



Article Population Ageing, Financial Deepening and Economic Growth: Evidence from China

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Abstract: Using a panel of 31 Chinese provinces from 2000 to 2016, we investigated the impact of population ageing and financial deepening on economic growth. Based on the dynamic panel system GMM estimators, the empirical results address that both population ageing and financial deepening have a significantly positive impact on economic growth, while the interactions between them have a significantly negative effect on economic growth. From the perspective of total marginal effect, we also find that population ageing does contribute to economic growth but only when financial deepening is less than a threshold level; however, on the whole, financial deepening has an inhibitory effect on economic growth which increases with population ageing.

Keywords: population ageing; financial deepening; economic growth; system GMM; total marginal effect

1. Introduction

With rapid economic growth that even surpassed most developed countries and increasing international influence over the past two decades in China, the factors that affect China's economic growth have attracted much attention. Population ageing and financial deepening are two important factors affecting economic growth in developed countries [1,2]. Evidence from developed countries showed that the process of population ageing and financial deepening reform took place in different periods. For instance, both the United States and Japan have advanced financial deepening reforms long after population ageing, while South Korea has carried out financial deepening reform before entering the ageing society. Different from developed countries, China has undergone the process of population ageing and financial deepening reform during the same period. Evidence shows that China has entered the ageing society since 2000 [3] and China's financial deepening reform which began in 1996 has been completed by 2015. Therefore, we mainly focus on what impact would population ageing and financial deepening have on China's economic growth.

Population ageing could affect economic growth by affecting savings [4–6]. Developed countries generally have low savings rates. In some European countries such as Greece and Portugal, the savings rate of the whole society was even negative for some time resulting from people's excessive consumption. This undoubtedly goes against population ageing affecting economic growth through savings channel. Moreover, in developed countries, bank deposits only account for a small proportion of household assets and corporate financing can be achieved mainly through direct financing in financial markets. Instead, the overall savings rate of China is very high and bank deposits are the main household assets for Chinese people. In China, investment is the core driving force of rapid economic growth [7] and the funds of investment are mainly from savings. The process of converting savings into investment mainly depends on banking financial institutions. Nevertheless, long-standing financial repression in China makes the extremely low efficiency of capital allocation in banking

financial institutions [8]. Hence, the impact of population ageing on China's economic growth would be affected by the savings-investment conversion efficiency. However, the extant empirical studies on the impact of population ageing on economic growth have always been controversial. Some scholars believe that population ageing has a positive impact on economic growth [9], more studies do not support this view [10,11].

Financial deepening could have an important impact on the savings-investment conversion efficiency of banking financial institutions. And most scholars hold the view that financial deepening could promote the conversion efficiency [12–14], while some believe that financial deepening would reduce the conversion efficiency [15]. Meanwhile, there is no consistent conclusion about whether financial deepening could promote economic growth or not yet. Although more empirical studies find that financial deepening has a positive impact on economic growth [12,13,16–18], some reach the opposite conclusion that financial deepening is harmful to economic growth [19–21].

What impact would population ageing have on economic growth on the special situation of China? Would the impact of population ageing on economic growth be improved by implementing financial deepening reform in China? Meanwhile, what impact would financial deepening have on China's economic growth? We consider adding population ageing, financial deepening and economic growth into the framework to solve the above-mentioned problems.

Compared with the previous studies, the main contribution of this paper is to put population ageing, financial deepening and economic growth into the framework, which focuses on the impact of population ageing and financial deepening reform on China's economic growth. We use an econometric model based on one-step system generalized method of moments (system GMM) estimators to achieve the goal. The empirical results are shown as follows: (1) Both population ageing and financial deepening significantly promote China's economic growth. An increase in the natural logarithms of population ageing indicators and financial deepening indicator by 1%, could increase the natural logarithm of real GDP per capita by about 0.3% and 9.6–12.4 basis points respectively; (2) The interactions between population ageing and financial deepening significantly impede China's economic growth. It indicates that the impact of population ageing on China's economic growth should not be improved by implementing financial deepening reform; (3) In terms of total marginal effect, although population ageing promotes the China's economic growth, the marginal effect of growth would decrease as the degree of financial deepening increases. Furthermore, when financial deepening is above some critical level, the total marginal effect of population ageing on economic growth would be negative. Meanwhile, the total marginal effect of financial deepening on economic growth, which decreases as the degree of population ageing increases, would always be negative.

The rest of this paper is organized as follows. Section 2 reviews the related literature. Section 3 introduces the empirical methodology and data. Section 4 presents and discusses the empirical results. Finally, Section 5 provides the conclusions.

2. Literature Review

This section briefly reviews the literature relevant to the impact of population ageing and financial deepening on economic growth and the impact of population ageing on financial deepening.

2.1. The Impact of Population Ageing on Economic Growth

Although many studies focused on how population ageing affects economic growth have been made [9–11], so far there is no uniform conclusion. The literature concerning the impact of population ageing on economic growth can be traced back to Keynes [22]. Based on analysis from the direct channel, he believes that population ageing reduces the labor force in the economy and is detrimental to economic growth. However, the artificial intelligence replacing human makes the adverse effects of population ageing on economic growth through direct channel have been greatly weakened [23]. Hence, many later studies pay more attention on the indirect channels through which population

ageing can affect economic growth. The savings channel is a critical indirect channel. Population ageing can affect economic growth by influencing savings [4–6] and savings-investment conversion.

There is a lack of consensus on how population ageing affects growth through savings channel in existing studies. Based on the life cycle theory, some scholars believe that older populations become larger would result in an increase in consumption and a reduction in social savings, which reduces funding for investment activities [24,25]. However, increased life expectancy is an important cause of population ageing [26]. Some researchers discuss the beneficial effects of population ageing on economic growth based on the precautionary savings theory. They believe that people tend to save more during the working period in order to get adequate security for longer retirement, leading to an increase in social savings and investment funds [27,28].

In the special case of China, there is also disagreement on how population ageing affects China's economic growth. Some scholars believe that population ageing is harmful to China's economic growth. For instance, based on China's national data from 1953 to 2000, Modigliani and Cao [29] find that population ageing has negative impacts on savings rate and economic growth. Kuijs [30] uses the United Nations population projections and finds that the elderly dependency ratio has negative effects on economic growth. However, some researchers believe that population ageing is beneficial to China's economic growth. For instance, Chamon and Prasad [28] find that the characteristics of China's urban household savings rate are the opposite of the life cycle. This indicates that population ageing is conducive to increasing savings rate and economic growth.

According to Lee and Mason [9], population ageing could produce the second demographic dividend for the countries that have just entered in their early stage of ageing. They believe that when people enter the early stage of their old-age, they have the strong precautionary savings motive and high savings rate. Therefore, although the proportion of elderly people has increased during the first two decades after ageing, the savings of the whole society would increase and economic growth would be promoted. Since China has entered the ageing society since 2000, we could make the following hypothesis.

Hypothesis 1. Population ageing has a significant positive effect on China's economic growth.

2.2. The Impact of Financial Deepening on Economic Growth

Whether financial deepening can promote economic growth or not has been the focus of academic debate. The literature with positive views in this area can be traced back to Mckinnon [12] and Shaw [13]. The theories of financial repression and financial deepening, which put forward by Mckinnon [12] and Shaw [13] respectively, suggest that implementing financial deepening reform can increase the overall social savings and promote the savings-investment conversion efficiency, thereby promoting economic growth. These two theories lay the theoretical foundations for developing countries to carry out financial deepening reform and are supported by some empirical studies [31,32].

However, there are some criticisms of financial deepening from two different perspectives. On the one hand, from the perspective of banks, some argue that financial deepening would result in higher risk-taking preference [33,34] and lower savings-investment conversion efficiency for banks [35,36]. On the other hand, from the perspective of enterprises, some argue that the implementation of financial deepening reform in developing countries would increase the financing costs of enterprises and reduce their investment activities [15]. Hence, financial deepening would have a negative effect on economic growth.

As for the situation in China, there is no consensus on how financial deepening affects China's economic growth in academia. Some believe that financial deepening is beneficial to China's economic growth. For instance, Cheng and Degryse [16] use a panel of 27 Chinese provinces from 1995 to 2003 and find that the development of banking business has a significant role in promoting local economic growth. It indicates that financial deepening is conducive to economic growth. Based on the data for 286 Chinese cities covering the period 2001–2006, Zhang et al. [18] find that there is a

significant positive correlation between financial deepening and economic growth. However, some believe that financial deepening is harmful to China's economic growth. For instance, with the use of a panel data set of 29 Chinese provinces for the period 1990–1999, Boyreau-Debray [19] finds that financial deepening has a significantly negative correlation with economic growth. Based on a panel of 31 provinces in China over the period 1986–2002, Hasan et al. [20] find that financial deepening, measured with the proportion of bank loans to GDP, has an adverse effect on economic growth.

In China, savings are the main source of funds for investment and the process of converting savings into investment mainly depends on banking financial institutions. Since financial deepening could promote the conversion efficiency [12–14], we could make the following hypothesis.

Hypothesis 2. Financial deepening has a significant positive effect on China's economic growth.

2.3. The Impact of Population Ageing on Financial Deepening

Increased life expectancy is an important cause of population ageing [26]. In order to ensure adequate security for longer retirement, people tend to work harder in their working-age, so that they can have more savings in their old age [37]. As society enters the ageing stage, the number of older individuals as well as the savings of the whole elderly population become larger. However, older people have quite different savings behaviors than younger individuals [38]. The elderly would keep more savings in the form of bank deposits due to low risk tolerance, making banks have more loanable funds. In the case of financial repression, the capital allocation efficiency of banking financial institutions is often rather low and many enterprises have difficulty in getting sufficient investment funds [8]. This is undoubtedly detrimental to economic growth. In order to solve the financing problems of enterprises and promote economic growth, the government would be urged to accelerate the implementation of financial deepening reform. Therefore, the capital allocation efficiency of banking financial institutions could be increased and the conversion of savings into investment could be promoted.

However, because of the increased life expectancy and inadequate social security system of China, people have strong precautionary savings motive and consume little to ensure a longer retirement. This results in serious shortage of consumption in the whole society. Moreover, the serious shortage of domestic demand would make the investments of many enterprises become excess capacity, which is harmful to economic growth. Therefore, we could make the following hypothesis.

Hypothesis 3. The impact of population ageing on China's economic growth could not be improved by implementing financial deepening reform.

3. Data and Empirical Methodology

3.1. Data

This paper uses various sources to obtain a panel data set of 31 Chinese provinces from 2000 to 2016.

For the indicator of economic growth (denoted by *PGP*), measured with real GDP per capita, is obtained by adjusting the annual nominal GDP per capita according to the GDP per capita index with 2000 as the base year. The data of calculating this indicator are from China Statistical Yearbook as well as China Economic and Social Development Statistics Database.

The two core variables in this paper are population ageing (denoted by *AGE*) and financial deepening (denoted by *FD*). For the first core variable, population ageing (i.e., *AGE*), based on the indicators adopted by Weil [39] and Teixeira et al. [2], is proxied by elderly population coefficient (denoted by *COA*) and elderly dependency ratio (denoted by *OAD*) respectively. The first indicator (i.e., *COA*), measured with the ratio of individuals aged 65 and over to total population, considers life expectancy and measures the changes of the elderly share of the population directly. The higher

the value of elderly population coefficient is, the larger the proportion of the elderly population is and the more serious the population ageing is. However, only this indicator could not fully reflect the impact of social burden of the elderly resulting from changes in age structure on economic growth. The second indicator (i.e., *OAD*), measured with the ratio of individuals aged 65 and over to persons aged between 15 and 64, considers the dependency burden of per capita workforce as well as changes in the elderly and working-age population. The higher the value of elderly dependency ratio is, the heavier the burden of raising the elderly is and the more serious the problem of ageing is. Moreover, the robustness of the results could be tested by using the second indicator in analysis. We employ the data of these two indicators from China Population and Employment Statistics Yearbook.

For another core variable, financial deepening (i.e., *FD*), based on the indicator adopted by Wu et al. [40], is proxied by the ratio of bank loans to GDP. Banks dominate the Chinese financial market and bank loans are the main source of investment funds for Chinese enterprises. Meanwhile, most of bank loans are delivered to enterprises in China. The enterprises could easily get more funds for investment when the level of financial sector development is higher. Therefore, the ratio of bank loans to GDP could reflect the level of financial sector development to some extent. The higher value of this indicator suggests that the level of financial deepening is higher and more bank loans would be delivered to enterprises, which could promote the savings-investment conversion and economic growth. The data of this indicator are from the statistical yearbooks of Chinese provinces.

Other factors (denoted by X_e) affecting economic growth used in this paper include: (1) national savings rate(denoted by SAV), measured with the difference between GDP and final consumption as a proportion of GDP [41]; (2) human capital (denoted by HM) [42], measured with the average years of schooling for individuals aged 6 and over. This indicator is calculated according to: (a) the school diploma, high school diploma and college diploma and above respectively and (b) the ratio of persons aged 6 and over with corresponding educational attainment to the total population aged 6 and over; (3) fixed capital investment (denoted by FCF), measured with fixed capital formation rate [43]. This indicator is calculated as the ratio of the gross fixed capital formation to GDP; (4) government final consumption expenditure to GDP [44]; (5) foreign trade (denoted by TRA), measured with the ratio of the total import and export of goods to GDP [6]; and (6) total population (denoted by POP) [43], measured with the total population at the end of the year. The data of these control variables are from China Statistical Yearbook as well as China Population and Employment Statistics Yearbook.

The definitions and descriptive statistics of all the above variables are shown in Table 1.

Variable	Definition	Obs.	Mean	Std.Dev.	Min.	Max.
PGP	Real GDP per capita (RMB yuan)	527	21,465.91	16,780.39	2662	103,693
COA	Individuals aged 65 and over (% of total population)	527	8.84	2.02	4.33	16.38
OAD	(Individuals aged 65 and over/persons aged between 15 and 64) * 100 (%)	527	12.12	2.65	6.27	21.88
FD	(Bank loans/GDP) * 100 (%)	527	112.52	40.56	53.29	267.50
SAV	Difference between GDP and final consumption (% of GDP)	527	47.36	9.05	8.90	65.90
HM	Average years of schooling for individuals aged 6 and over (years)	527	8.36	1.22	3.43	12.30
FCF	Gross fixed capital formation (% of GDP)	527	53.96	17.61	27.71	138.07
GF	Total government final consumption expenditure (% of GDP)	527	15.87	6.19	8.45	52.26
TRA	(Total import and export of goods/GDP) * 100 (%)	527	31.69	40.72	3.21	184.29
РОР	Total population at the end of the year (10,000 persons)	527	4245.01	2687.66	263	10,999

Table 1. Definition of variables and summary statistics.

3.2. Empirical Methodology

This section aims to construct an econometric model to examine the impact of population ageing and financial deepening on economic growth. It is necessary to build a benchmark model that examines the effect of population ageing on economic growth. Based on the model used by Teixeira et al. [2], the benchmark model of this paper is presented as Equation (1).

$$\ln(PGP_{it}) = \beta_1 \ln(PGP_{it-1}) + \beta_2 \ln(AGE_{it-1}) + \sum_{e=1} \gamma_e \ln(X_e)_{it-1} + \lambda_i + u_t + \varepsilon_{it}$$
(1)

where subscripts *i* and *t* represent province and time period respectively; $\ln(\bullet)$ denotes natural logarithmic function; *PGP* is real GDP per capita and denotes economic growth; *AGE* denotes population ageing; X_e denotes a series of conditions that affect economic growth and control cross-provincial differences in steady state; λ_i and u_t denote unobservable provincial effect and the time effect respectively; ε_{it} denotes the random error term.

In order to further investigate the influence of financial deepening on the relationship between population ageing and economic growth, the natural logarithm of financial deepening variable (i.e., $\ln(FD)$) and the interaction term $\ln(AGE) \times \ln(FD)$ are added to the benchmark model (1). The specific model is constructed as follows:

$$\ln(PGP_{it}) = \beta_1 \ln(PGP_{it-1}) + \beta_2 \ln(AGE_{it-1}) + \beta_3 \ln(AGE_{it-1}) \times \ln(FD_{t-1}) + \beta_4 \ln(FD_{t-1}) + \sum_{e=1}^{n} \gamma_e \ln(X_e)_{it-1} + \lambda_i + u_t + \varepsilon_{it}$$
(2)

The above two econometric models are dynamic panel data models and both of them have endogenous problems. Because both of their explanatory variables contain first-order lags of the explained variables, which are related to the random error terms. Therefore, using static estimation methods such as pool ordinary least squares, fixed effect and random effect of panel data would cause the estimators to be biased and inconsistent. Although the first-order difference GMM method proposed by Arellano and Bond [45] could solve the endogenous problems well, this method tends to cause the weak instruments problem. This may result from insufficient instruments. Moreover, the first-order difference GMM method filters out the influence of non-time-varying parameters [46]. For these two reasons, Arellano and Bover [47] as well as Blundell and Bond [48] put forward the system GMM method. This method allows to add more instruments by assuming that the first-order differences of all instrumental variables are not related to the fixed effect [49]. Compared with the first-order difference GMM method, the system GMM method solves the weak instruments problem and has better finite sample properties [48]. The system GMM method could be divided into one-step method and two-step method. Since in the finite sample case, unlike the asymptotic standard errors of the two-step estimators are seriously biased [48,50], those of the one-step estimators are unbiased [51], therefore, the one-step system GMM method is used in this paper.

It is necessary to check whether there is second-order autocorrelation in first-differenced errors and whether the instruments are valid for system GMM estimations. The test statistics used are AR(2)and Hansen test statistics, whose null hypotheses are: there is no second-order autocorrelation in first-differenced errors and the instruments are valid respectively. Meanwhile, it is important to use the cluster-robust standard errors for system GMM estimations in that the ordinary standard errors would be inaccurate. Therefore, the *p*-values of AR(2) and Hansen test statistics as well as the cluster-robust standard errors of the estimated coefficients are given simultaneously in this paper.

4. Empirical Results and Discussion

4.1. The Impact of Population Ageing on Economic Growth

Table 2 presents the empirical results of the benchmark model (1) based on one-step system GMM method. According to columns (1)–(4) of Table 2, the *p*-values of AR(1) are all less than 1%, while those of AR(2) and of the Hansen test are all more than 10%. This indicates that the four estimations are all first-order autocorrelation in first-differenced errors but not second-order autocorrelation. Meanwhile, the instruments used are all valid. Therefore, the four estimation results are all reliable.

Variable	(1)	(2)	(3)	(4)	
	0.9714 ***	0.9572 ***	0.9759 ***	0.9611 ***	
$\ln(PGP)$	(0.0062)	(0.0117)	(0.0058)	(0.0116)	
$\ln(COA)$	0.0468 ***	0.0414 ***			
$\operatorname{III}(\operatorname{COA})$	(0.0110)	(0.0160)			
$\ln(OAD)$			0.0459 ***	0.0342 **	
III(OAD)			(0.0102)	(0.0162)	
$\ln(SAV)$		0.0608 ***		0.0621 ***	
$\operatorname{III}(3AV)$		(0.0164)		(0.0173)	
ln(HM)		-0.0233		-0.0200	
		(0.0161)		(0.0170)	
$\ln(ECE)$		0.0213 **		0.0215 **	
$\operatorname{III}(I \mathbb{C}I)$		(0.0103)		(0.0101)	
$\ln(CF)$		0.0034		0.0022	
		(0.0107)		(0.0110)	
$\ln(TRA)$		0.0092 *		0.0084 *	
		(0.0052)		(0.0050)	
$\ln(P \cap P)$		-0.0002		-0.0001	
		(0.0033)		(0.0034)	
constant	0.2586 ***	0.1072	0.1999 ***	0.0667	
	(0.0615)	(0.1135)	(0.0625)	(0.1142)	
AR(1)	0.0020	0.0010	0.0020	0.0010	
AR(2)	0.9230	0.1180	0.8280	0.1060	
Hansen test	1.0000	1.0000	1.0000	1.0000	
Number of instruments	138	114	138	114	
Ν	496	496	496	496	

Table 2. The impact of population ageing on economic growth.

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively; the values in parentheses are cluster-robust standard errors; N is the number of observations; the values corresponding to AR(1), AR(2) and Hansen test are *p*-values; in order to control the influence of time-varying factors on the estimated results, annual dummy variables are added to all regressions; however, the regression results of annual dummy variables are not listed.

To test the robustness of the results, in Table 2, neither of the columns (1) and (3) includes other control variables but the annual dummy variables, while both of the columns (2) and (4) include all the control variables. For population ageing, both coefficients on the indicator $\ln(COA)$ in columns (1) and (2) as well as both coefficients on the indicator $\ln(OAD)$ in columns (3) and (4) are significantly positive at the 1% confidence level. It suggests that since entering an ageing society in 2000, population ageing has boosted China's economic growth. This result supports our Hypothesis 1.

For control variables, in columns (2) and (4) of Table 2, both coefficients on the variable $\ln(SAV)$ are significantly positive at the 1% confidence level. It indicates that savings have a significant positive impact on China's economic growth. This may be because China's high savings rate provides a large source of investment funds for economic growth [29]. Both coefficients on the variable $\ln(HM)$ are insignificant. It suggests that human capital has no significant effect on China's economic growth, which is inconsistent with the findings of Benhabib and Spiegel [42]. This result may be due to that the education opportunity inequality results in the overall low level of education in China [52]. According

to the results of Benhabib and Spiegel [42,53], China's overall low level of education could have a negative impact on technology diffusion and total factor productivity. Moreover, human capital investment affects R&D [54,55] and innovation [56]. However, China's overall low level of education leads to the homogenization of human capital and large numbers of low-skilled workers. It has a negative impact on overall R&D and innovation [56,57]. All these factors make human capital has an insignificant effect on China's economic growth.

Both coefficients on the variable $\ln(FCF)$ are significantly positive at the 5% confidence level. It suggests that fixed capital investment is positively associated with China's economic growth, which is consistent with the findings of Hao et al. [7]. Both coefficients on variable $\ln(GF)$ are insignificant, suggesting that government consumption has no significant impact on China's economic growth. This may be due to that China's serious administrative barriers and resource flow constraints make government consumption could not provide positive incentives, resulting in no direct causal relationship between government consumption and economic growth [58]. Both coefficients on the variable $\ln(TRA)$ are significantly positive at the 10% confidence level. It indicates that foreign trade is conductive to China's economic growth. This may be because of China's active opening-up policy, which makes foreign trade could have a positive impact on economic growth by increasing investment [59]. Both coefficients on the variable $\ln(POP)$ are insignificant. This result suggests that the total population has no significant impact on economic growth, which is consistent with the population neutral theory of Bloom and Freeman [60]. The reason may be that prevailing institutional barriers limit the free flow of labor in China.

4.2. The Impact of Population Ageing and Financial Deepening on Economic Growth

This section will empirically estimate the impact of population ageing and financial deepening on economic growth by model (2). Table 3 reports the estimation results for model (2) based on one-step system GMM method. According to columns (1)–(4) of Table 3, the *p*-values of AR(1) are all less than 1%, while those of AR(2) and of the Hansen test are all more than 10%. This indicates that all the four estimation results are reliable.

To test the robustness of the results, none of other control variables except the annual dummy variables are added in columns (1) and (3) of Table 3, while all the control variables are added in columns (2) and (4). Table 3 shows that both coefficients on the indicator $\ln(COA)$ in columns (1) and (2) as well as both coefficients on the indicator $\ln(OAD)$ in columns (3) and (4) are significantly positive at the 1% confidence level. This result indicates that population ageing has a significant positive effect on China's economic growth. It supports our Hypothesis 1. In terms of the size of the impact of population ageing on economic growth, according to columns (2) and (4) of Table 3, an increase in $\ln(COA)$ by 1% would increase the natural logarithm of the real GDP per capita (i.e., $\ln(PGP)$) by 0.29%, while an increase in $\ln(OAD)$ by 1% would increase $\ln(PGP)$ by 0.32%. This result suggests that the natural logarithms of the indicators of population ageing increase by 1%, population ageing would result in the natural logarithm of real GDP per capita (0.3%).

For the impact of the financial deepening on economic growth, according to columns (1)–(4) of Table 3, the coefficients on the indicator $\ln(FD)$ are all significantly positive at the 1% confidence level. It indicates that financial deepening is positively associated with China's economic growth. This supports our Hypothesis 2. From columns (2) and (4) of Table 3, it could be found that an increase in $\ln(FD)$ by 1%, would increase the natural logarithm of real per capita GDP (i.e., $\ln(PGP)$) by 9.6–12.4 basis points.

Variable	(1)	(2)	(3)	(4)
	0.9828 ***	0.9717 ***	0.9804 ***	0.9718 ***
$\ln(PGP)$	(0.0051)	(0.0092)	(0.0059)	(0.0100)
$l_{\alpha}(\mathcal{O}(A))$	0.3058 ***	0.2869 ***	. ,	
$\ln(COA)$	(0.0892)	(0.0731)		
$\ln(COA) \times \ln(DD)$	-0.0578 ***	-0.0538 ***		
$\ln(COA) \times \ln(FD)$	(0.0184)	(0.0148)		
lm(OAD)			0.2917 ***	0.3197 ***
$\operatorname{III}(OAD)$			(0.0889)	(0.0999)
$\ln(OAD) \times \ln(ED)$			-0.0538 ***	-0.0604 ***
$\operatorname{III}(OAD) \times \operatorname{III}(ID)$			(0.0187)	(0.0205)
$\ln(ED)$	0.1084 ***	0.0960 ***	0.1092 ***	0.1242 ***
$\operatorname{III}(I D)$	(0.0473)	(0.0330)	(0.0409)	(0.0474)
$\ln(SAV)$		0.0289 **		0.0315 ***
$\operatorname{III}(\mathcal{O}\mathcal{IV})$		(0.0118)		(0.0117)
$\ln(HM)$		-0.0123		-0.0015
		(0.0150)		(0.0172)
$\ln(FCF)$		0.0156 *		0.0169 *
		(0.0084)		(0.0100)
$\ln(GF)$		-0.0064		-0.0051
		(0.0080)		(0.0095)
$\ln(TRA)$		0.0076 *		0.0078 *
		(0.0040)		(0.0044)
$\ln(POP)$		-0.0040		-0.0052
		(0.0037)		(0.0045)
<i>cons</i> tan <i>t</i>	-0.3175	-0.2809	-0.3394	-0.4630
	(0.2105)	(0.1616)	(0.2255)	(0.2260)
AR(1)	0.0010	0.0010	0.0010	0.0020
AR(2)	0.8320	0.2060	0.7910	0.1910
Hansen test	1.0000	1.0000	1.0000	1.0000
Number of instruments	200	142	140	146
N	496	496	496	496

Table 3. The impact of population ageing and financial deepening on economic growth.

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively; the values in parentheses are cluster-robust standard errors; N is the number of observations; the values corresponding to AR(1), AR(2) and Hansen test are *p*-values; in order to control the influence of time-varying factors on the estimated results, annual dummy variables are added to all regressions; however, the regression results of annual dummy variables are not listed.

For the interactions between population ageing and financial deepening, according to Table 3, both coefficients on $\ln(COA) \times \ln(FD)$ in columns (1) and (2) as well as both coefficients on $\ln(OAD) \times \ln(FD)$ in columns (3) and (4) are significantly negative at the 1% confidence level. This result shows that there are significant interactions between population ageing and financial deepening and such interactions would have a significant inhibitory effect on China's economic growth. Therefore, the implementation of financial deepening reform could not improve the impact of population ageing on China's economic growth. It supports our Hypothesis 3.

From the perspective of total marginal effect, we further analyze the impact of financial deepening on the relationship between population ageing and economic growth, as well as the impact of population ageing on the relationship between financial deepening and economic growth. As far as the first aspect is concerned, according to columns (2) and (4) of Table 3, the total marginal effect of $\ln(COA)$ on $\ln(PGP)$ and the total marginal effect of $\ln(OAD)$ on $\ln(PGP)$, which are denoted by MU_1 and MU_2 respectively, could be expressed as $MU_1 = 0.2869 - 0.0538 \times \ln(FD)$ and $MU_2 = 0.3197 - 0.0604 \times \ln(FD)$. This result suggests that both MU_1 and MU_2 would decrease with the increase of FD and an increase in $\ln(FD)$ by 1% would decrease MU_1 and MU_2 by 5.4 and 6 basis points respectively. Moreover, MU_1 is positive if and only if FD is less than 207 and when FD is above 207, MU_1 will be negative. Similar to MU_1 , MU_2 is positive if and only if FD is less than 198.95 and when FD is above 198.95, MU_2 will be negative. However, the overall sample mean of FD is 112.52, which makes both MU_1 and MU_2 are positive. It indicates that population ageing has, on balance, a positive impact on economic growth. However, the total marginal effect of population ageing on economic growth decreases with the increase of financial deepening. And such total marginal effect would be negative when financial deepening exceeds some critical level, leading to population ageing impeding economic growth.

As to the second aspect, according to columns (2) and (4) of Table 3, the total marginal effects of $\ln(FD)$ on $\ln(PGP)$, which are denoted by MU_3 and MU_4 respectively, could be expressed as $MU_3 = 0.096 - 0.0538 \times \ln(COA)$ and $MU_4 = 0.1242 - 0.0604 \times \ln(OAD)$. This indicates that MU_3 would decrease with the increase of COA and an increase in $\ln(COA)$ by 1% would decrease MU_3 by 5.4 basis points; while MU_4 would decrease with the increase of OAD and an increase in $\ln(OAD)$ by 1% would decrease MU_4 by 6 basis points. Meanwhile, MU_3 is positive if and only if COA is less than 5.96 and MU_3 will be negative when COA is above 5.96; while MU_4 is positive if and only if OAD is less than 7.82 and MU_4 will be negative when OAD is above 7.82. However, the overall sample means of COA and OAD are 8.84 and 12.12 respectively, which makes both MU_3 and MU_4 are negative. It suggests that financial deepening has, on balance, a negative effect on economic growth. Hence, financial deepening has impeded China's economic growth since entering the ageing society and such inhibitory effect would be enhanced with the increase of population ageing.

4.3. Robustness Test

To test the reliability of our results, we perform robustness tests by changing sample interval. We choose the years from 2000 to 2014 for these 31 Chinese provinces to re-estimate the models (1) and (2) with one-step system GMM method. The estimation results are shown in Tables 4 and 5.

Variable	(1)	(2)	(3)	(4)
	0.9711 ***	0.9556 ***	0.9761 ***	0.9596 ***
$\ln(PGP)$	(0.0070)	(0.0112)	(0.0064)	(0.0110)
lr(COA)	0.0521 ***	0.0409 **		
IR(COA)	(0.0100)	(0.0170)		
lm(OAD)			0.0498 ***	0.0316 *
III(OAD)			(0.0093)	(0.0173)
$\ln(\epsilon AV)$		0.0697 ***		0.0712 ***
$\operatorname{III}(3AV)$		(0.0160)		(0.0170)
$\ln(HM)$		-0.0215		-0.0189
		(0.0167)		(0.0174)
$\ln(FCF)$		0.0276 ***		0.0281 ***
$\operatorname{III}(I \subset I)$		(0.0105)		(0.0103)
$\ln(CF)$		0.0002		-0.0017
$\operatorname{III}(\operatorname{OI})$		(0.0112)		(0.0117)
$\ln(TRA)$		0.0085 *		0.0078 *
$\operatorname{III}(1X1)$		(0.0050)		(0.0047)
$\ln(POP)$		-0.0002		0.0001
$\operatorname{III}(I \otimes I)$		(0.0034)		(0.0035)
AR(1)	0.0000	0.0010	0.0000	0.0010
AR(2)	0.9160	0.1070	0.8280	0.0980
Hansen test	1.0000	1.0000	1.0000	1.0000
Number of instruments	120	100	120	100
N	434	434	434	434

Table 4. The impact of population ageing on economic growth.

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively; the values in parentheses are cluster-robust standard errors; N is the number of observations; the values corresponding to AR(1), AR(2) and Hansen test are *p*-values; in order to control the influence of time-varying factors on the estimated results, annual dummy variables are added to all regressions; however, the regression results of annual dummy variables and constant terms are not listed.

Variable	(1)	(2)	(3)	(4)
	0.9841 ***	0.9720 ***	0.9835 ***	0.9718 ***
$\operatorname{III}(PGP)$	(0.0053)	(0.0097)	(0.0061)	(0.0099)
$\ln(COA)$	0.3435 ***	0.2875 ***		
III(COA)	(0.1146)	(0.0819)		
$\ln(COA) \times \ln(ED)$	-0.0654 ***	-0.0543 ***		
$\operatorname{III}(\operatorname{COTI}) \times \operatorname{III}(\operatorname{ID})$	(0.0237)	(0.0167)		
$\ln(OAD)$			0.3231 ***	0.3335 ***
()			(0.1046)	(0.1204)
$\ln(OAD) \times \ln(FD)$			-0.0602 ***	-0.0633 **
	0 1000 **	0.0001 **	(0.0219)	(0.0248)
$\ln(FD)$	0.1202^{33}	0.0924^{44}	$0.11/4^{33}$	(0.1255^{**})
	(0.0311)	(0.0370)	(0.0409)	(0.0300)
$\ln(SAV)$		(0.0297 ***		(0.0323
		(0.0110) -0.0066		0.0059
$\ln(HM)$		(0.0155)		(0.003)
		0.0221 ***		0.0241 **
$\ln(FCF)$		(0.0083)		(0.0101)
		-0.0106		-0.0112
$\ln(GF)$		(0.0086)		(0.0099)
$l_{T}(TDA)$		0.0071		0.0074
$\operatorname{III}(T K A)$		(0.0045)		(0.0050)
$\ln(P \cap P)$		-0.0042		-0.0060
$\operatorname{III}(I \cup I)$		(0.0038)		(0.0045)
AR(1)	0.0010	0.0010	0.0000	0.0010
AR(2)	0.7390	0.1190	0.7460	0.1210
Hansen test	1.0000	1.0000	1.0000	1.0000
Number of instruments	174	124	122	128
Ν	434	434	434	434

Table 5. The impact of population ageing and financial deepening on economic growth.

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively; the values in parentheses are cluster-robust standard errors; N is the number of observations; the values corresponding to AR(1), AR(2) and Hansen test are *p*-values; in order to control the influence of time-varying factors on the estimated results, annual dummy variables are added to all regressions; however, the regression results of annual dummy variables and constant terms are not listed.

For Tables 4 and 5, the *p*-values of AR(1) are all less than 1%, while those of AR(2) are all more than 5% and those of the Hansen test are all more than 10%. This indicates that all the estimation results of Tables 4 and 5 are reliable.

Comparing Table 4 with Table 2 and comparing Table 5 with Table 3, we find that the sign and significance of the regression coefficients of all variables have almost unchanged. Therefore, all the regression results of Tables 2 and 3 are robust.

5. Conclusions

Based on a panel of 31 Chinese provinces from 2000 to 2016, we investigate the impacts of population ageing and financial deepening on economic growth by one-step system GMM estimation method. The empirical results show that as far as population ageing and financial deepening are concerned, both population ageing and financial deepening have played a significant role in boosting China's economic growth since entering the ageing society. Moreover, an increase in the natural logarithm of the indicators of population ageing by 1% could increase the natural logarithm of real GDP per capita by about 0.3%, while an increase in the natural logarithm of the financial deepening indicator by 1% could increase the natural logarithm.

The results also reveal that there are significant interactions between population ageing and financial deepening, however, such interactions have a significant negative correlation with economic growth. This indicates that such interactions have impede economic growth since entering the ageing

society and the implementation of financial deepening reform could not improve the impact of population ageing on China's economic growth.

Furthermore, the results reveal that from the perspective of total marginal effect, population ageing has boosted China's economic growth since entering the ageing society. However, the total marginal effect of population ageing on economic growth would decrease with the increase of financial deepening. And such total marginal effect would be negative when financial deepening is above a threshold level. This indicates that the beneficial effect of population ageing on economic growth has disappeared and population ageing would impede economic growth. Meanwhile, the total marginal effect of financial deepening on economic growth is negative and decreases with the increase of population ageing. It indicates that financial deepening has impeded China's economic growth since entering the ageing society and such inhibitory effect of financial deepening on economic growth would increase with population ageing.

In addition, the results of this paper could bring five important policy implications. First, in the context of population ageing, the level of financial deepening should be moderate, because both excessive and low levels of financial deepening would have adverse effects on economic growth. Second, while implementing financial deepening reforms, social security systems such as medical care and pensions should also be improved. This is because when the uncertainty of income and expenditure faced by people reduces, people's consumption and domestic demand would increase, leading to more enterprises invest effectively. Hence, population ageing and financial deepening both play an active role in the interactions between them. Third, measures such as strengthening basic education in rural and poor areas, promoting the sharing of social public resources and breaking the dual household registration system in urban and rural areas should be taken actively. The reason is that such measures could improve the situation of education opportunity inequality as well as reduce administrative barriers and institutional obstacles, resulting in human capital, government consumption and population all could exert a beneficial impact on economic growth. Fourth, savings level should be moderate. This is because that, on the one hand, low savings level would be harmful to economic growth in that savings have a significant positive impact on China's economic growth; on the other hand, high savings level means low level of consumption for people, therefore it would also be harmful to economic growth. Fifth, since both fixed capital investment and foreign trade in China have a significant positive impact on economic growth, measures such as further increasing fixed capital investment and promoting trade openness should be implemented actively.

Since our work is limited 31 provinces in mainland China, future research can include Hong Kong, Macao and Taiwan in the analysis to better understand the impact of population ageing and financial deepening on China's economic growth.

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