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Does low birth rate affect China's total factor productivity?

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ABSTRACT

This study uses the DEA-Malmquist method to measure total factor productivity by employing the provincial panel data from 1998 to 2017 in China and constructing a panel data model to test the relationship between birth rate and human capital and the influence of labour in different age groups on total factor productivity. It was found that the increase in the birth rate has a significantly negative effect on human capital accumulation, while the effect of the birth rate on human capital shows an inverted 'U' shape. That is, when birth rate decreases, human capital increases, and when birth rate increases, human capital decreases. Thus, too low or too high birth rates will reduce human capital. Ultimately, human capital accumulation will significantly promote the growth and decomposition of total factor productivity. The effect of the labour age structure on total factor productivity also shows an inverted 'U' shape. Labour between 40 and 49 years old contributes the most to the promotion of total factor productivity. Eventually, due to the low birth rates, the proportion of 50-59 years old will keep at high level. Therefore, total factor productivity will decline significantly.

1. Introduction

Recently, fertility has continued to decline in China, well below the global average. As the most populous country in the world, China has the lowest fertility rate. With the continued decline of fertility, the degree of aging is increasing, and subsequently labour supply will be affected, which will further affect future economic growth. According to the latest data released by the *National Bureau of Statistics*, the total number of births was 15.23 million in 2019, with a birth rate of 10.94‰, a mortality rate of 7.13‰, and a population growth rate of 3.81‰. In terms of age structure, the working-age population aged 16 to 59 was 897.29 million, accounting for 64.3% of the total population, and the working-age population aged 60 and over was 24.949 million, accounting for 17.9% of the total population, of whom 16.658 million were

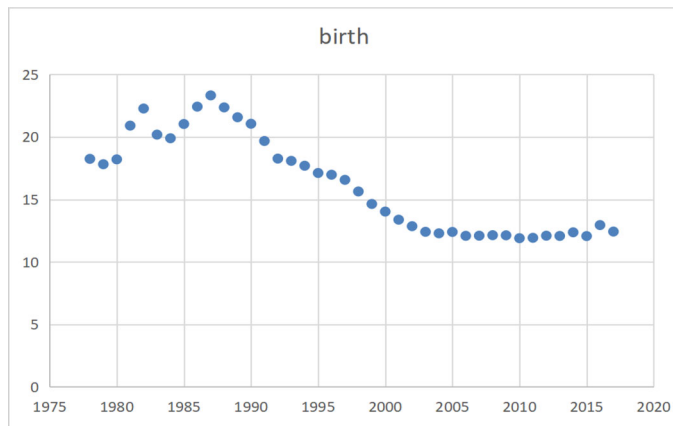CONTACT Xiang Zhao ✉ xzhao@hqu.edu.cn

Figure 1. The birth rate in China in 1978–2018.
Data source: World Bank database

aged 65 and over, accounting for 11.9% of the total population. According to these data (Figure 1), the birth rate in 2018 was the lowest since 1978, while the absolute number of workers fell for the first time. Although China has implemented a 'comprehensive two-child' policy to raise the birth rate, population growth is not as good as expected.

Judging from the demographic transition trajectory of developed economies, in the era of low birth rates, even with encouraging policies to increase birth rates, the current situation of low birth rate is difficult to change in the short term, and it is inevitable that China will enter an era of low birth rates. With changing Chinese generations, baby-boomer workers in the 1960s began to age and withdraw from the labour market, and in the 1980s, the 1990s, and 2000s those people born during the strict implementation of the family planning policy began to enter the labour market. The birth rate has declined greatly under the control of previous policies, leading to a decrease in the current working-age population in China. Moreover, with the improvement in medical technology, the elderly population has increased, and the demographic dividend to promote economic growth has gradually disappeared (Cai, 2011).

Population growth is not as dramatic as expected. But the total factor productivity (hereinafter TFP) is more noteworthy. Although there are no official statistics, the TFP growth rate has fallen to zero, or slightly above zero in China according to estimates by different economists. There are also many scholars who calculate the negative growth of TFP. Since TFP directly reflects a country's economic competitiveness, it is widely valued, especially since the new normal, when TFP was considered to be the core driver of economic growth. How to improve the current growth rate of China's TFP is a hot topic. Since TFP reflects an increase in output achieved through technological progress, more opinions are focused on how to further optimize resource allocation, increase capital mobility, and enhance technology research and development. We certainly need to focus on these areas, but we cannot ignore the natural resource endowments, the core that determines TFP. In addition to the

natural resource endowments, there are human resources, which not only are an element of output, but also can change the efficiency of the use of other inputs and outputs.

In the context of low birth rates, we are required to change the mode of traditional extensive economic growth and embark on the path of innovation-driven economic growth in China. The important role of TFP in the development of economic transformation should be considered. Therefore, there is an urgent need to study whether the low birth rate can promote the growth of TFP and how to improve TFP in China. Sustaining low birth rates can make a significant difference to human resource endowments. Under the circumstance that the increase in the labour market remains at a certain level, the younger the labourers entering the labour market, the higher the labour population growth rate, and the faster the increase in social innovation and TFP. Therefore, on the basis of maintaining a certain level of labour force growth, the general total factor growth rate has a positive relationship with the number of people entering the labour market each year. Many microscopic studies prove this. Usually, the 25-35-year-old workforce is the most productive and innovative. Thus, what is the impact of low birth rate on TFP? Is it suppression or promotion? This needs to be investigated carefully. To solve the above problems, it is helpful to understand the impact of low birth rate on economy, judge the changing trend of future economic growth potential, and provide the theoretical basis for the formulation of scientific and reasonable population policies.

This paper uses the DEA-Malmquist (DEA: data envelopment analysis) method to measure TFP by employing the provincial panel data from 1998 to 2017 in China and constructing a panel data model to test the relationship between birth rate and human capital and the influence of labour in different age groups on TFP. Considering the different degrees of economic development between different regions in China, this study analyses regression in different regions. This study contributes to the research linking fertility with the technical level and can further enrich the relevant empirical research.

The marginal contribution is as follows. First, this study enriches the existing literature. Second, starting with the low birth rate, we systematically investigate the relationship between the low birth rate and the total factor growth rate through studying human capital. In addition, based on the current status of population development in China, empirical research shows that not only the impact of the change in the birth rate on human capital has a significant inverted 'U' shape characteristic, but also the population transition has a hysteresis effect on the accumulation of human capital and it influences TFP.

2. Literature review

The current birth population through a generational shift will gradually grow into the future labour force and affect the future age structure of the working population. Low birth rate will reduce future labour supply, and the working-age population will gradually age. On the one hand, older labour tends to be less motivated, less responsive, and less sensual, thus reducing labour productivity (Shephard, 2000). On the

other hand, because the benefits of new technologies need time, the elderly labour takes on the responsibility of developing and applying new technologies, giving up leisure time, but being unable to reap the profits of new technologies in their lifetime. Thus, the elderly labour does not support development and the use of new technologies. As the aging process of the labour deepens, more and more people do not support development and the use of new technologies, which makes it difficult for new technologies to be used effectively and productivity is difficult to be increased significantly (Canton et al., 2002). Feyrer (2007) empirically studied the effect of the labour age structure on TFP in Organisation for Economic Co-operation and Development (OECD) countries in the same period. It was found that the age structure of the workforce has a significant impact on TFP and that the 40-49-year-old workforce contributes the most to TFP. In addition, some researchers (Skans, 2008) found a strong positive correlation between labour age and TFP or labour productivity. Huang et al. (2018) found that the implementation of comprehensive two-child policy will stimulate the long-standing fertility potential in the short term, increase fertility, and promote TFP. They found that multiple births will not only increase future labour supply and capital stock, but, more importantly, will also increase the growth rate of TFP.

In addition, low birth rate can also affect labour productivity by affecting human capital accumulation. Pecchenino and Pollard (2002) argued that a decline in the birth rate in the long-term demographic shift means population aging in the future, with the attendant increase in the burden of family pensions. Investment in educational resources for the younger generation will be squeezed, leading to a decline in investment in human capital. Miyazawa (2006) agreed that the declining birth rate would lead to deepening population aging. This has a negative impact on investment in human capital. Li and Xia (2014) believe that although the family planning policy controls the rapid growth of the population, it brings about demographic problems. The aging of young children will have a negative impact on future human capital and its stock.

However, some scholars argue that low birth rate can contribute to human capital accumulation. Kalemli-Ozcan et al. (2003) believe that the rise in the infant survival rate reduces the preventive needs of parents for their children and increases their motivation to invest in the education of their surviving children. There is a greater tendency to reduce the number of children to increase investment in the human capital. Chu et al. (2013) established a kumpeter growth model involving endogenous birth rate and human capital accumulation. The impact of birth rate on human capital accumulation was studied, and the increase in birth rate had a negative impact on the growth rate of human capital. Chen (2013) carried out an empirical analysis and found that the higher the human capital inequality, the higher the birth rate. High birth rate will have a reverse barrier effect on human capital accumulation, further aggravating the inequality in human capital between regions. Liu and Sun (2018) thought that the acceleration of the population aging process does not reduce families' investment in children's education and health human capital. The decline in birth rate will lead families to increase their investment in their children's education and health.

Some scholars also believe that there is a non-linear relationship between birth rate and human capital investment. For example, Boikos et al. (2013) found that with the increase in the birth rate, the level of per capita human capital investment will gradually increase, but when the birth rate reaches a certain high level, human capital investment will decrease. That is, there is an inverted 'U' shape relationship between birth rate and per capita investment in human capital. Li and Zhao (2019), based on the method of unidirectional causality, measure and analyse the long-term and short-term dynamic effects and the causality relationship between population aging and technological innovation in China. They found that population aging will eventually have a continuous long-term impact, although it has little effect on technology innovation in the short term, with the child dependency ratio having a remarkable unidirectional causal effect on technological innovation in the short term. Liu (2020) used the multiagent simulation technology, integrated the two-child policy into a complex model featuring population, resources, and economic growth, and found that it would be more economically advantageous to combine a two-child policy with a policy that promotes human capital growth.

Hypothesis 1: The birth rate will affect TFP by affecting human capital.

Regarding the influence of age composition and human capital on TFP, Ji and Lai (2015) found that improving human capital allocation efficiency is the best way to TFP growth. Paz and Bernardí (2020) thought that intangible capital (human capital) has a positive effect on companies' productivity as well as a spillover effect. Ilmakunnas et al. (2004) used matching data on Finnish manufacturing enterprises and workers to examine the impact of workers' personal characteristics on labour productivity. They found that factors such as education and work experience (length of service) had an important impact on the productivity of enterprises. Qu et al. (2019) used the Heckman maximum likelihood estimator and Topel two-step estimation methodology to correct sample selection bias and individual heterogeneity. They found that returns to experience are higher for men than women, especially for married men and women. Pan and Zhao (2020) suggest that the integration of the manufacturing industry and the Internet at the technical level has improved TFP. This is mainly achieved by optimizing the allocation of capital factors within the enterprise. In particular, workers in their 40 s contribute the most to the productivity of enterprises. Setiadi et al. (2020) thought the productivity effects of changes in education, work experience, and age of labor force is of paramount importance. And that the level of education has significant effects on labor productivity and the age composition of the labor force has a significant impact on productivity. Stephen and Shoaib (2020) thought that age and size significantly moderate the impact of slack time on innovation and that the age and size of firms efficiently moderate the slack-performance relationship to support the introduction of innovation.

Peng (2007) studied the effect of human capital on TFP in China and found that human capital at the level of primary education and average human capital have significantly negative effects on TFP. Zhao and Li (2020) used micro survey data and found that years of education, health status, and work experience have a significant effect on individual labour productivity. Sergio et al. (2019) thought that the CEO's educational profile in management is preferable to a pure technical background,

because it complements better the firm's knowledge and technological capabilities by facilitating the transformation of a scientific or technological project into a successful entrepreneurial innovation, which creates new value.

Hua (2005) measured the Malmquist Index of TFP and its two components (technological efficiency and technological progress) and investigated the extent to which human capital at different levels of education affected the three components. Liu et al. (2008), using the method of cointegration analysis, concluded that higher education is the reason for Granger's technological progress in China. Guo and Jia (2009) found that the educational resources of basic education are conducive to regional economic growth, while the impact of secondary vocational, technical, and higher education expenditure is vague. The promotion of a university enrolment policy is not significant. Grossman and Helpman (1993) demonstrate that the technological composition has an important impact on innovation activities. The increase in the number of high-skilled workers is conducive to technological innovation and has positive impact on economic growth, while the increase in the number of low-skilled workers has a negative impact on economic growth. Wu (2010) found that the tertiary educated human capital is negatively related to TFP. The reason may be inefficiency in allocation. Furthermore, Chen (2019) found that the misallocation of human capital reduces China's productivity significantly. Most importantly, we argue that the important channels through which the misallocation of human capital affects productivity are industrial structure upgrading, technological innovation, and labour productivity.

Hypothesis 2: The impact of human capital on TFP differs according to the workforce age structure.

With the acceleration of China's aging process, does low birth rate affect TFP? Is it a fiction effect or facilitation effect? This is worth investigating. However, there are few studies on the effects of birth rate on TFP, especially empirical studies. The literature on the impact of changes in the birth rate on human capital and thus on TFP is even rarer. Most studies are based on the age structure of the workforce. From the perspective of labour supply, there is little literature on how the birth rate is related to TFP and influences it. In general, the research objects of domestic and foreign literature are mostly developed countries in the West, especially OECD countries. Capital accumulation in developed countries has reached a very high level, and the contribution of labour to the economy is relatively low. Thus, the impact of birth rate changes in developed countries on TFP may not be as significant as China. The population growth rate of developed countries has gradually increased after the economic and social development to a certain extent, and the process is relatively slow. The implementation of the family planning policy has led to a rapid decline in the population growth rate in China. The aging process is much faster than that of the West. The conclusions of foreign literature do not necessarily apply to the reality in China, nor can they solve the actual economic problems. It is necessary to study the impact of low birth rate on TFP in view of the specific situation in China and try to make up for the shortcomings of domestic research in this field.

In view of the above, this paper measured TFP in China using the DEA-Malmquist method, constructed a measurement model to examine the effect of

different age groups of labour on TFP, and analysed the effect of low birth rate on TFP according to the changing trend of the age structure in China.

3. Empirical model, variable, and data

3.1. Theoretical

According to the Cobb-Douglas production function, the effect of human capital on TFP can be expressed as follows:

$$Y = K^{\alpha}(A\bar{H})^{1-\alpha} \tag{1}$$

In this equation, Y represents the total output, K represents physical capital stock, H represents human capital-enhanced labour, and A represents technological progress, which is used to represent technology innovation capability (TFP). Let $y = Y/L$ and $h = H/L$, and we can express the production formula (1) in per capita form:

$$\ln TFP = \ln A = \ln y - \frac{\alpha}{1-\alpha}\ln\frac{K}{Y} - \ln\bar{h} \tag{2}$$

The change in TFP is explained by assuming the time of A change, but this expression cannot distinguish which factor affects the change in TFP.

3.2. Measurement model

First, Kraay (2000) proposed a measurement model, and in order to study the impact of birth rate on human capital, the following panel data estimation equation is established:

$$HUM_{it} = \alpha_0 + \alpha_1 birth + \phi X_{it} + \mu_i + \varepsilon_{it} \tag{3}$$

In this equation, HUM stands for human capital, $birth$ stands for birth rate, and X stands for other control variables.

Second, in order to study the effect of human capital and labour age structure on TFP with low birth rate, the following empirical measurement model is constructed:

$$TFP_{it} = \alpha_0 + \sum_{j=1}^{3} \alpha_j LS_{it} + \beta_1 HUM + \phi X_{it} + \mu_i + v_{it} \tag{4}$$

Here, TFP stands for total factor productivity, LS stands for the proportion of labour force in all age groups, X stands for the control variables, μ_i stands for the individual non-observed effect, α、β for the parameters to be estimated, v_{it} for random disturbance, i、t representative province and period. In formula (2), we not only consider the impact of human capital on TFP, but also analyse the impact of different age groups of labour on TFP. This is important for further analysis of the birth rate of the population and its influence on TFP by affecting the age composition.

The control variables include the following. (a) Industrial structure: Due to the great differences in production technology and management, different industries have different TFP. Therefore, the industrial structure is an important factor affecting TFP. (b) Opening up: The degree of opening up to the outside world is also a major factor affecting TFP. On the one hand, foreign direct investment will bring advanced technologies and management concepts. The spillover effect of technology will also improve the level of technology and management in domestic enterprises. On the other hand, foreign investment and domestic enterprises participate in the international market. The law of the survival of the fittest in the market will force these enterprises to learn advanced production technology and management ideas and strive to occupy a place in the international market. (c) Urbanization: In the process of urbanization, production resources are further concentrated, and the effect of human capital accumulation is gradually emerging. The spillover effect based on the effect of knowledge aggregation can become the factor that promotes the increase in TFP. (d) Government intervention: Whether the government is a 'helping hand' or a 'grab hand' in the local economy plays a major role in economic development. (e) Infrastructure: It is an important material basis for the development of the national economy and a key factor in building regional comparative advantage and promoting productivity growth.

3.3. Variable selection and data description

3.3.1. TFP

This paper investigates the effect of human capital on TFP with low birth rate. Thus, accurate measurement of TFP is the key concept of research. This paper uses the DEA-Malmquist index method, a nonparametric estimation method based on the data network analysis method (DEA) developed in recent years. Compared with other TFP measurement methods, the DEA-Malmquist index method does not need to specify the form of production function, nor does it need to make corresponding assumptions about market competition and the distribution of inefficient items. Therefore, it can effectively avoid the measurement bias caused by the randomness of the model setting. Thus, we can get more robust measurement results. In addition, the Malmquist index can break down TFP into two parts of technological progress and efficiency improvements.

Specifically, in order to measure TFP in 31 provinces (autonomous regions and municipalities directly under the central government) in China between 1998 and 2017, the areas are considered as basic decision-making units. It is assumed that in a certain period of t ($t = 1998, 1999, \ldots, 2017$), the region of i ($i = 1, 2, \ldots, 31$) input is $x_{i,1}^{t} 、 x_{i,2}^{t}$, where $x_{i,1}^{t}$ represents the first factor input and $x_{i,2}^{t}$ represents the second factor input, and the output is y_{i}^{t}. Typically, under conditions of constant scale compensation (CRS) and the input element being strong and disposable (S), the Malmquist index calculates four distance functions. Under the technical conditions for a given period of t, the production functions of the periods t and $t + 1$, that is, $D_{0}^{t}(x^{t}, y^{t})$ and $D_{0}^{t}(x^{t+1}, y^{t+1})$, are calculated. Under the technical conditions for a given period of $t + 1$, the production functions of the periods t and $t + 1$, that is,

$D_0^{t+1}(x^t, y^t)$ and $D_0^{t+1}(x^{t+1}, y^{t+1})$, are calculated. Thus, the Malmquist TFP index for periods t and $t+1$ is

$$M_0^t(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \tag{5}$$

$$M_0^{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)} \tag{6}$$

The geometric average of the two Malmquist indices above is the Malmquist TFP index:

$$M_0(x^t, y^t, x^{t+1}, y^{t+1}) = \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \cdot \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)} \right]^{1/2} \tag{7}$$

Fare et al. (1994) changed the Malmquist index to the full factor productivity index:

$$\begin{aligned}
& M_0(x^t, y^t, x^{t+1}, y^{t+1}) \\
&= \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \left[\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \cdot \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \right]^{1/2} \\
&= TEC(CRS) \times TC(CRS)
\end{aligned} \tag{8}$$

TC represents technical improvements, TEC represents comprehensive efficiency improvements, and CRS represents the same size compensation. Thus, the formula shows that the change in TFP can be divided into two parts: one is improvement in technology and the other is improvement in efficiency.

Using the DEA-Malmquist method to measure TFP, input and output data are required. The regional capital stock and the amount of labour are selected as inputs and regional GDP is selected as output. Labour input is the total number of employees in each province (autonomous region and municipality) at the end of the year, while the regional capital stock does not have readily available statistics and needs to be estimated. The most commonly used estimate of the capital stock is the 'sustainable inventory' proposed by Goldsmith in 1951. Zhang et al. (2004) estimates of capital stock have been recognized and used by the vast majority of scholars. This study also refers to this method to estimate the capital stock of various regions. Specifically, to estimate the capital stock, four variables need to be determined: the amount of investment in the calendar year, the total amount of capital formation in the calendar year as the investment flow, the fixed asset investment price index, and the investment flow into constant price value, mainly using the various provinces' fixed asset investment price index. The lack of regional fixed asset investment price index before 1995 can be estimated according to Zhang et al. (2004) method. The capital stock of the base period, the year 1978 being selected as the base period, is provided by Zhang et al. (2004). Capital depreciation rate: It is assumed that the average life of buildings and equipment is 40 and 20 years, respectively, and the average

life of other fixed assets is 25 years. Thus, the annual depreciation rates of the three are 6.9%, 14.9%, and 12.1%, as a weighting of various types of capital investment (63% for construction and installation works, 29% for equipment, and 8% for other expenses), and the annual depreciation rate of 9.6% is calculated for each province (autonomous region and municipality).

3.4. Core variables

In demography, labour is a collective concept, and anyone with the ability to work, regardless of age, is called labour. However, the labour population is not equivalent to the working-age population, and all those aged between 16 and 64 years of age, whether they are able to work or not, fall into the category of the working-age population. Labour has a large mobility, and it is difficult to consider both the employed population in the working age and the employed population in the non-working age. In contrast, the working-age population is not easily affected by economic and social changes. Therefore, the concern of this paper is the aging of the working-age population, not the aging of the labour population. Human capital usually includes education and health, given that the average health level of the labour does not change significantly in the short term and that data are feasible. This study measures the human capital indicator using the ratio of education, specifically, the labour's average years of education. It is calculated on the basis of 6 years of primary school, 9 years of junior high school, 12 years of high school, and 16 years of college and above. That is, $Hum = 6L_1 + 9L_2 + 12L_3 + 16L_4$, where L_i (i=1, 2, 3, 4) indicates the number of educated people in the labour with primary, middle, high, tertiary, and higher education.

The education of the population statistics can be calculated according to the China Statistical Yearbook in the past years. The industrial structure is the proportion of the tertiary industry (indstr) and the value added of the tertiary industry as a proportion of GDP. Government intervention (fiscal) is the proportion of fiscal expenditures on GDP, while urbanization (urb) is the ratio of the urban population to the total population. The level of infrastructure (hmile) is measured by the number of miles (km/km2) of transport roads per unit of land area. Infrastructure is an important material basis for the development of national economy and a key factor to build regional comparative advantage and promote productivity growth. Old-age dependency ratio (or) is measured by the ratio of the population over the age of 65 to the working-age population aged 15-64. Per capita disposable income (lninc) is used to measure the living standards of residents in a region. The National Bureau of Statistics conducted a survey on the incomes, expenditures, and living conditions of urban-rural integrated households after 2013. Before 2013, the survey was divided into urban and rural households. Error and logarithmic processing: Urban-rural gap (gap) is measured by the ratio of urban per capita disposable income to rural per capita net income.

Sample data were collected on the regional gross domestic product and the number of people employed at the end of the year in 31 provinces, and the original data for calculating the capital stock are derived from the Historical Data on China's GROSS Domestic Product Accounting (1952–1995), the New China 60 Years of

Table 1. Descriptive statistics for variables.

Variables	Obs	Mean	Std. Dev.	Min	Max
birth	620	11.83	3.29	4.28	23.9
gro	620	5.777	3.26	3.24	16
cr	620	26.569	8.39	9.64	57.78
nedu	620	8.21	1.32	2.95	12.5
workpop	620	0.72	0.04	0.61	0.84
or	620	12.13	2.77	6.13	21.89
lninc	620	9.07	0.75	7.61	10.99
gap	620	2.89	0.65	0.94	5.60
indstr	620	0.37	0.10	0.07	0.53
urb	620	0.43	0.19	0.06	0.9
hmile	620	1.02	1.16	0.08	6.9
fiscal	620	5.27	3.41	1.01	28.56

Source: the Historical Data on China's GROSS Domestic Product Accounting (1952–1995), the New China 60 Years of Statistics Compilation, and the Yearbook of Statistics of China.

Statistics Compilation, and the Yearbook of Statistics of China in previous years. The calculation of TFP growth and decomposition is done using DEAP2.1 software.

Table 1 shows the descriptive statistical results of the sample data used in this paper. According to these results, the birth rate has reached an average level (11.83‰). The average number of years of education is 8.21, which is very close to the level of nine-year compulsory education. It shows that the implementation effect of the compulsory education system is obvious in China. The proportion of the working-age population (workpop) is 72%.

4. Empirical analysis

4.1. Birth rate and human capital

This paper analyses the relationship between birth rate and human capital accumulation. According to the results of the Hausman test, the statistical values of 90.16 and 595.96 both reject random effects at the 5% significance level. Therefore, of the random effect model and the fixed effect model, the latter is selected for estimation. Furthermore, due to the large time dimension of panel data, the results of the random disturbance form test analysis show that the Wald test and Wooldridge test correspond to a P-value of 0.000. So we can reject the original assumption of the homogenous variance between groups and the original hypothesis of no autocorrelation problem in the non-order group. The P-value corresponding to the Pesaran, Friedman, and Free tests is less than 0.01, and this disproves the original assumption of the cross-sectional correlation between groups. Based on the above, it may be biased to choose the fixed effect model directly for regression, and the FGLS can overcome the bias problem to some extent. Therefore, the level of human capital accumulation and its related explanatory variables are investigated using FGLS estimation, and the fixed effect model and random effect model are included in Table 2 as a reference.

Among the models presented in Table 2, Model (4)-Model (6) are based on Model (1)-Model (3), adding the square of the birth rate. According to Table 2, the coefficient of the birth rate is significantly negative. That is, the increase in the birth rate has a significantly negative impact on human capital accumulation. In Model (3), when the birth rate decreases, the corresponding level of investment in human capital

Table 2. Estimated impact of birth rate on human capital.

Variables	RE Model (1)	FE Model (2)	FGLS Model (3)	RE Model (4)	FE Model (5)	FGLS Model (6)
birth	−0.070***	−0.041***	−0.093***	0.091***	0.114***	0.073***
	(0.008)	(0.013)	(0.003)	(0.030)	(0.037)	(0.007)
birth2				−0.006***	−0.006***	−0.007***
				(0.001)	(0.001)	(0.0003)
or	−0.008	−0.007	−0.042***	−0.001	0.0002	−0.045***
	(0.008)	(0.014)	(0.003)	(0.008)	(0.017)	(0.002)
lninc	0.936***	0.919***	0.818***	1.000***	0.997***	0.751***
	(0.055)	(0.076)	(0.017)	(0.055)	(0.083)	(0.018)
indstr	0.008***	0.007*	0.014***	0.006**	0.004	0.018***
	(0.003)	(0.004)	(0.001)	(0.003)	(0.004)	(0.001)
hmile	−0.001	−0.022	0.155***	0.0255	0.126***	−0.103***
	(0.022)	(0.016)	(0.005)	(0.031)	(0.037)	(0.010)
gap	0.019	0.126***	−0.092***	0.002	−0.002	0.018***
	(0.031)	(0.040)	(0.012)	(0.002)	(0.003)	(0.001)
urb	0.003	0.0001	0.016***	−0.008	−0.028	0.162***
	(0.002)	(0.003)	(0.001)	(0.021)	(0.017)	(0.004)
fiscal	−0.026***	0.024*	−0.129***	−0.044***	0.001	−0.131***
	(0.010)	(0.012)	(0.003)	(0.010)	(0.013)	(0.003)
Constant	0.236	−0.328	1.893***	−1.180**	−1.756**	1.417***
	(0.404)	(0.576)	(0.127)	(0.465)	(0.707)	(0.167)
Observations	620	620	620	620	620	620
Adjusted R^2	0.872	0.878		0.879	0.885	
F-value		270.89			385.91	
Wald test	3644.43		25309.55	3881.90		39034.18
Hausman test	chi2 = 90.16			chi2(9) =595.96		
	Prob > chi2 = 0.0000			Prob > chi2 = 0.0000		

Note: The standard deviation of each coefficient is shown in parentheses, representing the significant levels of 1%, 5%, and 10%, respectively.
Source: the Historical Data on China's GROSS Domestic Product Accounting (1952–1995), the New China 60 Years of Statistics Compilation, and the Yearbook of Statistics of China.

increases. This can be explained by Becker's 'quantity-quality' substitution theory. When the number of families giving birth increases, the level of investment in human capital for each child decreases under the constraints of limited resources (Becker et al., 1990). That is to say, when the birth rate decreases, human capital investment increases and the improvement in population quality will make up for the decrease in the population to some extent (Yang & Zhang, 2019). According to Model (6), the coefficient of the birth rate is 0.073, while the secondary coefficient of the birth rate is significantly negative. The effect of the change in the birth rate on human capital shows the inverted 'U' shape. As the birth rate increases, human capital decreases. Thus, too low or too high birth rates will reduce the human capital accumulation.

The effect of the dependency ratio of the elderly population on education is significantly negative, and the coefficients in Models (3) and (6) are, respectively, −0.042 and −0.045. The deepening of the aging process will adversely affect the improvement in human capital investment. The coefficients of influence of per capita disposable income on education are 0.818 and 0.751, respectively. The increase in per capita disposable income is conducive to the improvement in human capital investment. This result is consistent with the fact that when the income of the household increases, this means that the resources available to the family for their children's education will increase as well as the investment in human capital for each child. Consistent with many studies, the coefficients of influence of industrial structure and infrastructure construction are significantly positive. This shows that the more

Table 3. The lag effect of birth rate on human capital.

Variables	Total Model (1)	East Model (2)	Central Model (3)	West Model (4)
birth	−0.011*	−0.030***	−0.005	0.018
	(0.006)	(0.011)	(0.022)	(0.018)
L.birth	−0.089***	−0.059***	−0.028	−0.120***
	(0.006)	(0.011)	(0.022)	(0.018)
or	−0.047***	0.005	−0.100***	−0.069***
	(0.002)	(0.005)	(0.012)	(0.007)
lninc	0.789***	0.086**	1.114***	1.351***
	(0.027)	(0.043)	(0.113)	(0.071)
indstr	0.016***	0.038***	0.017***	−0.013***
	(0.001)	(0.002)	(0.002)	(0.003)
hmile	0.170***	0.027**	0.016	0.136***
	(0.004)	(0.013)	(0.050)	(0.010)
gap	−0.088***	0.0195	0.200***	−0.041
	(0.013)	(0.024)	(0.048)	(0.030)
urb	0.015***	0.0220***	0.006*	0.002
	(0.001)	(0.002)	(0.003)	(0.002)
fiscal	−0.133***	0.123***	−0.075***	−0.159***
	(0.003)	(0.014)	(0.025)	(0.007)
Constant	2.290***	5.500***	−1.099	−0.630
	(0.254)	(0.310)	(0.860)	(0.615)
Observations	620	620	620	620
Wald test	954.89	889.71	879.74	673.20

Note: The standard deviation of each coefficient is shown in parentheses, representing the significant levels of 1%, 5%, and 10%, respectively.
Source: the Historical Data on China's GROSS Domestic Product Accounting (1952–1995), the New China 60 Years of Statistics Compilation, and the Yearbook of Statistics of China.

reasonable the economic development structure, the more beneficial it is in improving human capital. The influence of the coefficient of the urban-rural income gap is significantly negative, while the influence of the coefficient of the urbanization rate is significantly positive. The reduction of the urban-rural income gap and the improvement in the urbanization rate are conducive to the improvement in human capital.

In addition, the impact factor of fiscal expenditure is significantly negative. This is due to the fact that, first, the scope of the indicator is related to investment in educational human capital, which covers science and technology, education, culture, and health. Second, education is improved in China. In addition to government support, it still depends on family investment to a greater extent. Therefore, the impact of family income and the amount of financial expenditure on science, education, culture, and health shows that the effect of improving the investment of family education on improving the human capital is more obvious than government.

In the analysis of the impact of birth rate on human capital, we consider the changes in the burden of dependency brought by changes in the birth rate. This may show the impact of different mechanisms on human capital at different stages. Therefore, we further analyse the lag effect of the birth rate on human capital, which also helps to reduce the endogenous effect of the regression model. The relevant regression results estimated using FGLS are shown in Table 3.

Considering the lag effect of the birth rate, the birth rate (L.birth) coefficient of the late one period remains significantly negative. The level of human capital is affected not only by the current birth rate, but also by the lag effect of the birth rate in the early period. Considering the different degrees of economic development

between different regions in China, this study analyses regression in the east, central, and western regions in Model (2)-Model (4). On the one hand, there are regional differences in the impact of lower birth rate on human capital. On the other hand, further robustness analysis of the previous results can be carried out. By comparison, it can be found that the effect of the change in the birth rate on human capital is greatest in the western region.

4.2. Human capital, labour supply, and TFP

Table 4 reports the regression results of human capital and labour supply affecting TFP, technological progress, and efficiency improvement. In order to reduce heterogeneity in Models (2), (4), and (6), the labour age structure is divided into age groups. Defined as the proportion of the total labour in each age group, the population aged 20-59 is divided into four groups by age, namely, the 20-29, 30-39, 40-49, and 50-59 age groups, referred to as W20_29, W30_39, W40_ 49, and W50_59. The three variables W20_29, W30_39, and W50_59 are referenced by W40_49. If the parameters of the above three variables are negative, the contribution of the three variables to TFP is less than W40_49.

First, Table 4 shows that the effect of education on TFP growth and decomposition is significantly positive, except for Model (5). It indicates that the improvement in human capital has positive effect on TFP growth. Under other conditions, human capital can promote the growth and decomposition of TFP significantly. On the one hand, human capital accumulation will promote the growth and decomposition of TFP directly. On the other hand, it is conducive to industrial structure adjustment and transformation and promotes the growth and decomposition of TFP indirectly. Usually, human capital influences TFP in two ways: one is technological innovation

Table 4. Regression results of human capital and labour supply for total factor productivity and technological and efficiency improvements.

Variables	Total factor productivity		Technological progress		Efficiency improvements	
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
nedu	0.242***	0.303***	0.257***	0.503*	0.019	0.032*
	(0.062)	(0.016)	(0.055)	(0.254)	(0.018)	(0.017)
workpop	−1.777*		−2.692***		0.619	
	(1.032)		(0.900)		(0.382)	
W20_29		−0.325***		−0.222**		−0.256**
		(0.124)		(0.120)		(0.106)
W30_39		−0.244**		−0.134**		−0.197*
		(0.130)		(0.058)		(0.110)
W50_59		−0.148*		−0.068*		−0.043*
		(0.086)		(0.053)		(0.038)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.803	2.415***	1.356***	6.120*	0.587***	1.696*
	(0.516)	(1.316)	(0.401)	(3.353)	(0.205)	(1.017)
Observations	620	620	620	620	620	620
R-squared	0.426	0.701	0.427	0.780	0.413	0.775
F-value	2.95**	3.01***	4.73***	22.01***	2.94**	1.57*

Note: The values in brackets in the table are the heterogenous robust criteria errors, and the regression results are significant at the confidence levels of 1%, 5%, and 10%, respectively.
Source: the Historical Data on China's GROSS Domestic Product Accounting (1952–1995), the New China 60 Years of Statistics Compilation, and the Yearbook of Statistics of China.

and the other is technological imitation. Under the condition of low birth rate, it is beneficial to promote the improvement in human capital, optimize the overall allocation of resources, and promote the improvement in TFP. Second, compared with the labour in the 40-49 age group, the regression coefficient of other age groups for the growth and decomposition of TFP is negative. This indicates that the labour in the 40-49 age group has the greatest impact on the growth and decomposition of TFP. Moreover, the effect of the labour in the 50-59 age group on the growth and decomposition of TFP is less than that of the labour in the 40-49 age group, but greater than that of the labour in the 20-29 and 30-39 age groups. Moreover, the effect of the labour in the 30-39 age group on the growth and decomposition of TFP is greater than that of the 20-29 age group. Therefore, the effect of the labour age structure on TFP growth and decomposition is expressed as an inverted 'U' shape relationship, consistent with the results of Feyrer (2007).

Opening up to the outside world can strengthen communication with the outside world. Learning the technology of foreign production and introducing foreign advanced equipment can contribute to the growth of TFP and improvement in decomposition. Increasing the proportion of the tertiary industry will significantly promote the growth and decomposition of TFP, while increasing the proportion of the secondary industry will inhibit the growth and efficiency improvement of TFP. This may be due to the unreasonable production structure of the secondary industry in China. The influence of the labour age structure on the growth and decomposition of TFP is quite different in the secondary and tertiary industries. The acceleration of the urbanization process will significantly improve technological progress, while government intervention will significantly inhibit improvement in efficiency.

4.3. Robustness analysis

The impact of the change in the birth rate on human capital is gradually manifested through demographic transition. Survival rate has to be considered when the

Table 5. Estimated impact of population growth rate and child dependency ratio on human capital.

Variables	RE Model (1)	FE Model (2)	FGLS Model (3)	RE Model (4)	FE Model (5)	FGLS Model (6)
gro	−0.065***	−0.032**	−0.088***			
	(0.009)	(0.014)	(0.002)			
cr				−0.046***	−0.038***	−0.038***
				(0.004)	(0.006)	(0.001)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−0.060	−0.543	1.444***	2.593***	1.846**	3.692***
	(0.407)	(0.565)	(0.130)	(0.449)	(0.711)	(0.187)
Observations	620	620	620	620	620	620
Adjusted R^2	0.869	0.876		0.889	0.893	
F-value		263.75			283.92	
Wald test	3502.66		7459.59	4196.12		10626.71
Hausman test	chi2 = 112.24			chi2 = 111.77		
	Prob > chi2 = 0.000			Prob > chi2 = 0.0000		

Note: The relevant control variables are the same as Table 2. The standard deviation of each coefficient is shown in parentheses, representing the significant levels of 1%, 5%, and 10%, respectively.
Source: the Historical Data on China's GROSS Domestic Product Accounting (1952–1995), the New China 60 Years of Statistics Compilation, and the Yearbook of Statistics of China.

Table 6. The lag effect of population growth rate and child dependency ratio on human capital.

Variables	Total Model (1)	East Model (2)	Central Model (3)	West Model (4)	Total Model (5)	East Model (6)	Central Model (7)	West Model (8)
gro	−0.030***	−0.035***	−0.043*	0.065***				
	(0.007)	(0.013)	(0.024)	(0.019)				
L.gro	−0.057***	−0.052***	0.011	−0.135***				
	(0.007)	(0.013)	(0.024)	(0.019)				
cr					−0.043***	−0.019***	−0.033***	−0.053***
					(0.002)	(0.005)	(0.009)	(0.007)
L.cr					0.006**	−0.020***	0.009	0.018***
					(0.002)	(0.005)	(0.009)	(0.007)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.762***	4.798***	−1.640*	−1.341**	3.750***	7.008***	0.186	0.625
	(0.184)	(0.286)	(0.877)	(0.574)	(0.168)	(0.357)	(0.823)	(0.502)
Observations	620	620	620	620	620	620	620	620
Wald test	8210.26	7136.74	778.81	2903.94	8827.58	7186.76	713.01	1789.90

Note: The relevant control variables are the same as Table 3. The standard deviation of each coefficient is shown in parentheses, representing the significant levels of 1%, 5%, and 10%, respectively.
Source: the Historical Data on China's GROSS Domestic Product Accounting (1952–1995), the New China 60 Years of Statistics Compilation, and the Yearbook of Statistics of China.

population gradually grows from birth to labour force. Therefore, in order to obtain a more robust estimation result, this study further uses the child dependency ratio that takes into account the population mortality rate and the intergenerational transition of the population as a substitute variable for the birth rate and re-estimates the influence of the substitute variable on human capital. The estimated results are listed in Table 5.

According to the estimated results in Table 5, the influence of the coefficient of the population growth rate and child dependency ratio on the average years of education is significantly negative. That is, the increase in population fertility has a significantly negative impact on human capital accumulation. This conclusion is basically consistent with the data presented in Table 2.

Similarly, this study further considers the lag effect of the birth rate. Table 6 lists the lag effects of the substitute variables of the population growth rate and child dependency ratio on human capital. According to the regression results in Table 6, after considering the lag effect of low fertility rate, Models (1) and (5) show that the coefficients of the population growth rate (gro) and child dependency ratio (bir) are significantly negative, while the lag effect of the child dependency ratio (L.cr) in the first period is significantly positive. As the birth rate continues to decline, the number of children and the elderly continues to increase through generational changes, which makes the working-age population gradually decrease and the structure of labour supply gradually older. Under these circumstances, the government can only increase investment in education, especially in higher education, to improve the human capital level of the current and future labour and alleviate the predicament of insufficient labour supply. In other words, the level of human capital will be affected not only by the level of the current birth rate, but also by the lag effect of the previous level.

Simultaneously, through comparison, it can be found that in Model (1) in Table 3 and Model (1) in Table 5, the absolute value of the lag period coefficient is greater than the absolute value of the original sequence coefficient. Therefore, with the advancement of demographic transition, there is still a strong lag effect of low birth rate on the improvement in human capital. This result confirms the previous empirical results. In addition,

by comparing the estimation results of different regions, it can be concluded that the effect of changes in the birth rate on human capital is the highest in the western region.

5. Conclusions

This paper uses the DEA-Malmquist method to measure the growth and decomposition of TFP and empirically analyses the effect of human capital and labour age structure on the growth and decomposition of TFP with low birth rate.

The increase in the birth rate has a significantly negative impact on human capital accumulation, but the reality is that the birth rate is currently low in China and the burden of child support is gradually reduced. When the birth rate falls, human capital investment will rise. The improvement in the population quality to a certain extent make ups for the decline in the number of population. Moreover, the effect of the change in the birth rate on human capital shows an inverted 'U' shape. That is, when the birth rate decreases, human capital increases, but when the birth rate increases, human capital decreases. Thus, too low or too high birth rates will reduce the impact of human capital accumulation.

Considering the lag effect of the birth rate, human capital will be affected not only by the current period, but also by the lag effect of the birth rate in the early period. On the one hand, there are regional differences in the impact of low birth rate on human capital. On the other hand, further robustness analysis of the previous results can be carried out. By comparison, it can be found that the effect of the birth rate on human capital is greatest in the western region.

Human capital accumulation will significantly promote the growth and decomposition of TFP directly, and it is conducive to industrial structure adjustment and transformation. Moreover, it promotes the growth and decomposition of TFP indirectly. In the face of an aging population and the sharp decline in labour in the future, improving the quality of labour, vigorously developing education, and strengthening human capital accumulation can reduce or eliminate the impact of the aging of labour and the reduction of the number of labour products on economic growth and labour productivity.

The influence of the labour age structure on TFP growth and decomposition is shown as an inverted 'U' shape. Labour in the 40-49 age group has the greatest influence on the growth and decomposition of TFP. At present, the proportion of labour in the 40-49 age group is much higher than that of labour in the 50-59 age group, and the inhibition effect of the labour age structure on the growth and decomposition of TFP is not significant. Delaying retirement is a response in the face of the negative effects of an aging population and the rapid decline in the workforce in the next few decades.

6. Suggestions

According to this study, it is necessary to achieve high-quality economic and social development in our country. We should promote the transformation of human resources to human capital and realize the transformation of the economic growth mode. We make the following suggestions. First, we should increase investment in

education, adjust the educational structure, improve the quality of higher education, vigorously develop vocational education, improve the population's skills and experience, and attach importance to the cultivation of innovative talents, so as to finally realize the substitution of labour quality for quantity. Second, physical fitness is the most basic condition not only for judging whether workers can enter the labour market, but also for realizing the substitution of labour quality for quantity. Therefore, the government should pay more attention to investment in health while increasing investment in education. Third, from the perspective of maintaining the quality of childbirth, proper birth spacing is desirable.

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References

Becker, G. S., Murphy, K. M., & Tamura, R. (1990). Human capital, fertility, and economic growth. *Journal of Political Economy*, *98*(5), S12– 37. https://doi.org/10.1086/261723

Boikos, S., Bucci, A., & Stengos, T. (2013). Non-monotonicity of fertility in human capital accumulation and economic growth. *Journal of Macroeconomics*, *38*(part A), 44–59. https://doi.org/10.1016/j.jmacro.2013.06.006

Cai, F. (2011). How long China's demographic dividend will last. *Economic Perspectives*, *52*(6), 3–7. doi:CNKI:SUN:JJXD.0.2011-06-002.

Canton, E. J. F., De Groot, H. L. F., & Nahuis, R. (2002). Vested interests, Population ageing and technology adoption. *European Journal of Political Economy*, *18*(4), 631–652. https://doi.org/10.1016/S0176-2680(02)00112-X

Chen, G. H. (2013). Human capital inequality and birth rate mechanism of human capital investment—Analysis based on panel data parallel equation model. *Economic Problems*, *35*(8), 23–27. doi:CNKI:SUN:JJWT.0. 2013-08-006.

Chen, Y. A. (2019). Misallocation of human capital and productivity: Evidence from China. *Economic Research-Ekonomska Istrazivanja*, *32*(01), 3348–3365. https://doi.org/10.1080/1331677X.2019.1663546

Chu, A. C., Cozzi, G., & Liao, C. H. (2013). Endogenous fertility and human capital in a Schumpeterian growth model. *Journal of Population Economics*, *26*(1), 181–202. https://doi.org/10.1007/s00148-012-0433-9

Fare, R., Grosskopf, S., & Norris, M. (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *American Economic Review*, *84*(1), 66–83. https://www.jstor.org/stable/2117971.

Feyrer, J. (2007). Demographics and productivity. *Review of Economics and Statistics*, *89*(1), 100–109. https://doi.org/10.2139/ssrn.325365

Grossman, G. M., & Helpman, E. (1993). Innovation and growth in a global economy. *Mit Press Books*, *1*(02), 323–324. https://doi.org/10.2307/2554862

Guo, Q. W., & Jia, J. X. (2009). Public education policy, economic growth and human capital premium. *Economic Research Journal*, *55*(10), 23–36. doi:CNKI:SUN:JJYJ.0.2009-10-003.

Hua, P. (2005). Impact of different educational levels on total factor productivity growth—Empirical study from Chinese provinces. *China Economic Quarterly*, 5(01), 151–170. doi: CNKI:SUN:JJXU.0.2005-04-005.

Huang, Q., Ma, T. M., & Wang, W. (2018). Analysis of China's future TFP and GDP trends under the comprehensive two-child policy. *Statistics & Decision*, 34(09), 112–116. https://doi.org/10.13546/j.cnki.tjyjc.2018.09.026

Ilmakunnas, P., Maliranta, M., & Vainiomaki, J. (2004). The roles of employer and employee characteristics for plant productivity. *Journal of Productivity Analysis*, 21(3), 249–276. https://doi.org/10.1023/B:PROD.0000022093.59352.5e

Ji, W. W., & Lai, D. S. (2015). Human capital, allocation efficiency and total factor productivity growth. *Research on Economics and Management*, 36(06), 45–55. https://doi.org/10.13502/j.cnki.issn1000-7636.2015.06.007

Kalemli-Ozcan, S., Sørensen, B. E., & Yosha, O. (2003). Risk sharing and industrial specialization: Regional and international evidence. *American Economic Review*, 93(3), 903–918. https://doi.org/10.1257/000282803322157151

Kraay, A. (2000). Household saving in China. *The World Bank Economic Review*, 14(3), 545–570. https://doi.org/10.1093/wber/14.3.545

Li, J. X., & Xia, C. C. (2014). Population birth rate policy needs to be completely and thoroughly reformed—Analysis based on human capital and innovation ability. *Exploration and Free Views*, 30(6), 11–15. https://doi.org/10.3969/j.issn.1004-2229.2014.06.002

Li, X., & Zhao, X. D. (2019). Interaction between population aging and technological innovation: A Chinese case study. *Journal of Advanced Computational Intelligence and Intelligent Informatics*, 23(6), 971–979. https://doi.org/10.20965/jaciii.2019.p0971

Liu, J. G., & Sun, Q. Y. (2018). Population aging, birth rate and human capital investment: Empirical analysis based on generational overlapping model and China provincial panel data. *Northwest Population Journal*, 39(04), 34–43. https://doi.org/10.15884/j.cnki.issn1007-0672.2018.04.005

Liu, Y. (2020). Aging and economic growth: Is there a role for a two-child policy in China? *Economic Research-Ekonomska Istraživanja*, 33(1), 438–455. https://doi.org/10.1080/1331677X.2019.1699436

Liu, Z. Y., Hu, Y. Y., & Yi, X. Z. (2008). The mechanism test of the role of heterogeneous human capital to economic growth. *The Journal of Quantitative & Technical Economics*, 25(04), 86–96. https://doi.org/10.3969/j.issn.1000-3894.2008.04.008

Miyazawa, K. (2006). Growth and inequality: A demographic explanation. *Journal of Population Economics*, 19(3), 559–578. https://doi.org/10.1007/s00148-005-0047-6

Pan, M. M., & Zhao, Y. L. (2020). Internet convergence, labor structure, and total factor productivity in manufacturing. *Studies in Science of Science*, 38(12), 2171–2182. https://doi.org/10.16192/j.cnki.1003-2053.2020.12.007

Paz, R., & Bernardí, C. B. (2020). Intangible capital and business productivity. *Economic Research-Ekonomska Istrazivanja*, 33(01), 3034–3048. https://doi.org/10.1080/1331677X.2019.1699139

Pecchenino, R. A., & Pollard, P. S. (2002). Dependent children and aged parents: Funding education and social security in an aging economy. *Journal of Macroeconomics*, 24(2), 145–169. https://doi.org/10.1016/S0164-0704(02)00024-1

Peng, G. H. (2007). Total factor productivity and composition of human capital in China. *China Industrial Economics*, 25(02), 52–59. https://doi.org/10.1016/j.cyto.2007.07.152

Qu, D., Guo, S. S., & Wang, L. F. (2019). Experience, tenure and gender wage difference: Evidence from China. *Economic Research-Ekonomska Istraživanja*, 32(1), 1169–1184. https://doi.org/10.1080/1331677X.2019.1592695

Sergio, C. H., Jose, A., & Tomas, G. C. (2019). How technology-based firms become also highly innovative firms? The role of knowledge, technological and managerial capabilities, and entrepreneurs' background. *Journal of Innovation & Knowledge*, 4(03), 162–170. https://doi.org/10.1016/j.jik.2018.12.001

Setiadi, P. B., Ursula, R., Ti, R., & Setini, M. (2020). Labour productivity, Work experience, Age and education: The case of lurik weaving industry in Klaten, Indonesia. *Webology*, *17*(2), 487–502. https://doi.org/10.14704/WEB/V17I2/WEB17047

Shephard, R. J. (2000). Aging and productivity: Some physiological issues. *International Journal of Industrial Ergonomics*, *25*(5), 535–545. https://doi.org/10.1016/S0169-8141(99)00036-0

Skans, O. N. (2008). How does the age structure affect regional productivity? *Applied Economics Letters*, *15*(10), 787–790. https://doi.org/10.1080/13504850600749123

Stephen, K. M., & Shoaib, A. B. (2020). Product innovation and employees' slack time: The moderating role of firm age & size. *Journal of Innovation & Knowledge*, *5*(3), 151–174. https://doi.org/10.1016/j.jik2019. 11.001.

Wu, J. X. (2010). Knowledge diffusion, human capital composition and total factor productivity: A research based on Chinese provincial data. *Journal of Huizhou University (Social Science Edition)*, *30*(2), 60–65. https://doi.org/10.16778/j.cnki1671-5934.2010.02.012.

Yang, H. L., & Zhang, W. C. (2019). Fertility dividends, fertility desire and fertility support. *Shanghai Economic Research*, *38*(7), 57–69. https://doi.org/10.19626/j.cnki.cn31-1163/f.2019.07.006

Zhang, J. A., Wu, G. A., & Zhang, J. (2004). The estimation of China's provincial capital stock: 1952—2000. *Economic Research Journal*, *55*(10), 35–44. http://en.cnki.com.cn/article_en/cjfdtotal-jjyj200410004.htm

Zhao, X. D., & Li, X. (2020). The impact of education and health human capital on labor productivity. *Social Science Front*, *299*(05), 60–67. doi:CNKI:SUN:SHZX.0.2020-05-007.