of other provinces appears on the left side of the "inverted U-shape". That is, the increase in aged dependency ratio promotes economic growth. According to the "World Population Prospects" (UN, 2012), the aged dependency ratio in China will reach the peak at 16.63% around 2020. The negative effect of aged dependency ratio on economic growth will begin to appear.

Figure 2 The Relationship between Dependency Ratio and Economic Growth



Aged dependency ratio=16.63 Child dependency ratio=67.96

Third, the estimation result of each control variable are broadly in line with the expectation. Fixed investment as an indicator of the scale of social expansion of reproduction, has a significant positive effect on economic growth. The higher the degree of trade openness, the higher the level of marketization in the region, and the more significant the role of promoting regional economic growth. Foreign direct investment has not promoted China's economic growth. It has a crowding effect on domestic investment. In recent years, with the expansion of the scale of investment, domestic savings are also rising, and the total amount of domestic savings is higher than the total domestic investment, there is a double spillover phenomenon of internal capital idle and foreign investment. The advanced industrial structure means that the distribution of labor forces among industries is more reasonable and conducive to economic growth. Excessive government expenditure means low degree of marketization and is not conducive to economic growth. The increase in the proportion of urban population means that the increase in the level of urbanization promotes economic growth.

Based on the regression coefficients obtained in model 2, the marginal effects of the child dependency ratio and the age dependency ratio on China's economic growth can be measured. First, the marginal impact of child dependency ratio on China's economic growth has always been negative and has shown a downward trend. This shows that during the period from 1990 to 2015, the continued decline in the child dependency ratio contribute to the economic growth. Moreover, the marginal impact of the decline in child dependency ratio on China's economic growth continues to decrease.

Second, the marginal impact of aged dependency ratio on China's economic growth has always been positive with a downward trend. It shows that during the period from 1990 to 2015, the increase in aged dependency ratio has also contributed to the Chinese economy, but its marginal effect has weakened. The first and second conclusions indicate that the effect of dependency ratio on economic growth is in line with the law of diminishing marginal returns in economics. Specifically, in a certain range, the larger the value of the child dependency ratio or aged dependency ratio, the smaller impact of the change

Figure 3 Marginal Economic Contribution of Child Dependency Ratio

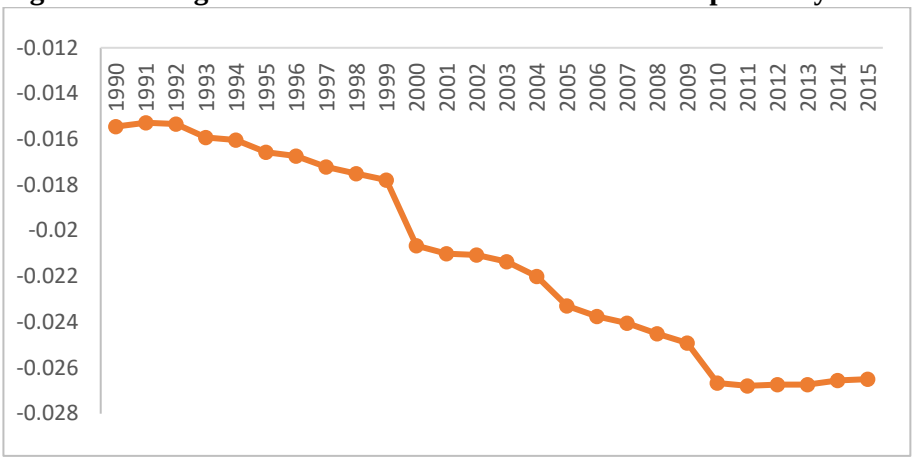
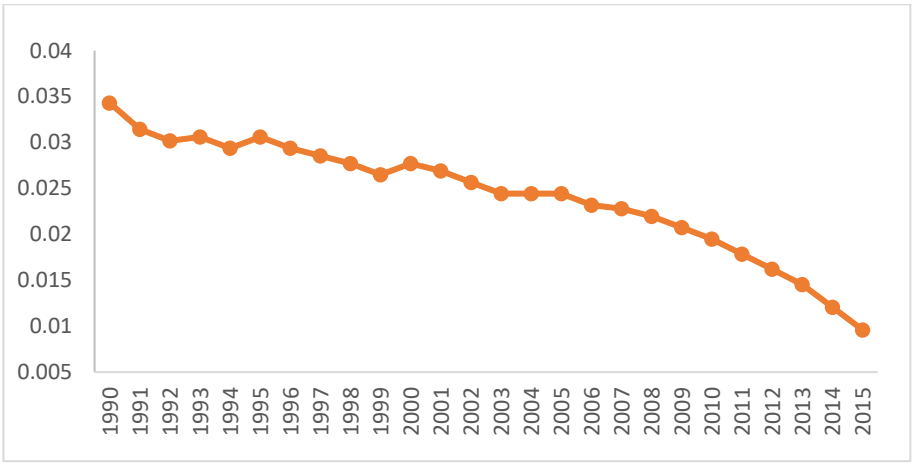


Figure 4 Marginal Economic Contribution of Aged Dependency Ratio



on economic growth.

Third, during the period 1990 and 2015, the effect of one percent increase in aged dependency ratio is always greater than the contribution of one percent drop in child dependency ratio, but the gap between the two continues to narrow.

5. CONCLUSIONS

The paper investigates the non-linear relationship between population age structure and economic growth by incorporating quadratic terms of child dependency ratio and aged dependency ratio into Cobb-Douglas production function. We select 31 provincial panel data from China in the period 1990-2015 as the sample. Using panel ARDL cointegration model, this paper estimates the effects of the child dependency ratio and aged dependency ratio on economic growth in the long-term.

Empirical results reveal that the non-linear effect of child dependency ratio on economic growth is significant. The quadratic coefficient of child dependency ratio is positive, indicating that the child dependency ratio has a U-shaped relationship with China's economic growth. Combined with the sample data used in this empirical study, it shows that the decline in the child dependency ratio promotes China’s economic growth. The non-linear effect of elderly dependency ratio on economic growth is also significant. The quadratic coefficient of the aged dependency ratio is negative, indicating that the aged dependency ratio has an “inverted U-shaped” relationship with China’s economic growth. That is, as the ratio of old-age dependency increases, the per capita real GDP increases. When the aged dependency ratio exceeds a certain value, the per capita real GDP decreases as the aged dependency ratio continues to increase. It is worthwhile to note that older persons can bring a positive effect on economic growth. Therefore, policies are demanded to allow elderly people to retain their employment for a longer period of time and to take advantage of the elderly people’s experience and knowledge, especially in the context of an aging society.

Although the paper presents four mechanisms through which age structure can influence economic growth, it does not identify them empirically. For future research, it may be interesting to investigate the mechanisms by estimating the same regressions where the dependent variables are labor supply, savings, and human capital. It may be also interesting to incorporate an interaction term between age structure and, respectively, labor supply, savings,

human capital, and public expenditure in explanatory variables. Specifically, human capital is highly valued because of its potential to enhance economic growth (Schultz, 1961 and 1982; Chun *et al*., 2012; Kim, 2013). Human capital includes a wide range of different components, such as knowledge, experience, competency, health, and others. It may be very important to find the relationship between age structure, human capital accumulation, and long-term economic growth.

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