Population Ageing, Industrial Structure and Innovation Efficiency

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Abstract. China's population is aging, the demographic dividend is gradually disappearing, and the proportion of working-age people continues to shrink. Reducing the negative impact of ageing on society is something that must be considered at this stage of China's economic and social development. And achieve high-quality, strong, healthy and green economic development in this period is a difficult task. The level of innovation and development is an important factor in improving the quality of economic development, and innovation is an important support for building a modernized economic system. China's investment in the field of innovation has been increasing, but in order to pursue high-quality economic development, a mere increase in quantity is not enough, and qualitative improvement and input-output efficiency, i.e., innovation efficiency, are needed. The improvement of innovation efficiency can truly reflect the innovation capacity and level of a region, as well as the height of future development in the field where scientific development, technological innovation and highly skilled personnel are concentrated. Therefore, exploring the interplay between innovation efficiency and ageing structure can promote and guide the future high-quality development of China's economy.

Keywords: Ageing; industrial structure; innovation efficiency; new structural economics.

1. Introduction

Population ageing is a phenomenon that cannot be avoided when economic development reaches a certain level, and at the same time, it reflects the continuous progress of society. The status quo of population aging in China is already an important economic and social objective fact, and while marking the social and economic progress of in China, the impact that population aging will have on the economy and society is also a problem that China must face and solve. According to statistics, by the end of 2022, the population aged 65 and above in China will be 2.135 billion, accounting for 14.9 per cent of the total population; the elderly dependency ratio will be 21.8 per cent. Developing at this rate, the proportion of China's elderly population will soon exceed 15 per cent, which means that a "deeply ageing society" is approaching. This means that a "deeply ageing society" is coming. Experts predict that the elderly population in China will reach a staggering 487 million in 2050. Population is an important factor affecting economic development. The economic development of developing countries mainly relies on cheap labor, and the promotion of "primitive accumulation" in China relies on the large and cost-effective labor resources, thus promoting economic growth. However, the demographic dividend is gradually disappearing as China's elderly population has been growing over the decades, while China's young people's reduced desire to have children and lower fertility rates have led to a lower proportion of the working-age population in recent years, and the rapidly rising cost of labor will also lead to the previous economic development will receive constraints. How to reduce the negative impact of aging on China's economic development and achieve high-quality, strong, healthy and green economic development in this period is a difficult task. The 19th CPC National Congress report states that "innovation is the first productive force leading development" and puts forward the new development concept of "innovation", reflecting the fact that innovation is an important support for building a modernized economic system. China's investment in the field of innovation has been increasing, but in order to make the development structure of the economy more advanced and the quality of development more excellent, a mere increase in quantity is not enough;

it requires qualitative improvement and an increase in the efficiency of inputs and outputs, i.e., an increase in the efficiency of innovation.

2. Literature Review

Many studies have explored the possible impact of population ageing on science and technology innovation. Generally, intuitively, ageing has a negative impact on science and technology innovation, but through what kind of pathway it brings about what kind of impact on innovation efficiency, which is important for how to implement the innovation development strategy at this stage. On the one hand, for developing countries (regions), population aging will bring about a reduction in the quantity of labor supply, accelerate the arrival of the "Lewis inflection point", cause the labor cost of traditional industries to continue to rise, and then push the leading industries to change from labor-intensive to capital-intensive and technology-intensive, and force enterprises to carry out technological innovation, increase the investment and application of artificial intelligence, forming a self-motivated mechanism to improve labor productivity and promote the transformation and upgrading of industrial structure (IS). On the other hand, with the deepening of aging, the aging phenomenon of the labor force in the production sector will become more and more serious, and the physical strength, learning ability and innovation ability of the elderly labor force are weaker than that of the young labor force, and the labor group with a larger number of elderly labor force has a weaker innovation ability and a lower innovation efficiency.

Conversely, raising the level of science, technology and innovation is also an important means of mitigating the negative effects of population ageing. On the one hand the continuous optimization of IS is an important manifestation of modern scientific and technological innovation. Different IS have different needs and matching degree to the population structure, which reflects that the age structure of the population matched by different modes of IS is different. On the other hand, with the continuous innovation and development of health investment and other fields, the IS will change, so as to adapt to the aging population structure, and ultimately to achieve the IS that best matches the current age structure of the population and improve the efficiency of economic development and growth rate. Therefore, it is especially important to study the relationship between the aging population structure, IS and innovation efficiency, which can also provide reference for China to promote innovation development at this stage.

Many of the previous studies are from the individual level that the physical function of the elderly declines, responsiveness imagination and other abilities decline, so the ability to innovate decreases, so the elderly population accounts for too much is not conducive to scientific and technological innovation [1]. Noda to research and development departments as capable employees, construction industry employees as incapacitated employees to construct the theoretical model, the results found that along with the population structural changes, the number of capable employees gradually decreases and the human capital in the R&D department of enterprises is insufficient, which in turn affects the innovation ratio [2]. Lancia et al. constructed a three-period overlapping generations model to prove that the increase of life expectancy in an aging society makes middle-aged and young-aged employees more inclined to vote in favor of the application of a certain new technology, whereas the elderly generally vote against the application of a new technology but Simonton et al. found that the peak age of innovation of researchers and inventors is 39 years old after conducting a research survey on a large number of scientists [3, 4]. Shao and Wang that demographic structure significantly affects technological innovation, as evidenced by the fact that innovation efficiency decreases when the proportion of juvenile and elderly population increases, here reflecting the inhibitory effect on innovation efficiency, whereas an increase in the proportion of working-age population positively promotes innovation efficiency [5]. There is a significant threshold effect of innovation based on the condition of heterogeneity between population ageing and technological innovation. After analyzing the relationship between population ageing and technological progress at different time stages, Deng

and Zhang found that the technological progress effect of population ageing shows a dynamic trend from weak to strong [6].

Shu and Zhen concluded that the IS follows its own law of evolution, and the aging of the labor force slows down the evolution of the IS to a certain extent, but the side effects of aging will become smaller and smaller when the IS adjustment is in line with the aging process [7]. Yang believes that aging brings new opportunities to the product consumption market and can promote industrial upgrading [8]. Xu et al. believe that population aging will indirectly affect IS upgrading through residents' consumption, on the one hand, inhibiting IS upgrading by lowering the consumption level, and on the other hand, promoting IS upgrading by improving the consumption structure [9]. Zhao believes that from the viewpoint of economic urbanization, if the region passes the threshold of real per capita income of 40,828-yuan and disposable income of urban residents of 43,851-yuan, and this is like a threshold, in areas above this level, the more severe the ageing is, the better it is for the optimization of the IS [10]. However, in areas below this level, the more severe the ageing, the more likely it is to hinder the process of advanced IS.

In terms of the relationship between population ageing, IS and innovation efficiency, there are still the following two aspects that need to be further explored in the previous studies: First, most of the studies have examined the relationship between population ageing and innovation, and between population ageing and upgrading of IS, and seldom analyzed the three in a unified framework. Second, most of the studies have focused on the inputs or outputs of innovations and have not analyzed them as innovation efficiency. They are not analyzed as innovation efficiency. Therefore, based on the above analyses, this paper explores a possible interrelationship between population ageing, IS and innovation efficiency under a unified structural analysis framework with the help of the relevant theories of new structural economics. The rest of the paper is organized as follows: The second section is a theoretical exposition of the interrelationship between population age structure based on IS and innovation efficiency from the perspective of new structural economics. The third section provides macro data support and data illustration. The fourth section contains the conclusions and implications.

3. Aalysis and Discussion

New structural economics considers the endowment structure to be the logical starting point for analyzing the development of an economy. The endowment structure determines the optimal IS of an economy, and comparative advantage can be maximized in industries that follow the endowment structure. Then only the IS that can maximize its own advantages is the most favorable for promoting economic development. Improvements in innovation efficiency can be maximized when the IS is adapted to the demographic structure that is the endowment; conversely, improvements in innovation efficiency can be mitigated by adjustments in the IS to mitigate the problems associated with an ageing demographic structure.

3.1. Analytical Framework

3.1.1. Ageing

There are two main types of commonly used measures of ageing: the old-age dependency ratio and the proportion of older persons in the population. The older dependency ratio is the ratio of the elderly population to the labor force; the larger the ratio, the greater the number of elderly dependents in the labor force and the more serious the degree of ageing, which better reflects the degree of ageing at the labor force and economic levels, whereas the elderly population ratio provides a more intuitive picture of the ageing of the population structure.

3.1.2. Innovation efficiency

Innovation efficiency is specifically expressed as the input-output ratio of innovation resources. In terms of input indicators, innovation inputs generally include capital factor inputs and labor factor inputs: in this paper, internal expenditure on research and experimental development (R&E) funding

is chosen as the capital factor input indicator, which makes the results of the indicator more intuitive and objective; and full-time equivalents of R&E personnel are used as the labor factor input indicator, instead of the number of scientific research workers, because it can better show the input of labor resources in the field of innovation. In terms of output indicators, patents are the most important indicator. In terms of output indicators, patent is the most used indicator to measure the output level of innovation activities, which is reliable, convenient and intuitive, so this paper chooses the number of invention patent applications granted to measure innovation output. Finally, the innovation efficiency value is calculated by data envelopment analysis (DEA) measurement method.

3.1.3. Human capital

This paper takes the proportion of people with different levels of education and weight them together to get the advanced level of human capital structure. The higher the level of education, the higher the proportion of weights will be given, so that the data obtained can better reflect the importance of advanced human capital.

3.1.4. Industrial structure

This study focuses on the distribution of employed persons by industry based on a demographic perspective, using the following indicators to characterize the IS:

$$I = I1 + 2I2 + 3I3 \quad (1)$$

I am the index of IS upgrading, and I_1, I_2 and I_3 represent the proportion of the employed population in each of the three industries to the total employed population respectively.

3.2. Data Description

In this paper, data for the whole country from 2003 to 2023, a time period that covers most of the time when China began to enter the ageing period and develop innovative industries, are selected from the National Bureau of Statistics.

3.3. Macro Data Support

Figure 1 below shows the changes in China's old-age dependency ratio over the past 20 years. As the figure shows, China's old-age dependency ratio has been rising over the past two decades, and the rate of increase has been increasing.

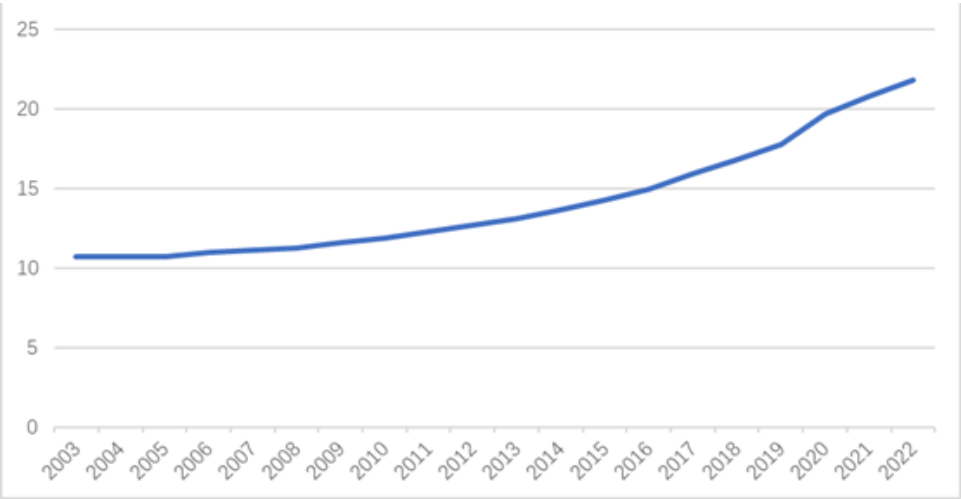

Fig 1. Elderly dependency ratio in China in the past 20 years (Photo credit: Original).

Figure 2 shows the elderly population ratio for the last 20 years. The elderly population therein refers to the population of 65 and above. As the figure shows, the proportion of older persons in China's overall population has also been rising, reflecting the objectively increasing ageing of China's demographic structure.

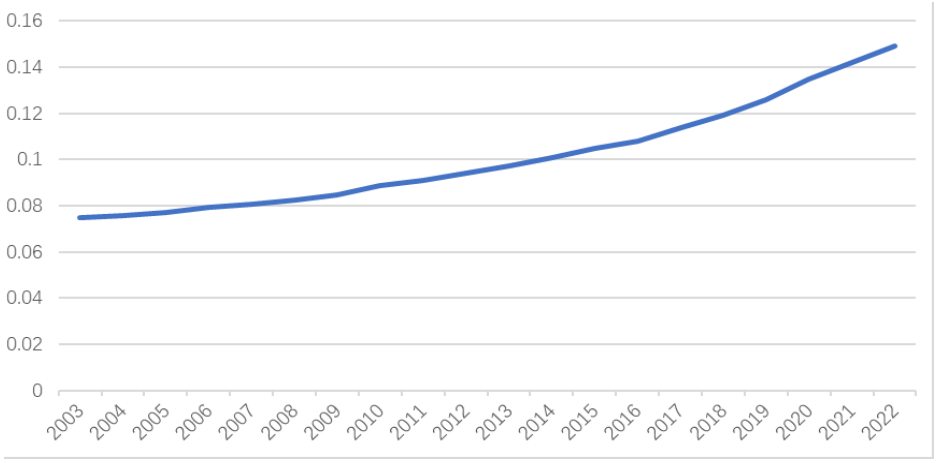

Fig 2. Elderly population ratio in China in the past 20 years (Photo credit: Original).

As shown in Figure 3, the number of authorized invention patent applications is generally on an upward trend, with only a small drop in 2013, and the rate of increase in the number is also on an upward trend.

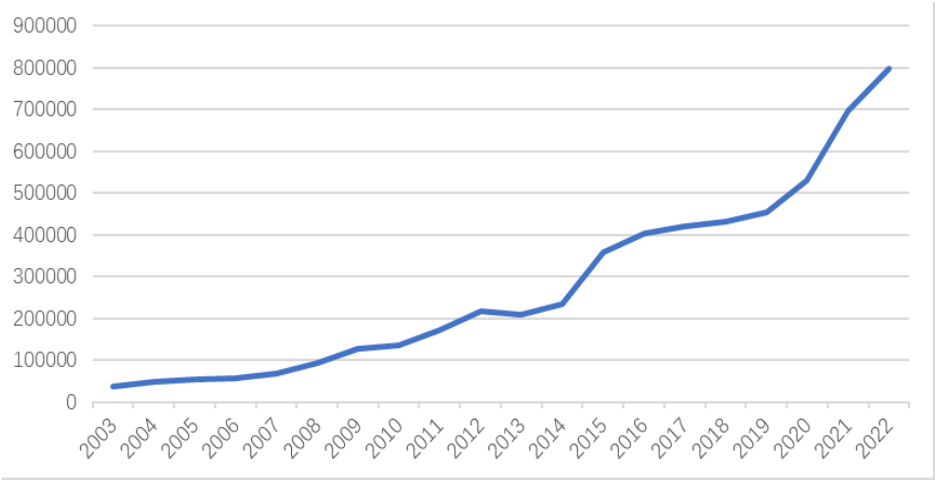

Fig 3. Number of invention patent applications authorized in China in the past 20 years (Photo credit: Original.

Figure 4 and Figure 5 show the expenditure on research and experimental development and the full-time equivalent of research and development personnel in China over the past two decades. As shown in these two figures, both have fluctuated around 2013 and 2014, while maintaining a general upward trend.

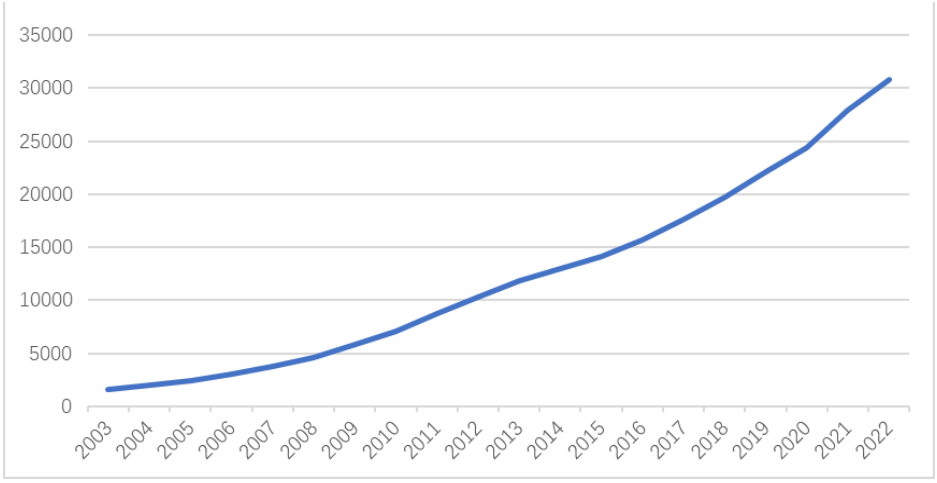

Fig 4. Expenditure on research and experimental development (Photo credit: Original).

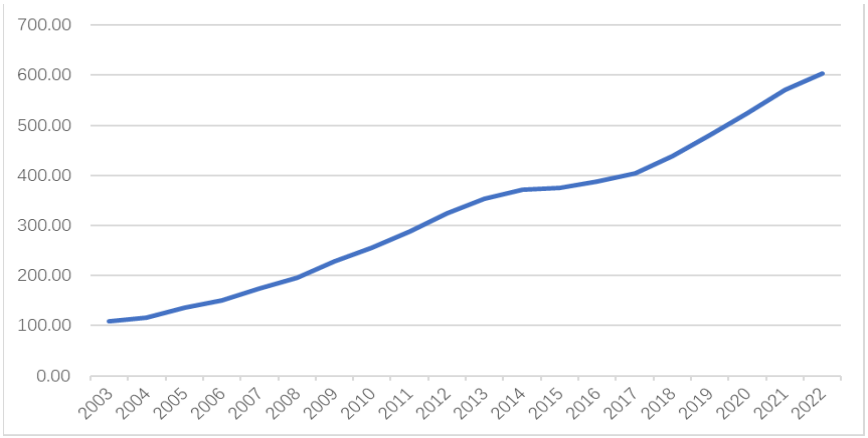

Fig 5. Full-time equivalents of research and development personnel (Photo credit: Original).

From the above analysis, it not difficult to get that the change of China's innovation efficiency in the past twenty years, including the degree of aging in China is deepening. However, the change of innovation efficiency is not always lower or decrease, so there must be a non-linear relationship between the two or the influence of other intermediate variables.

The nadir of innovation efficiency that appears in the graph is around 2013, and except for around 2019, which is affected by special reasons, the country's innovation efficiency has risen from 2013, when it reached its trough.

The following three figures show the changes in the share of China's three industries over the past two decades. As shown in Figure 6, Figure 7 and Figure 8, the share of the primary industry (PI) has continued to decline, the secondary industry (SI) has shown a trend of rising and then slightly declining, and the share of the tertiary industry (TI) has fluctuated and risen. It can be found that the peak of the share of the SI and the position of the fluctuation of the TI both occur near 2013.

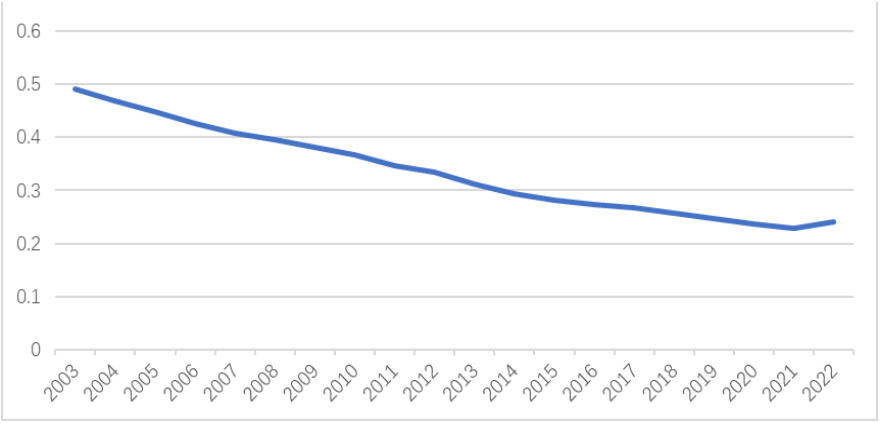

Fig 6. Proportion of PI of the economy in China (Photo credit: Original).

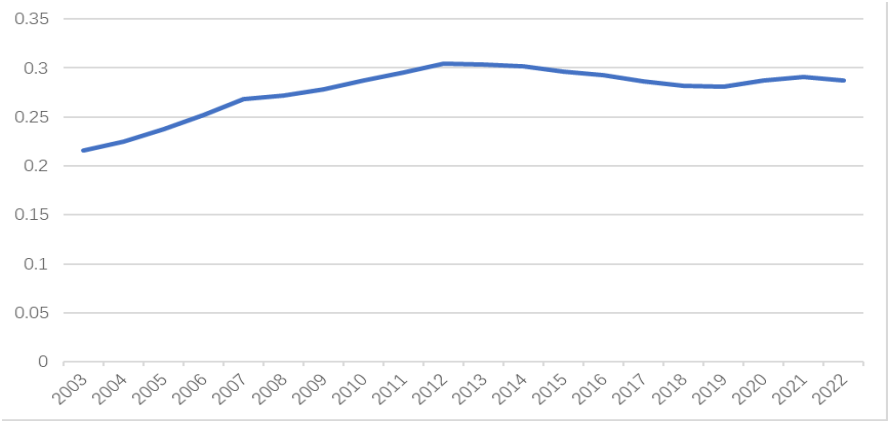

Fig 7. Proportion of Secondary sector of the economy in China (Photo credit: Original).

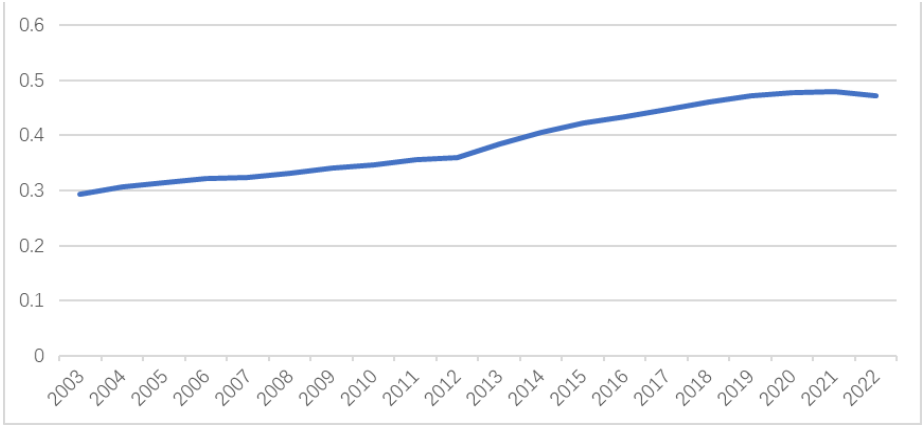

Fig 8. Proportion of tertiary sector of the economy in China (Photo credit: Original).

The following Figure 9 shows the trend of China's IS upgrading index. As shown in the figure, China's IS upgrading index is on an upward trend, with only minor fluctuations around 2013.

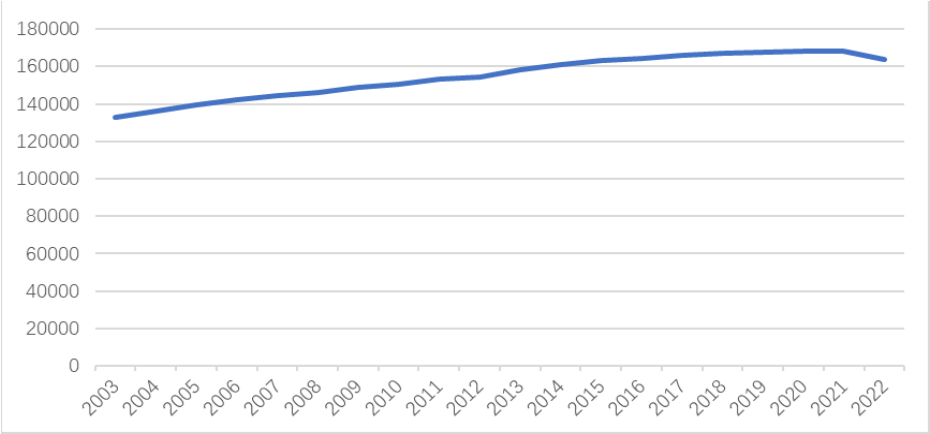

Fig 9. China IS Upgrading Index (Photo credit: Original).

To sum up, based on a series of macro data, the study can analyze and get that in China's development process in the last two decades, the degree of aging has been increasing, the investment in the field of innovation has been rising, and the index of upgrading the IS has been rising, but the efficiency of innovation is fluctuating. This shows that there is not a simple linear correlation between the degree of ageing and innovation efficiency. It can be noted that the inflection point in the data was around 2013, when the Third Plenary Session of the 18th Central Committee of the Communist Party of China (CPC) was held, which set out the tasks and objectives of a comprehensive reform in several areas, including the economic system and the operation of the market.

After 2013, the share of China's SI began to decline, while the share of the TI accelerated, which both corresponds to the current situation of an ageing society driving the growth of the service sector and confirms that innovation efficiency will only begin to rise when the IS is transformed to adapt to the demographic structure. If China only increases investment in innovation without supporting industrial restructuring, innovation efficiency will decline as a result of changes in the labor market brought about by an ageing population. On the other hand, the improvement of innovation efficiency also promotes the transformation of IS to adapt to the irreversible wave of population ageing, which provides a guarantee and support for the smooth development of China's economy in the following decades.

4. Conclusion

This paper illustrates the possible relationship between population aging, IS, and innovation efficiency through China's macro data in the last two decades, which provides theoretical support for subsequent panel data research. This paper uses macro data from the National Bureau of Statistics of

China to quantify and analyze the three factors of population ageing, IS and innovation efficiency, to find out the key nodes of key changes, and thus to find out what the macro policy reasons are and to get the relevant conclusions about the relationship between the three: it is not that the pursuit of IS advancement and the increase of inputs in the field of innovation can help to alleviate the disadvantages brought by the ageing of the population. Rather, it is important to find the most suitable IS for the current demographic structure through policy adjustments and industrial restructuring, to improve the efficiency of innovation and thus maintain a strong and stable economic growth in the period of increasing aging. Nowadays, China needs to pass the policy and industrial adjustment, increase the investment in the pension industry and strengthen the intelligent upgrade of the pension service industry, to adapt to the aging society and promote the economic operation.

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