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Assessing the Impacts of Labor Force Sustainability in Terms of Population Ageing on the Economic Sustainability

Zhichao Sun, Yu Song and Ivan K.W. Lai

Abstract: The age structure of a population will affect the labor force sustainability, which ultimately affects the economic sustainability of a country. This study aims to develop a model for assessing the labor force sustainability in terms of population ageing and its impacts on economic sustainability in different industries and the national economy. This model is based on a computable general equilibrium (CGE) mechanism that consists of three components: (1) forecast of labor supply; (2) forecast of labor demand; and (3) assessment of the impacts of labor market imbalance (shortage) on the macroeconomy. The results of the economic forecast of China prove that this model can effectively assess the impacts of labor market imbalance on economically sustainable development. Furthermore, a simulation forecast of China from 2014 to 2030 was performed. The results show that the contributions of most of China's industries to the gross domestic product (GDP) show a negative growth trend. From the medium- and long-term points of view, the influence of population ageing to the labor-intensive industries is the most serious. The construction industry's contribution to GDP growth rate still shows a rising trend, but the growth rate decreases annually. The service industry's contribution to GDP growth rate shows a significant upward trend, but the rate is decreasing annually. Economic growth shows a declining trend. Population ageing has little influence on consumption and investment, but in absolute numbers, the GDPs growth rate is lower in scenarios that consider population ageing than in scenarios that do not. The pulling effect of exports to economic growth will continue to decrease.

Keywords: population ageing; labor supply and demand; labor market imbalance; the macroeconomy; CGE model

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1. Introduction

The ageing of the population has caused concerns related to its effects on the labor markets of many countries [1]. The labor market can serve as an effective mechanism for contributing to economic growth and for transmitting the gains from economic growth [2]. In many developing countries, the economic rise depends on the supply of a large, cheap, and productive labor force. However, in the era of global ageing, the growth of the economy and the population ageing in developing countries are both accelerating. Meanwhile, the ageing of the population may affect the economy as productivity hardly increases due to labor shortage. This is the labor force sustainability problem [3].

In 1979, the Chinese government implemented the "One Child per Couple" policy aimed at slowing population growth [4]. The total fertility rate declined from 2.8 children per woman in 1979 to 1.7 in 2013 [5]. The age structure of the population has changed quickly in a developing country with a per capita gross domestic product (GDP) of USD 7485 in 2014. Chinese cities have begun to experience some shortages in unskilled labor [6]. Now, China is facing a new challenge of an ageing population, which could affect its labor force sustainability, and, ultimately, economic sustainability [7]. Economic sustainability is the ability of an economy to support a defined level of economic production indefinitely. Although there are some studies on the relationship of an ageing population and economic development in China, they mostly focus on the economic impact of population ageing on economic growth. There is a lack of studies on the effects of labor force imbalance (shortage) on the macroeconomic development.

The aim of this study is to develop a model for assessing the labor force sustainability regarding the ageing population and its impacts on economic sustainability in different industries and the national economy. Computable General Equilibrium (CGE) models are widely used for measuring the impacts of policy interference on sustainability issues [8]. In this study, the impacts of labor force sustainability (as a result of "One Child per Couple" policy) on economic sustainability will be assessed using a CGE model that consists of three components: (1) forecast of labor supply; (2) forecast of labor demand; and (3) assessment of the impacts of labor market imbalance (shortage) on the macroeconomy. This model will be validated using the data of previous Chinese economy outputs (1987–2005) to forecast the economic changes in following years (2006–2013). Furthermore, a simulation forecast (2014–2030) will also be performed to predict the economic situation based on current population ageing. Some macroeconomic policies regarding population ageing will be recommended in order to achieve sustainable economic growth in the future.

2. Literature Review

2.1. Studies on Population ageing and Its Impact to Economy

In 1994, the World Bank published its first report on the crisis of population ageing to determine the effects of reallocation of income, saving and insurance in national finance security systems. It recommended governments to employ a multi-pillar pension system to solve the financial crisis caused by population ageing [9]. In 1996, the World Bank published two more reports on Chinese population ageing problem. One report discussed problems of the Chinese Pay-As-You-Go (PAYG) pension system in the short run and long run and simulated several policies to solve the problem. The conclusion is that China's pension system must be combined with competition, diversification, and effective rules [10]. The other report estimated the speed and range of China's population ageing, and the cost of supporting the elderly. It suggested that China should establish a transparent, decentralized pension system with an occupational fund or individual savings account to improve the quality of old people's lives [11].

Many scholars studied the effects of population ageing on productive and economic growth. Beginning as early as 1989, when Auerbach and Kotlikoff [12] from the United States used a general equilibrium model with an Overlapping Generation Model (OLG) algorithm to study the economic dynamics of Germany, Japan, Sweden, and the USA. They found that the national savings rate, real wages, and savings are impacted the most. Williamson [13] first raised the concept of the "demographic gift" in studying East Asia's economies, referring to a relatively small proportion of teenagers and elderly but a relatively large proportion of the working-age population in the demographic structure. He believed that the large proportion of the working-age population in East Asia is helpful in promoting economic growth. Bloom, Canning, and Sevilla [14] used demographic dividends, representing the expanding gap of fertility and mortality, in underdeveloped countries that could offer sufficient labor. They believed that 1/4 of the East Asian economic miracle could be explained by the demographic dividend. Fougere and Merette [15] also found that population ageing would cause the national savings and per capita gross domestic product growth to decrease, but would also bring great pressure to the overall tax burden. Prettner [16] investigated the consequences of population ageing for long-run economic growth perspectives. He found that increases in population longevity have a positive impact on per capita output growth, while decreases in fertility have a negative impact on per capita output growth. The positive longevity effect dominates the negative fertility effect in the case of the endogenous growth framework, and population ageing fosters long-run growth in the endogenous growth framework, while its effect depends on the relative change in fertility and mortality in the semi-endogenous growth framework. Uddid, Islam, and Kabir [17] attempted to assess the demographic support and dividend of the ageing process in Bangladesh and found that future resources for supporting the elderly will be limited to both urban and rural areas if the current trends prevail. The degree of support for the elderly decreased due to the demographic transition. Foroni, Fulanetto, and Lepetit [18] proposed a new value at risk (VAR) identification scheme to disentangle labor supply shocks from wage bargaining shocks. According to analysis of US data over the period 1985–2014, labor supply shocks caused by population ageing and wage bargaining shocks are important drivers of decreasing output and unemployment, both in the short run and in the long run. They also found that labor supply shocks are the main drivers of the decreasing participation rate and account for about half of its decline in the aftermath of the Great Recession.

In recent years, studies on population ageing expanded from developed Western countries to developing countries. Scholars tend to study population economics from the perspectives of the non-canonical demographics or non-economics, while non-market population biology perspectives have gradually increased, as have studies involving community, political, cultural, human rights, humanitarian, etc. consequences of population ageing.

2.2. Studies on Population Ageing and Its Impact to China's Economy

Since the 1980s, with the implementation of "One Child per Couple" policy in China, the fertility rate dropped significantly, causing the proportion of working-age population to rise. China entered the "demographic gift" period. During this period, a higher proportion of the labor force provided a wealth of labor resources for economic growth. However, the continued low fertility and lower labor force participation rate will end the peak period of labor. According to population prospects from the United Nations [19], China's 15–64 working-age population will decrease after it reaches one billion in 2015. In the coming 20–30 years, the structure of the working-age population will change and the growth rate of the working-age population will gradually slow down [20]. At present, China's new labor force and the increased demand of labor force have been more or less balanced. Even though an absolute shortage of labor in China does not present itself, indications of a structural shortage have emerged. This means that the competitive advantage on the global market of cheap labor will continue to be weakened. Sooner or later, labor shortages will eventually become a reality [21]. China's population will reach a peak in 2023 after which it will decrease rapidly [22]. This demographic trend will lead to the very important issue of labor shortage. This period of abundant labor supply will remain for about 10 years, after which its size will gradually reduce. From an international point of view, after the transition of a country's population structure and the ageing of the working-age population, it will soon face labor shortages [23]. Yang and Luo [24] made an empirical study on the dynamic relationships of population ageing, technological innovation and economic growth using a panel data VAR model based on Chinese provincial panel data from 1999 to 2013. The results showed that in the short term, population ageing in China is bound to adversely affect economic growth, while in the long term, the influence of population ageing on economic growth lies in the comparison of its positive and negative effects. They also found that at present, population ageing did not significantly influence technological innovation. Hu and Xu [25] investigated how population ageing would affect the savings rate. Based on the optimal behavior of a household, they found that population ageing would affect the savings rate, showing different effects for urban households and rural households. With the Chinese Household Income Project (CHIP) data, they constructed pseudo-panel data and verified that the savings rate of an urban household was increased with population ageing, while that of a rural household was decreased with population ageing. Based on this result, they forecast that the savings rate in China would not decrease with population ageing. Wang and Tong [26] found that with population ageing, China's labor force participation rate has shown a declining trend in recent years. They used econometric methods to study how much population ageing affects the labor participation rate, and found that the ageing of the population, especially the ageing of the working-age population, has a negative impact on the labor force participation rate.

Compared to foreign research in this field, China started very late. Early scholars addressed more the age structure of population ageing, and cared more about supporting the elderly. Most of them discussed the economic consequences caused by population ageing, or made descriptions based on macroeconomic survey data from the perspective of demography, while lacking any theoretical basis of comparative dynamics.

2.3. The Development of Computable General Equilibrium (CGE) Model

French economist Léon Walras was the first to propose the general equilibrium (GE) concept in the Elements of Pure Economics in 1874. He expressed Adam Smith's "invisible hand" as a set of equations. In the late 1940s and 1950s, Kenneth Arrow, Gerard Debreu and Lionel McKinsey, respectively, proved the existence and validity of general equilibrium with their theories and methods, and laid the foundation of modern general equilibrium theory. After the 1950s, with the development of computer technology and data availability, GE theory was developed using computers to make the calculations. In 1960, Leif Johansen built the world's first CGE model, a multi-sectorial growth model [27]. Until the 1980s, CGE models have been developed very standardly and actively as a branch of economics.

CGE models are a digital set and description of the entire economic system. Various economic entities within the economic system are involved in balancing it, by adjusting the quantities of goods and factors as well as prices, and this process is the Walras GE between supply and demand. In simple terms, the purpose of the establishment of CGE models is to turn an abstract form into a mathematical model close to the real economy. CGE models can simulate the entire economic system. It was initially an academic research tool but has rapidly grown into an actual policy analysis tool for trade policy, tax policy, environmental policy, energy policy analysis, etc.

Fougere and Merette [15] integrated the cross-level iterative models using the CGE model and estimated the population ageing's impact on the economy. In recent years, scholars from China have also adopted CGE model to study the ageing population's impact on the economy, especially in the pension system. Bai and Xi [28] used the comparative static method in CGE to evaluate the overall impact of pension reform on the economic system with the indexes of GNP, unemployment, sectoral output, government deficit, investment in fixed assets as indicators, proposing appropriate countermeasures. They also studied the impacts of various reform options on the sustainability of the pension system and economic growth. Peng [29], using a CGE model and a given ageing profile of the population to forecast the growth path of China's economy during the 21st century, found that population ageing leads to declining economic growth as labor supply shrinks and the physical capital formation rate declines. The main force that can sustain China's economic growth against the backdrop of population ageing is productivity improvement.

3. Labor Force Sustainability Models

3.1. Forecast of Labor Supply

In this study, the population model is employed for forecasting the working-age population because its result is of high reliability. Here, the maximum life expectation is assumed to be 100. The population of age j in year t is predicted as:

$$P_j^t = P_{j-1}^{t-1}\left(1 - d_{j-1}\right),\ 100 \geq j \geq 0 \tag{1}$$

P_j^t is the population of age j in year t and d_j is the natural population mortality of age j.

The total number of babies born in year t is calculated using the entire 15–49-year-old female population $\sum_{i=15}^{49} P_i^{t-1}$ multiplied by its corresponding fertility S_i.

$$P_0^t = \sum_{i=15}^{49} P_i^{t-1} * S_i \tag{2}$$

where S_i is the fertility of i-year-old females.

The labor supply is assumed to be the 15–64 age group. The size of the labor supply is the population of 15–64 year olds minus students in the school-age group, domestic workers, and those who are unable to work. In order to have a figure closer to the actual situation, the concept of labor force participation rate recommended by Wang [30] is employed for calculating the labor supply. The labor supply in year t is:

$$L_s^t = \sum_{i=15}^{64} P_i^t * LFPR_i \quad (3)$$

where L_S^t Is the labor supply in year t and $LFPR_i$ is the labor force participation rate of i-year-old population. The forecast of labor supply is shown in Table A1.

3.2. Forecast of Labor Demand

In this study, the econometric model and the employment elasticity law are used to predict the labor demand [22]. For the economic model, because the number of employees of the current year and the number of employees of the previous year are closely linked, the establishment of self-regression model is built to predict the demand for labor.

$$L_t = a + bL_{t-1} + u_t \quad (4)$$

L_t represents the number of employees in year t, a is a constant number, and u_t is the random error.

The following describes the measurement of employment elasticity, where β_l represents employment elasticity value, Y represents economic output GDP, and L represents the employed labor force. Defined by the employment elasticity:

$$\beta_l = \frac{\frac{\Delta L}{L}}{\frac{\Delta Y}{Y}} \quad (5)$$

In Equations (1)–(5), the employment elasticity = employment growth/economic growth, so employment growth rate = employment elasticity × economic growth. Next are the employment elasticity β_l measurements. Double logarithmic model (logarithmic current model) can be used, and the employment in year t is L_t, and the gross domestic product is Y_t.

$$\ln L_t = \beta_0 + \beta_l \ln Y_t + \varepsilon_t \quad (6)$$

where ε_t is corresponding random error item. The resulting β_l from Equation (6) calculated with data is employment elasticity. In actual measurement, in order to be more accurate, employment elasticity can be carried out by industry, resulting in weighted average employment elasticity. The forecast of labor demand is shown in Table A2. It is quite clear that labor demand exceeds labor supply starting in 2015 (Tables A1 and A2).

3.3. Construction of a Static Model

A computable general equilibrium model is a powerful tool for policy analysis. Dervis et al. [31] constructed a CGE framework of an open economy. Lofgren et al. [32] of International Food Policy Research Institute (IFPRI) used General Algebraic Modeling System (GAMS) to realize this theoretical framework and develop the IFPRI model. IFPRI model is a standard model. It provides a flexible framework for static CGE analysis and complete GAM program code. It explains economy structure well and reduces the difficulty of secondary development: firstly, the production activities, commodities, and households accounts can be subdivided; secondly, it can remove unnecessary set up to simplify the model; and, thirdly, the standard model is very flexible for macro closure and factor markets closure set. More importantly, model and data are separated in this framework, which means the research of SAM data and model equations are strictly separated. The static model in this paper is constructed based on IFPRI model, and its dynamic expansion is referred from the work by Thurlow [33] and Diao et al. [34].

In this study, two Social Accounting Matrixes (SAMs) are prepared. The first matrix is a macro SAM (Table 1), which covers the production and consumption sectors. The second matrix is a micro SAM of each industry (data not shown). A GAMS program is used to solve the CGE model.

The data were acquired from the "China Statistical Yearbook" from 1987 to 2007 by the National Bureau of Statistics, and the method of processing data comes from Robinson et al. [35].

Table 1. Macro Social Accounting Matrixes (100 million).

	Activities	Commodities	Factors	Households	Enterprises	Government	Savings-Investment	Rest of the World (ROW)	Total
Activities		Marketed outputs 818,859		Home-consumed outputs 96,553					Activity income 818,859
Commodities	Intermediate inputs 552,815	Transaction costs		Private consumption		Government consumption 35,191	Investment 114,212	Exports 95,541	Demand 894,312
Factors	Value-added 227,525							Factor income from ROW	Factor income 227,525
Households			Factors incomes to households	Inter-household transfers	Surplus to households 41,457	Transfers to households 5447		Transfers to household from ROW	Households income 156,952
Enterprises			Factor income to enterprises			Transfers to enterprises 4834		Transfers to enterprise from ROW	Enterprise income 122,312
Government	Producer taxes, value-added taxes 38,519	Sales taxes, tariffs, export taxes 1433	Factor income to government, factor taxes	Transfers to government, direct 3186	Surplus to government, direct enterprise savings 8779			Transfer to government from ROW −5635	Government income 46,281
Savings-Investment				Household savings 57,213	Enterprise savings 72,075	Government savings 809		Foreign savings −15,885	Savings 114,212
Rest of the World		Imports 74,021	Factor income to ROW		Surplus to ROW	Government transfers to ROW			Foreign exchange outflow 74,021
Total	Activities 818,859	Supply expenditures 894,312	Factor expenditures	Household expenditures 156,952	Enterprise expenditures 122,312	Government expenditures 46,281	Investment 114,212	Foreign investment flow 74,021	

3.3.1. Equations of a Static CGE Model

In the model, there are three types of markets: activities, goods, and factors. Factors are divided into capital K and labor L. Activities and commodities include seven items, and are fully consistent with industries in SAM. The economic entities of this model include households h, enterprises ent, government gov, and foreign entity row. Government taxes are divided into production tax, income tax and customs duty, ta_a, $tins_{INSD}$, and tm_c, respectively.

(1) Mathematic description of a production module:

A production module is a two-layer nested production function. The first layer is a constant elasticity of substitution (CES) function with intermediate input $QINT_c$ and value added QVA_a. The second layer is a CES function composed of capital and labor, showing the incomplete substitution between capital and labor.

$$QVA_a = \alpha_a^{va}\left(\delta_a^{va} \cdot QL_a^{-\rho_a^{va}} + (1-\delta_a^{va}) \cdot QK_a^{-\rho_a^{va}}\right)^{-1/\rho_a^{va}}, \rho_a^{va} = \frac{1}{\sigma_a^{va}} - 1 \quad (7)$$

$$\frac{WL}{WK} = \frac{\delta_a^{va}}{1-\delta_a^{va}} \cdot \left(\frac{QL_a}{QK_a}\right)^{\rho_a^{va}-1} \quad (8)$$

$$PVA_a \cdot QVA_a = WL \cdot QLD_a + WK \cdot QKD_a \quad (9)$$

in which, the factors inputs include labor input QL_a and capital input QK_a; α, δ, and σ represent scale parameter, share parameter, and elasticity parameter, respectively; and WL and WK represent labor income and capital income, respectively. Equation (7) is the CES production function. Equations (8) and (9) are the first order terms of minimal cost and maximum profit. Total production QA_a has similar mathematical description (Equations (10)–(12)) and intermediate input $QINT_{ca}$ is Leontief composition of each intermediate input, shown as Equation (13).

$$QA_a = \alpha_a^q\left(\delta_a^q \cdot QVA_a^{-\rho_a} + \left(1-\delta_a^q\right) \cdot QINTA_a^{-\rho_a}\right)^{-1/\rho_a}, \rho_a = \frac{1}{\sigma_a} - 1 \quad (10)$$

$$\frac{PVA_a}{PINTA_a} = \frac{\delta_a^q}{1-\delta_a^q} \cdot \left(\frac{QINTA_a}{QVA_a}\right)^{1-\rho_a} \quad (11)$$

$$PA_a \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a \quad (12)$$

$$QINT_{ca} = ica_{c\ a} \cdot QINTA_a \quad (13)$$

(2) Mathematic description of a trade module:

The intermediate input composed commodity QQ_c uses the Armington Assumption, which is a CES function of domestic made commodity QD_c and imported commodity QM_c, as shown in Equations (14) and (15). PD_c and PM_c represent domestic made commodity price and imported commodity price, respectively.

$$QQ_c = \alpha_c^q \left(\delta_c^q \cdot QM_c^{-\rho_c^q} + \left(1 - \delta_c^q\right) \cdot QD_c^{-\rho_c^q} \right)^{-1/\rho_c^q}, \rho_c^q = \frac{1}{\delta_c^q} - 1 \tag{14}$$

$$\frac{QM_c}{QD_c} = \left(\frac{PM_c}{PD_c} \cdot \frac{1 - \delta_c^q}{\delta_c^q} \right)^{1/(\rho_c^q + 1)} \tag{15}$$

Each sector needs to decide the proportion between commodity for domestic consumption QD_c and commodity for export QE_c, and the total output is distributed between domestic consumption and export with incomplete conversion elasticity, shown as Equations (16) and (17). PE_c is the export commodity price.

$$QX_c = \alpha_c^t \left(\delta_c^t \cdot QE_c^{\rho_c^t} + (1 - \delta_c^t) \cdot QD_c^{\rho_c^t} \right)^{1/\rho_c^t}, \rho_c^t = \frac{1}{\sigma_c^t} + 1 \tag{16}$$

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PD_c} \cdot \frac{1 - \delta_c^t}{\delta_c^t} \right)^{1/(\rho_c^t - 1)} \tag{17}$$

(3) Mathematic description of an economic behavior module:

$$PQ_c \cdot QH_c = EH_h \cdot shif_{ch} \tag{18}$$

$$EH_h = (1 - tins_h)(1 - mps_h) \cdot YH \tag{19}$$

QH_c is the households consumption; PQ_c is the final composed commodity's price; EH_h is the consumption part of households income YI_h; $tins_h$ is personal income tax rate; and mps_h is marginal propensity to save.

Households' income YI_h is made up of factor income YF_f, and the transfer payments by enterprises and the rest of the world, $tran_{h,ent}$, $tran_{h,\ gov}$, and $tran_{h,\ row}$, respectively, shown as Equations (20) and (21). Households' expenditure is made up of personal income tax and consumption, and $\overline{EXR}$ means the exchange rate is given exogenously, shown as Equation (22).

$$YI_h = \sum_f shif_{h\ f} \cdot YF_f + tran_{h\ ent} + tran_{h\ gov} + tran_{h\ row} \cdot \overline{EXR} \tag{20}$$

$$YF_f = \sum_a WF_f \cdot QF_{f\ a} \tag{21}$$

$$EI_h = tins_h \cdot YI_h + EH_h \tag{22}$$

Enterprises' income and expenditure behaviors are given by Equation (23) and (24). Enterprises' income YI_{ent} is from the capital return YF_K and transfer payment by government $tran_{ent,gov}$; enterprises' expenditure includes enterprises' income rate and transfer payment to households:

$$YI_{ent} = YF_K + tran_{ent\ gov} \tag{23}$$

$$EI_{ent} = tins_{ent} \cdot YI_{ent} + tran_{h\ ent} \tag{24}$$

Equation (25) defines the government's income from households' income taxes, enterprises' income taxes, production tax, duty and transfer from the rest of the world. Equation (26) defines the government expenditure including transfer payment and government consumption $\overline{QG_c}$:

$$\begin{aligned} \mathrm{YG} = {} & \textstyle\sum_i tins_i \cdot YI_i \\ & + \textstyle\sum_a ta_a \cdot PA_a \cdot QA_a \\ & + \textstyle\sum_c tm_c \cdot pwm_c \cdot QM_c \cdot \overline{EXR} + tran_{gov\ row} \cdot \overline{EXR} \end{aligned} \tag{25}$$

pwm_c is the world price for commodity c.

$$\mathrm{EG} = \sum_c PQ_c \cdot \overline{QG_c} + \sum_{i \in h,ent} tran_{i\ gov} \tag{26}$$

(4) Mathematic description of closure

Macro closure includes the factor market and commodity market clearing, current accounts and government equilibrium, and investment saving equilibrium. The factor market equilibrium is given by Equation (27). Equation (28) describes the commodity clearing. The aggregation of all factor demand is QF_{fa} which equals the factor supply QFS_f. The composed commodity QQ_c is used in $QINT_{c,a}$, households' consumption $QH_{c,h}$, government's consumption $\overline{QG_c}$, and total investment $\overline{QINV_c}$. The current account equilibrium is described by Equation (29), in which pwe_c means the commodity export price.

$$\sum_a QF_{fa} = QFS_f \tag{27}$$

$$QQ_c = \sum_a QINT_{c\ a} + \sum_h QH_{c\ h} + \overline{QG_c} + \overline{QINV_c} \tag{28}$$

$$\sum_c pwm_c \cdot QM_c = \sum_c pwe_c \cdot QE_c + \sum_{i \epsilon h,ent} tran_{i\ row} + FSAV \tag{29}$$

The investment savings equilibrium is shown in Equation (30). The savings made up of personal savings $PSAV_i$, government savings GSAV and foreign savings

FSAV equal total investment. Equation (31) defines personal savings. Equation (32) defines government savings as endogenous.

$$\sum_{i \in h,ent} PSAV_i + GSAV + FSAV \cdot \overline{EXR} = \sum_c PQ_c \cdot \overline{QINV_c} \quad (30)$$

$$PSAV_i = mps_i \cdot (1 - tins_i) \cdot YI_i \quad (31)$$

$$\text{GSAV} = \text{YG} - \text{EG} \quad (32)$$

For a Keynesian closure, Equations (33) and (34) are needed.

$$\sum_a QK_a = \overline{QKS},\ \text{WK} = \overline{WK} \quad (33)$$

$$\sum_a QL_a = \overline{QLS}, \text{WL} = \text{WL} \quad (34)$$

The static CGE model is established.

3.3.2. Elasticities Value Selection

There is another data source in CGE model besides SAM: elastic parameter. Specifically, there are four in this paper: elasticities of substitution about the added value and intermediate input, factor elasticities of substitution, Armington elasticities in the export trade, and constant elasticity of transformation (CET) elasticities. The elasticity values and micro SAM can be used to calibrate the scale parameter and the share parameters, while other parameters such as the tax rate only requires SAM's calibration; SAM and all parameters constitute the database model required. The elasticity parameters in the production and trade activities are listed in Table 2.

Table 2. Elasticities. Trade elasticity and K–L production elasticity of substitution come from Global Trade Analysis Project (GTAP)'s 7 databases [36] and the rest from the model set.

Sectors	Trade Elasticities		Factors Elasticities	
	Armington	CET	VA-INTA	K–L
01	2.91	5.81	0.6	0.5
02	2.51	5.03	0.6	0.2
03	3.52	7.04	0.6	1.26
04	2.80	5.60	0.6	1.26
05	1.90	3.80	0.6	1.40
06	1.90	3.80	0.6	1.68
07	1.90	3.80	0.6	1.68

CET: Constant Elasticity of Transformation; VA-INTA: Factors elasticity of substitution indicates the elasticity of substitution between added value and intermediate inputs; K–L: elasticity of substitution between capital and labor factor.

3.3.3. Verification of the Static Model

Scholars with CGE model experience know that different closure rules have different impacts on the simulation results. Here, the paper tries to test the impact of different closure rules on the economy and determine the selection of closure.

The verification of the static model is set as expanding government consumption by 10% and 20%, and Table 3 is the result of the economic stimulus. With a Keynesian closure, the effect of government consumption to stimulate the economy is significant. The simulation results with a Keynesian closure can be regarded as short-term effects of policy shocks on the economy: to real GDP, increasing government consumption is favorable; and increased government spending is beneficial to employment. By expanding government consumption by 10%, the labor demand growth is 4.32%, which is about 470.2 billion Yuan. According to the total labor demand of 10,942.8 billion Yuan calculated in the base period equilibrium by the model and employment number 769.90 million in China Statistical Yearbook 2007 [37], it can be calculated that the total demand of 470 billion can increase the employment number by 33.26 million. This is good news for the rest of the labor force in China's national conditions.

Table 3. Simulation Results of Expanding Government Consumption by 10% and 20%.

Simulation Scenarios	Government Consumption Expanding by 10%			Government Consumption Expanding by 20%		
Closure	**Keynesian**	**Johansen**	**Neoclassical**	**Keynesian**	**Johansen**	**Neoclassical**
Real GDP	1.975	0.232	0.346	4.213	0.487	0.656
GDP deflator	−0.089	−0.005	0.011	−0.188	−0.012	0.022
Labor Return	−1.74	—	—	−3.36	—	—
Capital Return	1.395	−0.004	−0.004	2.805	−0.006	−0.006
Labor Demand	4.322	0.649	0.956	8.788	1.256	1.897
Private Savings	1.628	2.85	0.253	3.283	5.741	0.501
Government Savings	−13.35	−21.60	−20.63	−26.33	−43.01	−41.25
Foreign Savings	−1.02	−0.51	−0.22	−1.72	−1.01	−0.42
Private Consumption	2.155	−2.668	0.636	4.325	−5.321	1.242
Government Consumption	10	10	10	20	20	20

With a Keynesian closure, the impact of 10% increase in government consumption is the decline in government savings initially: In the short term, savings and investment cannot adjust, but overall level of savings cannot meet the original level of investment, and private saving adjust endogenously; to increase the corresponding savings, households will increase labor to increase income, thus increasing the labor employment, and labor return rate falls by 1.74%. The decreasing labor real return means that the cost of production is reduced, and the enterprise expands the output scale, which leads to the increase of capital demand, so the capital increases by 1.395%. The expansion of output finally causes the real GDP to increase by 1.975%. With Johansen and neoclassical closures, government consumption has a crowding out effect on private sector investment and consumption: the initial impact of the increase in government consumption is still a decline in government savings. With a neoclassical set of an economy driven by the savings, due to the assumption that the savings are exogenous, and long-term investment can be changed, it will automatically adjust to the appropriate level in line with the savings, resulting in private sector investment declining to a new balance of savings investment. The government consumption increases output, and private investment has shrunk to reduce the output. Similarly, with a Johansen closure, economy is driven by the investment, investment is assumed exogenous, and the decline in government savings will lead the government to improve the marginal saving rate of non-government organizations to increase private savings and maintain social total savings and investment balance. The private savings are forced to rise, which causes the reduction of private consumption. The consumption rises in the government sector, and declines in the private sector. The crowding effect makes the stimulation effect of expanding the government consumption on real GDP and employment less than that in Keynesian economics. Regarding import and export, the negative effect of decreased private investment or consumption is greater than the positive effects of expanding government consumption. The imports and exports show a downward trend.

This paper continues to investigate the difference between the three classic closures by expanding government investment by 5% in Table 4. As the index values in the neoclassical closure are 0, this item is omitted.

With a Keynesian closure, government investment increased by 5% will lead to reduced government savings. Because capital formation is fixed for a Keynesian closure, the non-governmental organizations savings rate is fixed, so that the original savings cannot meet the investment needs, and private savings adjusts endogenously. Under the situation of incomplete employment, households increase income by increasing labor supply which makes the savings meet the investment needs, so labor demand increases by 7.55%, and labor return falls by 3.28%. The decline in labor return means true enterprise production cost will also be reduced. The enterprises which pursue profit maximization will expand production, which results in an increase in the capital demand, in the fully supplied capital condition, leading to a capital return increase of 2.71%. The expansion of output results in real GDP increased by 3.24%. Due to government investment expenditure increases, government consumption expenditure decreases by 0.72%. The significant GDP improvement makes the government tax revenue increase and decreases the gap of government investment and income, and, finally, the government income grows by 3.22%.

Table 4. Simulation Results of Expanding Government Investment by 5%.

	Base Value	Expanding Government Expenditure by 5%	
		Keynesian	Johansen
Real GDP	263,758.91	3.24	−0.12
Labor Return	1.00	−3.28	—
Capital Return	1.00	2.71	0.01
Labor Demand	108,896.54	7.55	−0.36
Exchange Rate	1.00	0.09	0.01
Export	94,116.73	2.63	0.64
Import	−72,936.82	3.12	0.83
Private Savings	120,036.77	2.75	4.83
Government Savings	16,488.20	15.69	−1.89
Foreign Savings	−26,084.01	0.05	0.02
Private Consumption	98,317.50	2.88	−6.87
Government Consumption	45,375.64	−0.72	−0.01
Government Investment	110,440.95	5.00	5.00
Government Income	61,863.84	3.22	−0.41
Government Expenditure	45,375.64	−0.74	−0.01

With the neoclassical closure, because savings drive the economy, increasing government investment will crowd out a large number of private investments and fully offset the effect of increased government investment to the economy, and all indicators have no changes.

With the Johansen closure, many simulation results show reverse changes because government investment in the closure has great crowding out effect on consumption. The increase in the government investment first leads to a reduction in government savings; because investment is fixed, the government savings reduction will lead the government to improve the non-government organizations' marginal savings rate to meet the investment needs. The marginal savings rate of non-government organizations is forced rise, which leads to a lot of private consumption crowd-out. This negative effect of crowding out on the GDP is bigger than the pulling effect of investment to GDP, and ultimately the real GDP decreases by 0.12%, total demand for labor reduces by 0.36%, and the income of households is significantly reduced. In the case of a Keynesian closure, the stimulation effect of expanding government investment to the economy is the best. With the neoclassical closure, expanding government investment has no effect on the economy. With the Johansen closure, the expanding government's investment has almost a negative effect on the economy, in particular, it will crowd out a large number of private consumption, so there will be a substantial decline in the welfare of households.

After integrating the two kinds of expansionary fiscal policy simulation analysis, it can be found that different macro closures have different simulation results. The reason for this difference lies in policy shock having different mechanisms under different assumptions. The most important difference of the three closures is the assumption of savings and investment. The Keynesian closure reflects a short-term economic structure. At the same time, savings and investment are rigid and cannot react to shocks. Johansen and neoclassical closure are different, and reflect long-term equilibrium.

Therefore, macroclosure selection is mainly determined by the model constructor's macroeconomic background cognition and path conduction identification of policy simulation. The different policy simulation schemes should try to select the most appropriate closure rule to deal with flexibility. When policy shock produces function within a short period, and the researcher focuses on short-term economic effects, she can give priority to the Keynesian closure, or she can consider other macroclosures.

3.4. Construction of a Dynamic Model

3.4.1. Recursive Extension Based on the Static Model

This paper refers the dynamic extension of IFPRI standard static model by Thurlow [33] and selectively makes a recursive dynamic extension to the static CGE model. The recursive dynamic attributes of most models mainly embody three aspects: capital accumulation, labor growth, and total factor productivity change. In this paper, the dynamic expansion of the static model also follows these three aspects.

For capital accumulation process, according to the classic economic growth theory, the current period of depreciation of capital stock combined with the new investment forms the capital stock of the next phase.

$$QK_{a\ t+1} = (1 - \delta_a) \cdot QK_{a\ t} + QINV_{c\ t} \tag{35}$$

$$QKS_{a\ t+1} = (1 - \delta_a) \cdot QKS_{a\ t} + \sum_c QINV_{c\ t} \tag{36}$$

where QK_{t+1} represents the capital stock during the phase t+1, δ represents the depreciation rate, and $QINV_{c\ t}$ represents the investment in phase t in Equation (36).

For labor supply, this paper uses the forecast labor supply in Table A1.

Young [38] calculated China's Total Factor Productivity (TFP) in 1978–1998. He found that the annual growth rate of TPF is 3% with official GDP growth rate. Wang and Yao [39] found that in 1952–1977 China's TFP annual growth rate is −1.56% while in 1978–1999 China's TFP annual growth rate is 2.8%. Peng [29] found that in 1992–2000, China's TFP annual growth rate is 4.5%. This paper adopts Young's [38] study result and set TPF annual growth rate as 3% to 2030, shown in Equation (37).

$$\alpha^{va}_{a\ t+1} = \alpha^{va}_{a\ t} \cdot (1 + g_a), g_a = 3\% \tag{37}$$

The capital depreciation rates of each sector are referred from Xue and Wang [40] as shown in Table 5.

Table 5. Capital depreciation rates of each sector.

Sector	7	Capital Depreciate Rate (%)
01	Agriculture	6.7
02	Coal Mining	10
03	Oil and Gas Exploitation	12
04	Electric Power Production and Supply	5.45
05	Construction	12
06	Other Industries	8
07	Service	8

3.4.2. Verification of the Dynamic Model

This dynamic model established in this study reflects the economic situation in 2007, and so the base run dynamic range is selected as 2007–2015. If the base run dynamic range is extended, there are no real data to be contrasted, thus losing the ability of error checking. However, it should be noted that, from the beginning of 2008, China's economy endured a series of external shocks, such as the world financial crisis. In order to fight the crisis and maintain growth, in November 2008, the central government of China launched an economic stimulus investment plan to stimulate economic development. This four trillion Yuan stimulus package had a significant effect on the macroeconomy. Base run must take these factors into consideration.

The simulation scenario is used as base run foundation, with the actual GDP, and outputs of agriculture, construction and service as the error evaluation indexes. Table 6 gives the test results of the dynamic model.

The variable L refers to labor demand in 2007–2013 for simulating the impact of the population ageing on the economy by CGE model, as labor is not fully employed during these years. The variable K is determined endogenously with Equation (35). The variable α is set to increase at an annual rate of 3%. Because China does not publish statistics on the output of each industry every year, some industries with statistical data are selected to compare with the forecast results. These forecast figures are very close to the actual figures of the output changes of different industries. Therefore, the construction of the dynamic model is basically successful.

Table 6. Test results of the dynamic model (2007–2013).

	2007	2008	2009	2010	2011	2012	2013
Real Output Value							
Agriculture	48,893	58,002	60,361	69,320	81,304	89,453	96,995
Construction	15,297	18,743	22,399	26,661	31,943	35,491	38,995
Service	111,352	131,340	148,038	173,596	205,205	231,935	262,204
Real GDP	268,000	316,800	345,600	408,900	484,100	534,100	588,000
Real Ratio							
Agriculture	1	1.18	1.23	1.41	1.66	1.82	1.98
Construction	1	1.22	1.46	1.74	2.08	2.32	2.54
Service	1	1.17	1.28	1.55	1.84	2.08	2.35
Real GDP	1	1.18	1.28	1.52	1.80	1.99	2.19
Forecast Ratio							
Agriculture	1	1.13	1.23	1.36	1.69	1.82	1.86
Construction	1	1.26	1.51	1.80	1.88	2.28	3.02
Service	1	1.09	1.24	1.41	1.84	2.08	2.25
Real GDP	1	1.14	1.28	1.45	1.67	1.86	2.06
Average Error	—	−0.03	0.025	−0.05	−0.075	−0.0425	0.0325

3.5. Simulation with the Dynamic CGE Model

3.5.1. The Influence of Population Ageing to Industries

Along with the deepening of the population ageing and urbanization acceleration, declining labor supply has a great impact for many industries; at the same time, changes in the age structure of the population change the corresponding household consumption, savings and investment structure, thereby affecting economic growth. In Table 7, the annual growth rate of seven industries' contribution rate to GDP shows the influences of population ageing. (1) The contributions of most industries to GDP show a negative growth trend. (2) From the long-term point of view, the influence of population ageing on labor-intensive industries is the most serious. (3) The construction industry's contribution to GDP growth rate still shows a rising trend, but the growth rate decreases annually. (4) The service industry's contribution to GDP growth rate shows a more significant upward trend, but the rate is decreasing annually.

Table 7. Annual Growth Rates of Each Industry's Contribution Rate to Gross Domestic Product (GDP) (%).

Industry	2010–2015	2015–2020	2020–2025	2025–2030
Agriculture	5.07	1.68	0.46	−0.42
Coal Mining	−1.72	0.46	1.51	2.27
Oil and Gas Exploitation	−4.14	−4.47	−4.50	−4.76
Electric Power Production and Supply	−4.02	−2.21	−3.51	−2.36
Construction	5.72	2.61	1.09	0.19
Other Industries	−4.08	−3.28	−2.43	−2.03
Service	2.42	1.46	1.02	0.83

These phenomena can be understood as follows: (1) due to the decline of labor supply, the international competitiveness of China's labor-intensive industries declines, so that these industries reduce the pulling of the GDP; (2) population ageing acceleration will reduce the social savings rate, increasing the uncertainty of China's capital accumulation, thus the negative effect on capital intensive industries is relatively severe; and (3) the age structure of the population changes will reduce the amount of consumption, and change the consumption structure, thus the demand for service is rising, and, correspondingly, the pulling power of related industries on the economic changes.

3.5.2. The Influence of Population Ageing to Gross Domestic Product (GDP) and Its Components

Assuming the growth rate of labor supply in 2010–2030 is the same as the growth rate during 1990–2010, the other parameters and variables are consistent with the baseline scenario.

From the simulation results in Table 8, it can be seen that GDP growth rate at the base scenario in 2010–2015 keeps a rate of 9.02%, but the economic growth shows a declining trend; in 2025–2030, GDP growth rate goes down to 5.22%. Compared to the scenario without ageing assumption, i.e. the population growth rate stays at the 1990–2010 level with other conditions constant, GDP growth rate keeps a rate of 11% in 2010–2015, and, when it comes to 2025–2030, GDP growth rate keeps at 10% on average, almost double the base scenario, which indicates that demographic gift did pay an important role in promoting China's economy. When it gradually disappears, China's economic growth will slow down continuously without other policy stimulation.

Table 8. GDP growth rates of the base scenario and the no ageing scenario (%).

Scenario	2010–2015	2015–2020	2020–2025	2025–2030
Ageing	9.022	7.233	6.467	5.223
No Ageing	11.139	10.727	10.446	10.018

Furthermore, from the GDP components view (Table 9) and under the background of population ageing, population ageing has little influence on consumption and investment to GDP ratio. This is mainly because the model assumes that the government does not introduce any stimulating consumption or investment policies. In exports, there is a big difference in the no-ageing scenario and base scenario. In the no-ageing scenario, the average contribution rate of export rises to 45.60% in 2030 from 28.54% in 2015, while under the base scenario, the average contribution rate of export is 38.22% in 2030. The population ageing makes the total labor force decline, labor costs rise, and the comparative advantage of low labor costs decline. Therefore, the pulling effect by exports to economic growth will continue to decrease. It is worth noting that the population growth slowdown will affect the corresponding proportion of consumption and investment. Although the proportion of the consumption and investment accounted for GDP changes little, from the absolute number, its growth rate is lower than that in the population ageing scenario. For example, in the context of population ageing, the contribution rate of consumption and investment is 45.621% and 51.569%, respectively, in 2030, while, in the no-ageing scenario, those respective values are 46.146% and 50.620%. Therefore, the government should adopt policies to stimulate consumption, actively expand domestic demand, and enhance the basic role of consumption on economic growth, while increasing and guiding private investment to play a key role in investment of economic growth.

Table 9. GDP components of the base scenario and the no ageing scenario.

	Scenario	2015	2020	2025	2030
Consumption	Ageing	48.731	47.813	46.618	45.621
	No Ageing	49.022	48.023	47.235	46.146
Investment	Ageing	47.686	49.321	50.565	51.569
	No Ageing	47.351	48.563	49.837	50.620
Export	Ageing	28.537	30.748	34.231	38.228
	No Ageing	28.967	32.633	38.360	45.638
Import	Ageing	−25.223	−27.915	−31.564	−35.537
	No Ageing	−25.460	−29.328	−35.262	−42.262
GDP		100	100	100	100

4. Discussion and Conclusions

The abovementioned labor force sustainability measures indicate that the labor supply will have peaked in 2014 and then will decline annually. Furthermore, China will have faced a labor pressure after 2015. Indeed, according to the National Bureau of Statistics [41], China's working age population (16–65) in 2015 is 1003.61 million, showing a downward trend for the second consecutive year; at the same time, the proportion of working age population reached 73%, decreased by 0.4 percentage point compared with 73.4% in 2014. While the labor participation rate maintains a declining trend as Feng [42] found throughout his sample period (2002–2015), the results generally accord with prediction made before, which proves the correctness of the model. Thus, according to the existing level of economic development and economic structure situation, the labor force imbalance (shortage) will gradually increase after 2017. The labor supply will not meet China's needs for an economically sustainable development.

In fact, a structure contradiction exists in the labor market, which means that labor shortage and oversupply exist simultaneously. According to the supply and demand law, those industries with fast wages increase and high-pay face labor shortage because they demand people with high quality or skills, while those industries with slow wages increase and low-pay face a serious labor shortage. The oversupply of labor pertains mainly to people with few skills that include the labor working in the informal industries. Those people who work in informal industries with low income and bad working environments are not included in the statistical data. Over the past decade, China has conducted a total of three census surveys: the sixth census in 2010 [43], census of 1% population sample survey in 2005 [44], and the fifth census in 2000 [45]. However, unfortunately, unlike the census of 1% population sample survey in 2005 [44], the two other censuses did not provide information on the type and employment status of workers. Therefore, the 1% population sample survey data in 2005 are the most authoritative data of the current study of China's informal employment size and characteristics. The proportion of non-agricultural employment of Chinese cities and towns in informal employment is 58.85%. Because the employment number is 277 million in 2005, the number of informal employment should be 163 million. If this large number of informal workers is taken into account, the gap of labor force demand and supply will be put off to 2036 in the econometric model prediction, 2030 in the elasticity method at 6% GDP growth rate, 2028 in the elasticity method at 8% GDP growth rate, and 2026 in the elasticity method at 10% GDP growth rate.

Form the shock of labor supply declining, the contributions of most industries to GDP are showing a negative growth trend. From a medium- and long-term point of view, the influence of population ageing to the labor-intensive industries is the most serious. The construction industry's contribution to GDP growth rate still shows a rising trend, but the growth rate decreases annually. The service industry's contribution to GDP growth rate shows a significant upward trend, but the rate is decreasing annually. The economic growth shows a declining trend. Population ageing has little influence on consumption and investment to GDP, but from the absolute number, its growth rate is lower than that in the population ageing scenario. The pulling effect by exports to economic growth will continue to decrease.

In this study, a labor force sustainability model is constructed by using population ageing CGE mechanism to study the impact of labor force supply and demand to the economically sustainable development in the future. This study shows how the model can be used to predict the future population structure, and then calculate the balance of labor supply and demand, and shows how the labor force imbalance affects the macro-economy, specifically the outputs of different industries and the levels of consumption and investment of the economy.

Since the population ageing will slow down China's economic growth and hinder the improvement of living standard, the government should take active measures to deal with the challenges of population ageing. Increasing the total fertility rate to slow down the rate of population ageing to reduce the negative impact of population ageing on economic growth is one of the most popular international policy measures. However, the Australian Productivity Council's simulation study found that raising the fertility rate to cope with the problem of population ageing is not a wise choice for Australia. From 2000 to 2045, the impact of fertility increase will raise not reduce the total dependency ratio in Australia. The impact to GDP of increased education expenditure and subsidies for families and child care caused by fertility rate will exceed the impact to GDP of increased health and elderly care expenditure caused by population ageing [46]. The most appropriate public policy to address the negative impact of population ageing is not a policy that will bring another problem [47]. Technological progress and productivity improvement are the fundamental ways to deal with the negative impact of population ageing on economic growth. The results of this model also found that in the case of population ageing, technological progress is the core of sustainable economic growth in China. Therefore, the government should actively take measures to stimulate the development of productivity. As some Western scholars have pointed out, although in the ageing of the population labor force will be shrinking, the increase of human capital stock will make the workers more intelligent and more productive, which is equal to the increase of labor supply [48].

Because of declining fertility, if the benefits that support families with children are not raised and the costs are not reduced, as long as the social pension system is running well, it is difficult to rebound the low birth rate. Continued low fertility rates will lead to a continuing ageing population, which in turn will make it difficult to maintain the social pension system. Perhaps only when the social pension system breaks down, it may lead to a reconstruction of the social pension and foster system, and influence the fertility rate so that low fertility rate rebounds and returns to replacement level.

Germany, France, Russia, Singapore, Hong Kong, and Taiwan have taken a series of measures to support the family and reduce the cost of raising children in order to raise the level of fertility. The main measures include the government paying maternity period salary, tax cuts, monthly or one-time paid child subsidies, free education for children, providing housing subsidies or even offering free housing. Some high welfare countries under the severe stress of the population ageing in Northern Europe reform the old pension system in order to raise the level of fertility and reduce the pressure of pension payments. For example, Finland from the beginning of this century carries out the reform of the pension system through raising the retirement age, reducing the proportion of the average pension payments and the collection of pension tax.

China is constructing a social security system that covers the city and countryside, while the social pension system will be constructed gradually. China's population ageing is continuously increasing. Even if there is no birth control, it is still very difficult to increase the fertility rate for two reasons: China gradually formed a social pension system, and children are not required to care for their elderly parents as was traditionally common; and the urbanization process in China is advancing at a speed of nearly one percentage point each year, which discourages people having more children because it causes high living and educational costs. In 2015, the urbanization rate of China is 50%, while, according to the World Bank WDI data 2016 [49], the urbanization rate of developed countries is over 70%, within which the rates in the United Kingdom, the USA, and South Korea are 89.7%, 80.8%, and 80.8%, respectively. By comparison, the urbanization rates of developing countries such as Mexico, North Korea, and Mongolia are, 76%, 61.1%, and 56.7%, respectively. China's current urbanization rate is not only lower than the developed countries, but also lower than many developing countries. Even if the country does release birth control, the fertility rate may still be lower than 1.8. Therefore, China's population ageing will be a persistent and serious problem.

The population ageing problem needs to be paid more attention. From the mechanism of ageing, in the absence of other effective interventions, the ageing of the population will become a long-term feature in the future. We need to fully study the impact of ageing on the social economy. When we develop relevant social and economic policies, we should take ageing as one factor.

Also, a comprehensive view of the declining fertility rate is required. While China implements birth control policies, it does not have subsidies for children. Public transfer support is mainly embodied in the nine-year compulsory education. The elderly in urban areas obtain income through social pension system. Therefore, in China's urban areas, social pension system is actually formed. According to this reality, declining fertility rates need to be carefully evaluated as well as whether the decline is decided by national policy control or families' choice so that current population policy and its implementation effect can be evaluated.

The birth rates of Japan, Korea, Singapore, Hong Kong, Macau, and Taiwan are the lowest in the world. Due to the very low fertility rate and the negative impact of population ageing, these countries encourage fertility but with little success. China needs to learn from their experience. Although China's population is large, the low fertility rate will bring many negative effects. The social security system needs to be improved, and the level of social pension needs to be determined reasonably. Because the pension system has a direct impact on fertility rate and the population ageing degree and the construction and reform of social security system, the selection of social pension level needs to be based on the considerations of a healthy population age structure. Appropriate pension standards should be related to the reasonable cost and benefit of child-rearing, and correspond with the reasonable proportion of resource transferring from the working-age population.

Author Contributions: Zhichao Sun conceived and designed the model, performed experiments and wrote the paper; Yu Song analyzed the data; Ivan K.W. Lai contributed to modifications.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix

Table A1. Forecast of labor supply from 2014 to 2050.

Year	Population in 15–64 Age Group	Labor Supply	Year	Population in 15–64 Age Group	Labor Supply	Year	Population in 15–64 Age Group	Labor Supply
2014	977850287	779346679	2027	928576649	728004093	2040	826708835	637392512
2015	975328463	776361457	2028	917469464	718378590	2041	821509601	632562393
2016	972374894	773038041	2029	910601880	712090670	2042	817737174	628839887
2017	965744319	766800989	2030	902875829	705146022	2043	813294303	624610025
2018	958766844	760302107	2031	895606106	698572763	2044	808681362	620258605
2019	950946412	753149558	2032	890612342	693787014	2045	804902321	616555178
2020	942787922	745745246	2033	880739820	685215580	2046	801142632	612874114
2021	939119751	741904603	2034	872795781	678162322	2047	796092619	608214761
2022	933624923	736630064	2035	862747113	669491760	2048	793714195	605603931
2023	930324825	733095962	2036	854451796	662200142	2049	792060105	603549800
2024	930949222	732657038	2037	846665592	655319168	2050	790496583	601567900
2025	930637300	731480918	2038	839266030	648752641	—	—	—
2026	933650123	732915347	2039	832343598	642569258	—	—	—

Table A2. Forecast of labor demand from 2014 to 2050.

Year	Econometric Model	Elasticity Method at 6% GPD Growth Rate	Elasticity Method at 8% GPD Growth Rate	Elasticity Method at 10% GPD Growth Rate
2014	774059580	774971336	776704858	778438380
2015	778151839	780207817	783702192	787204375
2016	782055855	785479681	790762565	796069083
2017	785780285	790787168	797886545	805033617
2018	789333392	796130517	805074705	814099101
2019	792723056	801509970	812327623	823266671
2020	795956796	806925773	819645882	832537477
2021	799041783	812378171	827030072	841912681
2022	801984861	817867410	834480786	851393460
2023	804792557	823393740	841998624	860981002
2024	807471100	828957412	849584189	870676509
2025	810026429	834558677	857238093	880481197
2026	812464213	840197790	864960951	890396295
2027	814789860	845875006	872753384	900423048
2028	817008526	851590584	880616020	910562712
2029	819125134	857344781	888549489	920816559
2030	821144378	863137860	896554432	931185874
2031	823070736	868970083	904631491	941671958
2032	824908483	874841713	912781316	952276126
2033	826661692	880753019	921004562	962999708
2034	828334254	886704267	929301893	973844047
2035	829929879	892695728	937673973	984810505
2036	831452104	898727673	946121478	995900456
2037	832904308	904800376	954645087	1007115291
2038	834289709	910914112	963245484	1018456416
2039	835611383	917069158	971923363	1029925254
2040	836872259	923265795	980679420	1041523242
2041	838075135	929504302	989514361	1053251836
2042	839222680	935784962	998428896	1065112505
2043	840317436	942108061	1007423742	1077106737
2044	841361834	948473885	1016499622	1089236036
2045	842358189	954882724	1025657268	1101501923
2046	843308713	961334866	1034897414	1113905936
2047	844215512	967830606	1044220805	1126449630
2048	845080598	974370237	1053628190	1139134580
2049	845905891	980954057	1063120326	1151962374
2050	846693220	987582363	1072697977	1164934622

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