

The Impacts of Population Aging on China's Economy

Global Journal of Emerging
Market Economies
14(1) 105–130, 2022
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DOI: 10.1177/09749101211067079
journals.sagepub.com/home/eme



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Abstract

The Chinese economy had an extraordinary average GDP growth rate of 8.50 percent from 1980 to 2018. However, the implementation of one-child policy in the late 1970s has depressed the total fertility rate to below the replacement rate since 1992. China thus experienced an increasing composition of older populations in the past three decades, which puts pressure on Chinese economic growth and makes its eye-catching economic growth potentially unsustainable. This study develops an overlapping generations (OLG) model to investigate the impacts of this demographic transition in the Chinese economy. This study conducts six policy reform exercises to examine measures that could improve the sustainability of fiscal and pension systems. The simulation results indicate that a mild tax increase on either wage income or consumption does not improve the fiscal stance but creates distortionary effects on saving and consumption behaviors. Of the pension reform measures considered, the combination of extending the mandatory retirement age and cutting the replacement ratio offers the most significant improvement to pension sustainability. However, increasing the contribution rate of the working-age population has the least effect on pension sustainability and a noticeable distortionary effect on the consumption ratio and saving rate.

Keywords

Population aging, China's economy, pension reform, OLG model

Introduction

China as the World's Factory

China commenced economic reforms in 1978, transitioning from a centrally planned system to a market-oriented economy. Since then, China's growth engine took off and the economy maintained a rapid growth rate for decades. In the early economic development stage, China utilized its advantage of vast

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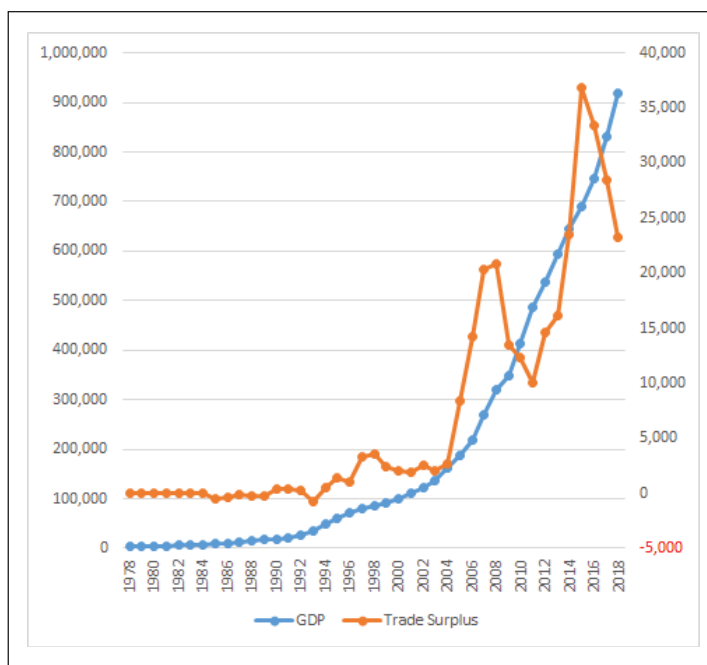


Figure 1. GDP and Trade Surplus of China, 1978–2018

Source: National Bureau of Statistics of China (<http://www.stats.gov.cn/>).

Note: The left and right axes represent GDP and the trade surplus, respectively. The unit of measure in both axes is 100 million RMB.

and cheap labor fully to manufacture labor-intensive industrial goods. Meanwhile, the Chinese government implemented various measures to attract foreign direct investment (FDI) to fill the gaps in capital and technology required for its development. Export-oriented manufacturing industries did not just play the role of China's growth engine but also made China "the world's factory." Factors that contributed to China's rapid economic growth include the abundance of low-wage workers, a low-compliance regulatory environment for manufacturers, and a strong business ecosystem in which a network of low-wage workers, a technical workforce, suppliers, component manufacturers, distributors, and consumers evolved to create a cost-effective environment for producers. Besides, the artificially weak Renminbi (RMB) and the relatively stable exchange rate provided China's export goods with price competitiveness in the world market. The Chinese government also introduced an export tax rebate policy in 1985 to boost the competitiveness of its exports; all exported manufactured goods were subject to zero VAT or enjoyed a VAT rebate. These tax and foreign exchange policies, together with other macroeconomic environment factors, attracted foreign investors and producers searching for low-cost products to establish production lines in China. Consequently, GDP per capita (constant 2010 US\$) in China grew from US\$ 347.12 in 1980 to US\$ 7752.56 in 2018. The average GDP growth rate from 1980 to 2018 was 8.50 percent per year. Figure 1 illustrates the GDP growth trends in China. The figure shows that after the economic reform in 1978, GDP growth was associated with the expansion of its trade surplus.

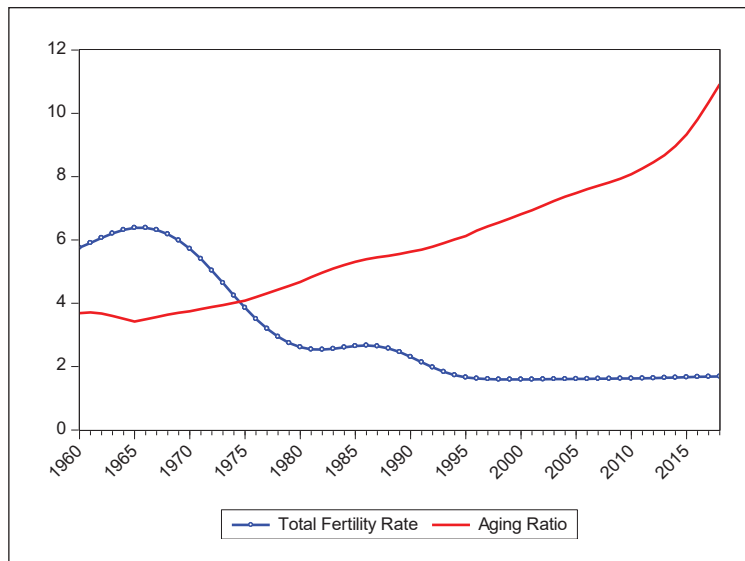


Figure 2. Total Fertility Rate and Aging Rate

Source: World Development Indicators, World Bank (<https://data.worldbank.org/country/china>).

The splendors of high growth rates hide some real concerns. The improved income status of Chinese people implies rising opportunity costs of childbearing. As in the Western developed economies, the fertility rate in China declined with the rise in national income. Besides the negative economic incentive for childbearing, in the era of economic reform, China also introduced an extreme population-planning program in 1979, the so-called “one-child policy.” Under this policy, only rural parents could have a second child if the first child was a daughter. The economically induced and politically mandated low fertility accelerated the pace of population aging in China.

The one-child policy lasted for more than three decades. In October 2015, the government of China officially removed regulations to allow a two-child limit for parents (Zeng & Hesketh, 2016). However, the fertility rate in China could not recover rapidly (Li et al., 2019). As Figure 2 illustrates, the aging rate (the ratio of population aged 65 and above to the total population) in China has increased since 1965 and accelerated after 2010. However, the total fertility rate decreased since 1965 and remained steady after 1995, at a rate of approximately 1.60. The low fertility rate and expanding longevity are the major forces driving population aging in China.

Based on the medium variant population projections by the Population Division of the United Nations (UN),¹ China will become a super-aged society in 2035 when the share of the aged population (ages 65 and over) exceeds 20 percent of its total population. Figure 3 illustrates the Chinese population structure from 1980 to 2050, as projected by the UN. The figure shows that the working generation, aged 15 to 64, will decline by approximately 8.3 percent from 2020 to 2050. On the other hand, retired generation, aged 65 and over, will increase by 11.7 percent from 2020 to 2050. The shrinking share of the working-age population and the expanding share of the old-age population imply an increasing old-age dependency ratio that will hurt future economic growth in China and generate pressure on the pension system.

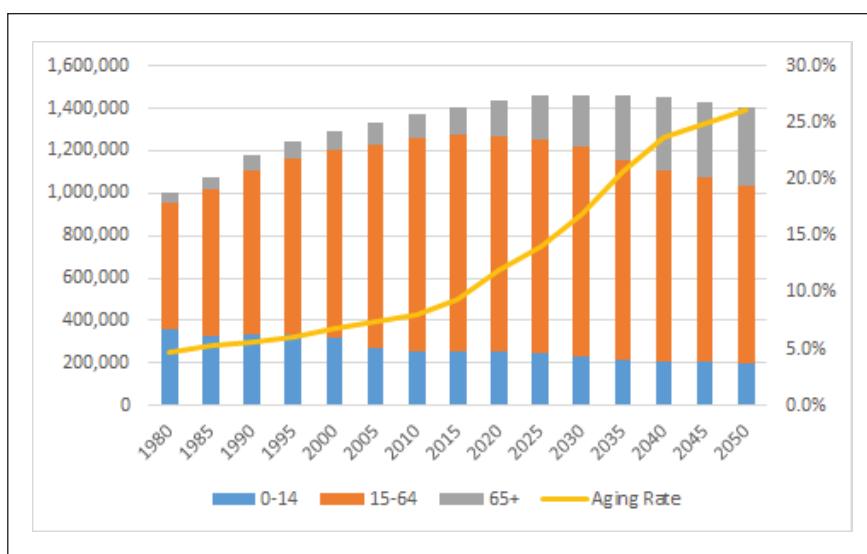


Figure 3. Historical and Projected Population by Age Group, 1980–2050

Source: The UN. <https://population.un.org/wpp/Download/Standard/Population/>

Note: The left y-axis reports the total population in units 1,000 persons; the right y-axis reports the aging rate measured as a percentage.

Background of China's Population Aging

Demographic development in China has several economic implications. The shrinking working-age population implies a decrease in the production power of the economy, whereas an increasing share of retirees implies an increase in the demand for consumption by the nonworking generation. Thus, China may face a domestic shortage of goods and services, which may lead to a decrease in China's exports overseas. This prospective development will end China's status as "the world's factory." Moreover, the changes induced by population aging in China may not only affect the Chinese domestic economy but also propagate to other economies importing goods from China.

The immediate effect of population aging on the economy would be on labor supply, production, and national income. A secondary effect would be on households' savings, consumption, and asset accumulation, with extended effects on capital formation. A further impact would be on the social welfare system, which would affect the government's budget and the pension system. This study investigates the effects of population aging on China's economy and examines policy measures that can mitigate the adverse impacts of population aging. This study uses a computable general equilibrium overlapping generations (OLG) framework for the investigation. The basic OLG model is driven by the life choices of a utility-maximizing representative agent in terms of labor supply, savings, and retirement, subject to a utility function that governs the individual's preferences at any given period and throughout the individual's lifetime. Several studies suggest that the OLG model is an appropriate framework to study the effect of demographic change on the macroeconomy because such a model setup permits researchers

to project the dynamics of savings and asset transfer over time and across generations (Auerbach & Kotlikoff, 1987; de la Croix & Michel, 2002; Diamond, 1965).

In the next section, we review the previously published literature and identify the key economic issues in the studies of population aging. This is followed by a description of the theoretical OLG model setting used in this study. The subsequent section illustrates the baseline results from the computational model and conducts simulation exercises using various policies to address measures that could be considered for mitigating the macroeconomic impacts of population aging in China. The last section concludes by summarizing the findings and discussing the policy implications.

Literature Review

Over the past decades, rapid economic growth in the BRICS emerging economies attracted much attention from industrialized Western economies. Notably, China, one of the BRICS members, after the implementation of the reform and opening-up policy in 1979, kept its annual GDP growth rate around 9 percent for more than 30 years and made a significant contribution to the global economy (Lin, 2011). Taking advantage of its demographic dividend, China became a world factory (Cai, 2018). Meanwhile, China's one-child policy and economic development decreased the demand for children (Becker & Lewis, 1973; Bongaarts & Greenhalgh, 1985), while the improved health conditions and rise in income levels drastically increased life expectancy in China (Luo & Xie, 2020). China has long had the largest population worldwide. Therefore, a slight shift in the age structure in China may produce great changes in terms of scale.

As most of the developed countries in Europe experienced population aging in the 1970s, there is a growing body of research that discusses the relationship between aging demographic transition and the many economic outcomes (Hills, 1989; Kim & Lee, 2007; Maxime & Mérette, 1998; Schön & Stähler, 2020). Previous studies conclude that population aging influences the economy in several aspects, including the labor force (Muto et al., 2016; Yashiro & Oishi, 1997), saving rate (Braun et al., 2009; Horioka et al., 2007; Mason, 1988), and fiscal balance (Ihori et al., 2011).

Population aging is a demographic dynamic that arises from the combined effects of declining fertility and increasing life expectancy. In East Asia, Japan is the most aged economy. Total fertility in Japan had declined since 1960 and remained at a stable rate around 1.42 after the year 2012; life expectancy at birth increased from 67.666 in 1960 to 84.211 in 2018 and it continues to rise.² Two other rapidly aging economies in Asia are China and the Republic of Korea. From 1960 to 2018, life expectancy at birth in China increased from 43.725 to 76.704 and it rose from 51.297 to 72.095 in Korea. The total fertility rate in China and Korea has shown a falling trend since 1960. However, total fertility in Korea dropped more rapidly. In 2018 the total fertility rate in Korea was 0.997 while it was 1.69 in China.

Various studies had investigated the impacts of population aging on Asian economies. Park and Shin (2012) investigated the impact of the demographic transition on the economic growth of 12 developing Asian economies from 2011 to 2020 and projected the impacts of population aging on these economies from 2021 to 2030 using the United Nations (UN) population projections. This study first estimated the impact of the old-age dependency ratio and the youth dependency ratio on labor force participation, capital accumulation, and the growth of total factor productivity (TFP), and then inferred their effects on economic growth. The study concluded that population aging has a sizable adverse impact on these 12 Asian economies. Otsu and Shibayama (2016) also investigated the effect of population aging on Asian economies. This study used a general equilibrium model to investigate the effects of projected population aging on potential growth in 17 Asian economies over the period 2015–2050. They concluded that

demographic aging is harmful to potential economic growth in Asian economies; this adverse effect is due to the reduced labor participation, capital accumulation, and TFP caused by population aging and population shrinking.

Some studies focused on the impact of population aging on the Korean economy. Kim (1999) addressed the issues relating to living arrangements and employment status of the elderly. The traditional family caregiving system is fragile in the rapidly aging society so that the government should provide social welfare and social security for the country's growing elderly population. Phang (2011) focused on the effect of demographic aging on productivity change, economic growth, and old-age income security in Korea. The author proposed policy measures to improve income security for the elders and to promote old age employment by subsidizing employers. Lee et al. (2017) specified an extended partial adjustment model to investigate the effects of demographic change in both the short run and long run. This concluded that population aging harms Korea's economic growth; policy measures that encourage the labor force participation of the old age workers can mitigate this adverse effect. Besides, the model fitted results indicated that population aging had a much more severe impact on the Korean economic growth than aging on the Japanese economy. The authors made a warning on the prospective Korean economic growth and claimed that Korea's economic future may be gloomier than Japan's present status because Korea's aging progress is more rapid than that in Japan and Korea's demographic prospects are even worse. They called for a holistic policy package to mitigate the problems faced by the Korean economy and claimed that the current stand-alone policy that aims to boost fertility to be ineffective.

Given that Japan had noticeable economic growth between 1960s and 1980s and that Japan is the first aged economy in Asia, many studies examined the effects of population aging on various macroeconomic aspects, including consumption, saving, investment, labor market evolution, fiscal sustainability, and pension reform schemas. Faruquee and Mühleisen (2003) investigated the impact of population aging on fiscal sustainability in Japan. They used a general equilibrium model to estimate the output loss caused by demographic changes and assessed the impact of aging on Japan's government finances. Demographic changes affect labor supply and thus national output on one hand; population aging has implications for aggregate consumption, saving, and investment on the other. The aggregate saving behavior in this study is modeled based on empirical age-earnings profiles using a life-cycle approach. This article then compares the effects of fiscal policy options to their impacts on output growth and economic welfare. Shimasawa (2007) developed a computable endogenous growth OLG model with human capital accumulation to investigate the effects of policy reform in the aging economy of Japan. The simulation results indicate that pension reform and fiscal consolidation can promote human capital accumulation and thus accelerate economic growth. Shimasawa and Oguro (2010) extended the OLG model to a multicountries case, quantified the impacts of immigration and fiscal reconstruction. They concluded that immigration will neither improve the Japanese economic growth nor the welfare of current and future generations. The study concluded that substantially increased inflows of working-age immigrants would alleviate the need for future fiscal reform and also help to dramatically reduce the public pension burden on the working generations. Muto et al. (2016) used an OLG model to investigate the macroeconomic impact of population aging on the Japanese economy. It finds that Japan's population aging has adverse effects on GNP growth, per capita GNP, and various fiscal variables. The decline in fertility rate plays a dominant role in those adverse effects as it reduces both labor force and saver populations. The simulation results from an extended open-economy OLG model indicate that a decline in the domestic capital return encourages investment in foreign capital and thus alleviates the adverse effects of population aging on GNP. Hsu and Yamada (2017) investigated the impact of population aging on the Japanese economy and examined the effects of reforms on health insurance and the fiscal system. They found reforms involved a conflict of intergenerational interests; the potential reforms improve the

welfare of future generations at the welfare costs for the current population. The analysis concluded that a gradual reform with an intergenerational redistribution would be more feasible than an immediate reform.

As China is the second-largest economy in the world, the economic consequences of demographic aging in China have attracted much attention in the scholarly community. Eggleston et al. (2013) argues that given the unprecedented demographic changes, several factors would determine future economic growth in China. Among the determinants are labor input and productivity, capital investment and savings, and multifactor productivity. Many studies examine the relationship between population aging and economic performance using China as an object of investigation. The subjects of investigation include the age structure and international trade (Fukumoto & Kinugasa, 2017; Gudmundsson & Zoega, 2014), population aging, household savings, and the current account (İmrohoroglu & Zhao, 2020; Zhu, 2011), population aging and public pension provisions (van Dulleman et al., 2017), aging and economic growth (Park & Shin, 2012), and household expenditures (van Dulleman et al., 2017). As the demographic changes in China are distinctive in terms of scale, scope, and speed, examining their effects on economic activities is still subject to open debate.

The recent progress of the computational general equilibrium (CGE) model and computer software popularized the use of the OLG model to study the macroeconomic effects of population aging. The seminal works of Samuelson (1958) and Diamond (1965) explicitly introduced the concept of age-specific choice in the OLG model with a two-period lifetime (young, old). In Diamond's (1965) OLG model, there is no government or social security system. Auerbach and Kotlikoff (1987) extends the original OLG model and introduces 55 OLG of adults and government institutions (the fiscal authority and the social security systems) into the model. Auerbach and Kotlikoff (1987) popularized OLG models in aging economy studies because the model is capable of making predictions on the outcomes of fiscal policy reform and pension restructuring. de la Croix and Michel (2002) and Weil (2008) offer a comprehensive introduction to the setup and derivation of the basic OLG model. Cipriani (2014) applies the OLG model to investigate the effect of declining fertility rates on the pay-as-you-go (PAYG) pension system. Choi and Shin (2015) use the OLG model to investigate the effect of population aging on the economic growth of Korea. Hviding and Mérette (1998) apply the OLG model to investigate the macroeconomic effects of pension reform in the context of population aging in seven OECD countries. Several works incorporate the government sector into the OLG model. Heer and Maussner (2009) assume that the government adjusts pension contributions based on inflation. Fougère and Mérette (1999) permit the government to collect different tax rates depending on the individual's abilities determined by the amount of education. Sanchez-Martin and Sanchez-Marcos (2010) allow the government to choose to penalize early retirement by imposing a penalty for an insufficient history of pension contributions over the individual's lifetime. Kudrna et al. (2015) investigate the dynamic fiscal effects of the demographic shift in Australia.

Following the recent developments in the methodology of population aging studies, we apply the OLG model to analyze the effects of population aging on China's economy.

The Model

Basic Model Structure

The basic model in this study relies heavily on Hsu (2017) and Heer and Maussner (2009), which is an extended dynamic OLG model. This model allows us to analyze the effect of population aging on

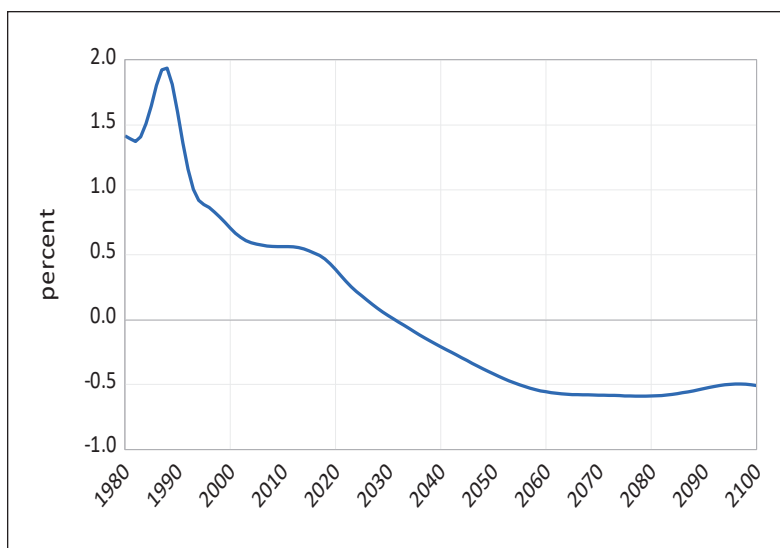


Figure 4: Population Growth Rate (%) in China, 1980–2100

Source: Authors' calculation based on UN population estimates.

savings, capital formation, and economic growth. We also use the model to evaluate the effect of public pension reform on the welfare of agents.

There are four sectors in the model economy: households, firms, the government, and a PAYG pension system. A representative individual with multiple generations in the household sector has a fixed lifetime of up to 78 years.³ The individual starts working at age 18 and retires at age 60.⁴ Each individual earns wage income and builds up savings for old age. The representative agent maximizes his/her intertemporal utility function with consumption. Firms maximize profits. The government collects taxes and social security contributions. The model is a one-country closed economy model, where both the goods and factor markets are assumed to be perfectly competitive. A period, t , in the model corresponds to one year. At each period, a new generation of households participates in the economy as newborns. This model considers only working and retired generations. The newborns have a real-life age of 18 years, corresponding to age 1 in the model, denoted by $s = 1$. All generations retire at age 60 and live up to a maximum age of 78 years. At each period, 60 different generations coexist.

Demographic Transition

Let N_t^s be the number of agents of age s at t . We assume that the population grows at the exogenous rate n_t , where we adopt the growth rates from the estimates by the Population Division of the UN. Figure 4 illustrates the population growth rate of China for 1980–2100. The year 2000 corresponds to $t = 0$, and we assume that the economy is in a steady state at $t = 0$. The population at time t is given by the following:

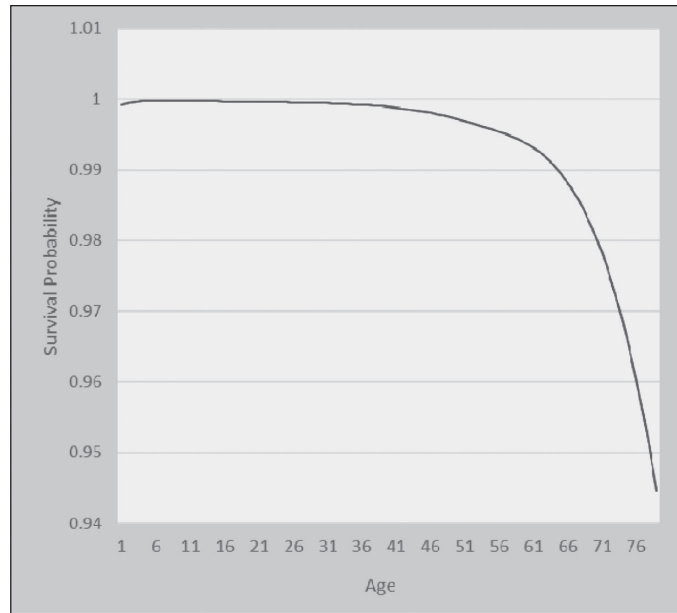


Figure 5. Survival Probability by Age

Source: Authors' calculation from China Life Insurance Mortality Table (2010–2013).

$$N_t = \sum_{s=1}^{60} \phi_t^s (1 + n_{t-1}) N_{t-1}^s \quad (1)$$

where ϕ_t^s is the survival probability of generation s at time t ,⁵ N_t is the aggregate population at time t . Figure 5 illustrates the survival probability of individuals at physical age 0–78, calculated as $\phi_t^s = 1 - q_t^s$, where q_t^s is the average mortality rate of males and females at age s .

Household Sector

Each household comprises of one representative worker. Households born in year t maximize intertemporal utility at the beginning of age 1 in period t :

$$\text{Max} \sum_{s=1}^J \beta^{s-1} \left(\prod_{j=1}^s \phi_{t+j-1, j-1} \right) u(c_{t+s-1}^s, l_{t+s-1}^s) \quad (2)$$

The instantaneous utility $u(c, l)$ is a function of consumption c and labor supply l :

$$u(c, l) = \frac{(c^\gamma (1-l)^{1-\gamma})^{1-\eta}}{1-\eta}, \quad \eta > 0, \gamma \in (0, 1), \beta > 0 \quad (3)$$

where $u(c, l)$ satisfies the usual concavity requirement, γ describes the trade-off between leisure and consumption, and $1/\eta$ is the elasticity of intertemporal substitution.

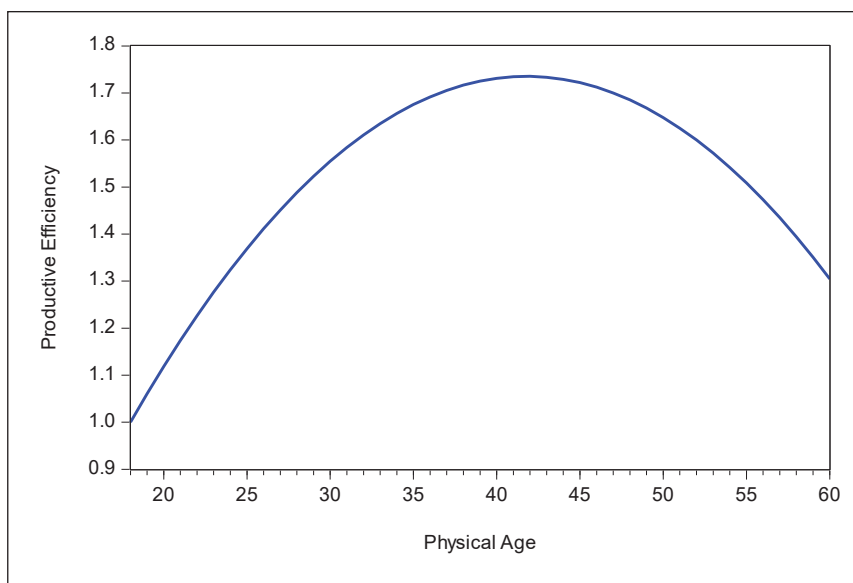


Figure 6. Lifetime Age-Earning Profile of a Representative Household

Source: Authors' estimations.

Note: Physical age 18 corresponds to age 1 ($s = 1$) in the model.

This model assumes that each agent's wage income is commensurate with his/her lifetime productivity and that life cycle productivity is hump-shaped to the individual's working age. That is, at the early stage of the agent's career, the individual is less experienced and less productive and thus earns a lower wage income. As working experience increases, the individual accumulates knowledge such that his/her productivity increases in the middle age of the career. At the later age of the career, the individual is aging, and is less agile and adaptive to new technology, leading to a decline in productivity. An individual agent's lifetime wage income profile corresponds to his/her life cycle productivity.

We assume that an agent's efficiency e^s depends on his/her age, $s \in S \approx \{1, 2, \dots, 60\}$ and uses the data from the 2017 China Household Finance Survey (CHFS2017)⁶ to estimate the age-efficiency profile to reflect the age-earning profile in China. The estimated life cycle labor efficiency profile is as follows:

$$e^s = 1.000 + 0.06181 \times s - 0.001299 \times s^2 \quad (4)$$

The efficiency of the representative generation is normalized with its efficiency at the beginning of the agent's career (Figure 6).⁷ The age-earning profile reaches its peak before the retirement age and then decreases thereafter.

The net wage income of the working-age population in period t of an s -year old is as follows:

$$(1 - \tau_w - \tau_b) w_t e^s l_t^s, \quad (5)$$

where w_t is the wage rate per efficient labor unit in period t , l_t^s is the labor supply of generation s , τ_w is the wage income tax rate, and τ_b is the worker's pension contribution rate. The newborn generation does not possess any assets at the beginning of age $s = 1$; hence, the assets of an agent with $s = 1$ is $\Omega_t^1 = 0$.

We assume that older generations do not have bequest incentives, so parents do not leave bequests to their heirs.⁸ The government confiscates all accidental bequests. Households with ages greater than 1 earn an interest income with wealth saved in previous periods. The interest rate on assets is rt , $r_t \in \mathfrak{R}$. Capital income is taxed at a rate of τr . Additionally, households receive lump-sum transfers Tr_t from the government. The retired household receives pensions b_t^s . For the working-age population, we have $b_t^s = 0$ if $s < R$ (where $R = 42$, the beginning of the retirement age in the model).

The budget constraint of an s -year-old household at time t with wealth Ω_t^s is as follows:

$$b_t^s + (1 - \tau_w - \tau_b)w_t e_t^s l_t^s + [1 + (1 - \tau_r)r_t]\Omega_t^s + Tr_t = c_t^s + \Omega_{t+1}^{s+1}. \quad (6)$$

We assume that the household's savings are held in government bonds (d_t^s) or loaned to firms for investment (k_t^s). Households' savings not held in bonds are the source of injection to national capital stock. The number of bonds held by each household is the average of the bonds held; that is, $d_t^s = \bar{d}_t = D_t/N_t$. For the s th generation during its working time, we can write its assets used in capital formation as the following:

$$\begin{aligned} k_t^s &= tr_t + (1 - \tau_w - \tau_b)w_t^s e_t^s - (1 + \tau_c)c_t^s - d_t^s && \text{for } s = 1, \\ k_t^s &= tr_t + [1 + (1 - \tau_r)r_t]k_{t-1}^s + (1 - \tau_w - \tau_b)w_t^s e_t^s - (1 + \tau_c)c_t^s + [1 + (1 - \tau_r)r_t]d_{t-1}^s - d_t^s && \text{for } 2 \leq s \leq 41, \\ k_t^s &= tr_t + [1 + (1 - \tau_r)r_t]k_{t-1}^s + b_t^s - (1 + \tau_c)c_t^s + [1 + (1 - \tau_r)r_t]d_{t-1}^s - d_t^s && \text{for } 42 \leq s \leq 60, \quad (7) \\ k_t^s &= 0 && \text{for } s = 61 \end{aligned}$$

where tr_t is the per-capita lump-sum transfer received; $tr_t = Tr_t/N_t$.

Firms

At each t , firms produce output Y_t using a Cobb–Douglas-type constant return to scale production function:

$$Y_t = A_t L_t^{1-\alpha} K_t^\alpha. \quad (8)$$

Productivity A_t grows at the exogenous rate gA , and g is the technological growth rate. The firm decides the demand for physical capital and effective labor to maximize profits with given factor prices. The factor prices, wage (w_t), and interest rate (rt) are determined in perfectly competitive markets. Profit maximization gives rise to first-order conditions:

$$\partial Y_t / \partial K_t = r_t + \delta = \alpha k_t^{\alpha-1} \quad (9)$$

$$\partial Y_t / \partial L_t = w_t = (1 - \alpha)k_t^\alpha \quad (10)$$

where $k_t = K_t / A_t L_t$ denotes the capital per effective labor in period t and δ denotes the depreciation rate.

The Pension Sector

The social security system is a PAYG pension system in this model. The pension sector grants a pension benefit to the retired generations while collecting the pension contribution from the working generations. Pensions are a constant fraction, ζ , of net labor income:

$$b_t^s = \begin{cases} 0 & s < R \\ \zeta(1 - \tau_w - \tau_b)w_t & s \geq R \end{cases} \quad (11)$$

We assume that the replacement ratio of *net pensions*, $\zeta = bt / (1 - \tau_w - \tau_b)wt$, is constant. The contribution rate τ_b is an exogenous policy variable. The budget constraint of the pension sector is that *the total pension contribution received from period $t - 1$* is equal to the current period, period t , and pension benefit payments. In case of a shortage, the government subsidizes to balance it.⁹ The source of the pension subsidy comes from either fiscal surplus or issuing a new bond to finance it. The total pension benefit outlays at time t is as follows:

$$B_t = \sum_{s=42}^{60} b_t^s. \quad (12)$$

In light of the socialist regime in China, the government is obliged to provide a certain portion of pension funds to elders as part of its social welfare provision. Therefore, the usual funds available for pension payments (P_t) consist of two parts: the total pension contribution received from the working-age population at time $t - 1$ and the portion of the government's obliged provision. When the pension budget is balanced, the total pension benefits are equal to the total funds available. That is,

$$B_t = P_t = \sum_{s=1}^{41} \tau_b w_t^s e^s + \rho B_t. \quad (13)$$

In Equation (13), ρ is the fraction of pension benefits from the government provision. Occasionally, when the pension budget runs a deficit (PD_t), the government provides a subsidy to balance it. In this case, Equation (13) becomes the following:

$$B_t = P_t = \sum_{s=1}^{41} \tau_b w_t^s e^s + \rho B_t + PD_t \quad (13)$$

The Government Sector

The government collects three types of taxes: consumption tax, wage income tax, and capital income tax to finance its expenditures on government consumption (G_t). The government's tax revenues (T_t) are given by the following:

$$T_t = \tau_w w_t L_t + \tau_r r_t \Omega_t + \tau_c C_t \quad (14)$$

where Ω_t is the aggregate wealth at time t . Government spending is a constant fraction (λ) of output:

$$G_t = \lambda Y_t \quad (15)$$

The government finances the deficits in the general expenditure by issuing new debt. Let D_t denote the government bonds outstanding at time t . We assume that the government budget is balanced in every period t such that the government budget constraint is as follows:

$$rD_t + G_t + Tr_t + PD_t = T_t + D_t, \quad (16)$$

where rD_t is the government's debt interest payment, $D_t = D_{t-1} + \Delta D_t$, and ΔD_t is the net change in public debt at time t .

Stationary Equilibrium

In the stationary equilibrium, individual behavior is consistent with the aggregate behavior of the economy, firms maximize profits, households maximize intertemporal utility, and the factor and goods markets are in equilibrium. The aggregate variables labor supply L_t , consumption C_t , taxes T_t , capital stock K_t , and bonds D_t are equal to the sum of the individual variables. Aggregate saving is the sum of K_t and D_t . The social security system budget and the government budget are balanced.

Model Estimation and Simulations

Data and Parameterization

In China, the normal pensionable age is 60 years for men, 50 years for blue-collar women, and 55 years for civil servants and white-collar workers, subject to a minimum of 15 years of contributions. We set the mandatory retirement age at 60, irrespective of sex.

The pension system in China evolved over the past decades. Before 1997, the pension system was part of the socialist welfare system, which provided an all-encompassing social security system for employees of state-owned enterprises. After the opening-up in the 1970s, the system underwent several major reforms in 1997, 2000, and 2004 that aimed to establish a national pension system that provides "wide coverage, basic security, multilevel options, and sustainability" by 2020 (Cai & Cheng, 2014). China enacted the Social Insurance Law in 2011 to force employers to pay pension contributions for their employees. This law led to a heavier burden on employers, with their social insurance and housing fund contributions reaching more than 40 percent of employees' wages. In 2016, the State Council lowered the contribution rates for employers to a cap of 20 percent. We set the contribution rate (τ_b) to 20 percent in the baseline simulation.

In addition to the pension contribution rate, another important parameter in the pension system is the replacement ratio. The average replacement ratio was approximately 70 percent in 2001, which declined steadily to around 46 percent in 2017 (Figure 4 of Fang & Feng, 2018). Given these facts and the development of the pension system in China, we assume a low replacement ratio (ξ) of 55 percent in the baseline stationary state simulation. In the policy simulation exercises, we change the replacement ratio to 45 percent.

Table 1 . Parameter Values

α	Capital's share of output	0.33
β	Time discount factor	0.97
δ	Depreciate rate	0.05
g	Technical progress rate	0.015
ρ	Pension-income replacement ratio	0.55
θ	Intertemporal elasticity of substitution for consumption	0.25
τ_r	Tax rate on capital income	0.20
τ_c	Consumption tax rate	0.13
τ_w	Wage income tax rate	0.13
τ_b	Worker's public pension contribution rate	0.20
λ	Government's share of public pension premium	0.40

Source: Elaboration of the authors.

Following the 2012–16 Value-Added Tax (VAT) reforms, there are only four VAT rates in China, plus a nil rating. The standard rate of VAT is 13 percent.¹⁰ We thus set the consumption tax rate (τ_c) to 13 percent. As for income taxes, an individual with capital gains is taxable in China at a rate of 20 percent, which we adopt for the capital income tax rate ($\tau_r = 0.20$). The wage income tax is more complicated. China's tax on an individual's income is progressive from 3 percent to 45 percent. The Chinese government defines incomes ranging from 60,000 to 500,000 Yuan per year as middle class. Therefore, we set the tax rate applicable to the middle-income class for wage income, at 13 percent ($\tau_w = 0.13$). According to the Penn World Table 9.1 (PWT 9.1), real TFP in China grows at an annual average rate of 0.016 from 1979 to 2017.¹¹ Based on the information from PWT9.1, we set a slightly conservative rate for the technological progress at 0.015 in the baseline model.

The household's intertemporal elasticity of substitution for consumption (θ) is 0.25, as in Auerbach and Kotlikoff (1987) and the time discount factor (β) is 0.97, as in Heer and Maussner (2009). We set the depreciation rate to 0.05, which is in line with data published in PWT 9.1. Table 1 reports the parameter values used in the model estimation.

Simulation Results

Baseline Results

Given the macroeconomic environmental parameters and the pace of population aging estimated by the UN, we investigate the impact of population aging on GDP and other macroeconomic variables in China. Population aging causes the aging of the labor force and reduces the proportion of the productive working-age population in the economy. Aging and the shrinking of the working-age population would lead to a decrease in total output. Figure 7 illustrates the simulated scenarios of key macroeconomic variables in the model.

The simulated scenarios of GDP indicate that GDP in China will decrease (see Panel A in Figure 7) due to the demographic transition of population aging and its outcome of a shrinking labor force. The aggregate labor supply, defined as the technology-augmented labor unit ($g \times L_t$), also decreases (Panel B), which causes GDP to decline. The saving rate in China will increase in the future (Panel C). This increase in saving along with the shrinking labor force will lead to capital deepening in China, measured

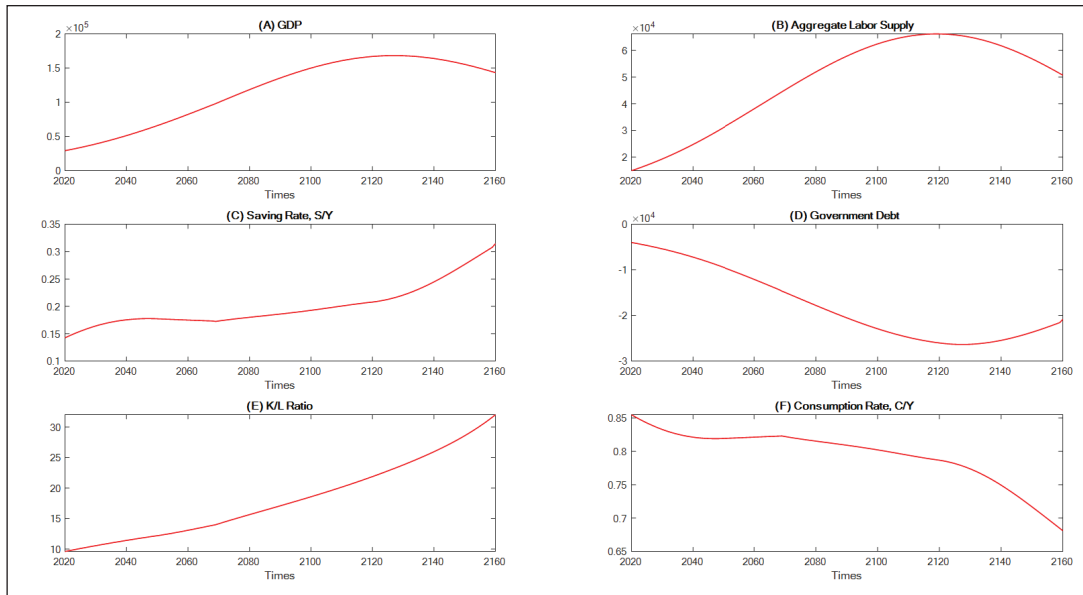


Figure 7. Simulated Macroeconomic Performance of China, 2020–2060

Source: Simulation results by the authors.

in the capital–labor ratio (K/L) in Panel E. Population aging in China intensifies the government’s fiscal stance and leads to an accumulated budget deficit in Panel D. Moreover, population aging in China will reduce the consumption rate among Chinese people. That is, the material welfare of the people in China will decrease in aging population.

In summary, population aging in China will lead to a future decrease in GDP and labor supply, along with a decrease in material welfare and the government.

It is generally argued that promoting technological progress can mitigate the adverse effects of a shrinking working-age population on aggregate output. We investigate this argument and conduct simulations to examine the effects of technological progress on the aging Chinese economy. In the experiment design, we assume two technological growth rates and compare their effects on future GDP. In the baseline model, we consider the effect of the technological growth rate as stipulated in Table 1, $g = 0.015$. In the alternative model, we assume a very sluggish growth rate of 0.00015. Figure 8 illustrates the GDP scenarios in these alternative simulations.

We assume that technological progress is in labor augmented technology or a human capital enhancement progress. Figure 8, Panel A, illustrates the effects of technological progress on GDP, where the right and left (solid line) scales show the case of slow technological progress and the baseline scenario, respectively. Given the population aging forecast published by the UN, the simulated scenarios of slow technological progress indicate that GDP in China will peak around 2045 and start declining thereafter. In this simulation, GDP starts to decline once the old-age dependency ratio (Panel B) starts to accelerate. However, with a technological progress rate of 1.5 percent per annum, China’s GDP will eventually decrease. The simulation indicates that the time of GDP decrease will be postponed for almost

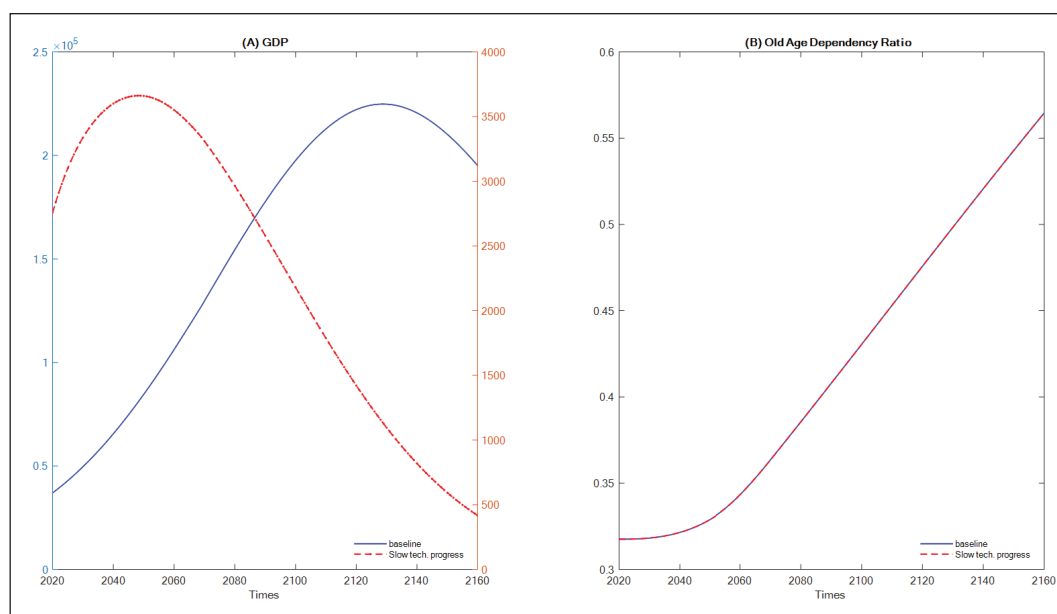


Figure 8. Simulated Future GDP in China, 2020–2160

Source: Simulation results prepared by the authors.

Note: The left y-axis in Panel (A) represents the baseline model.

100 years compared to the former case. These simulations clarify that population aging and the increasing old-age dependency ratio hurt macroeconomic performance. Although technological advancement may mitigate the adverse impact of population aging, it cannot correct the long-run down-turn pressure on GDP growth arising from population aging.

Policy Simulations

Population aging raises concerns not only about long-term economic growth but also about the sustainability of fiscal budget and pension system in an aging economy. In this subsection, we examine the effects of fiscal and pension reforms on the macroeconomy in China. Both reforms aim to improve the sustainability of the fiscal and pension systems. However, reforms in these areas would inevitably affect private saving/consumption decisions and capital formation. Any reform-induced capital accumulation decision would undoubtedly affect subsequent economic growth. We investigate the dynamic effects of reforms on China's macroeconomy.

We conduct policy reform exercises for six programs for the economy of China. In the tax reform programs, we consider measures to improve the government's budget by raising the consumption tax and wage income tax. Figures 9 and 10 illustrate the simulation results for these reforms. For the pension reforms, we consider the following four programs: (a) extending the mandatory retirement age by 1 year, (b) cutting the replacement ratio from 0.55 to 0.45, (c) increasing pension contribution from 12 percent

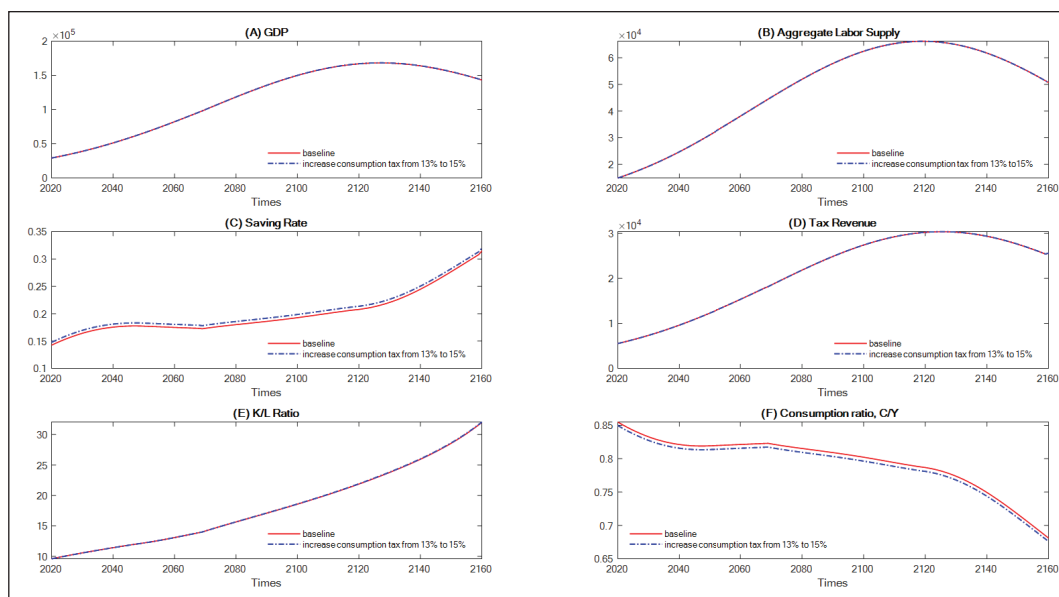


Figure 9. The Effects of Tax Reform: Increase Consumption Tax by 2%

Source: Simulation results prepared by the authors.

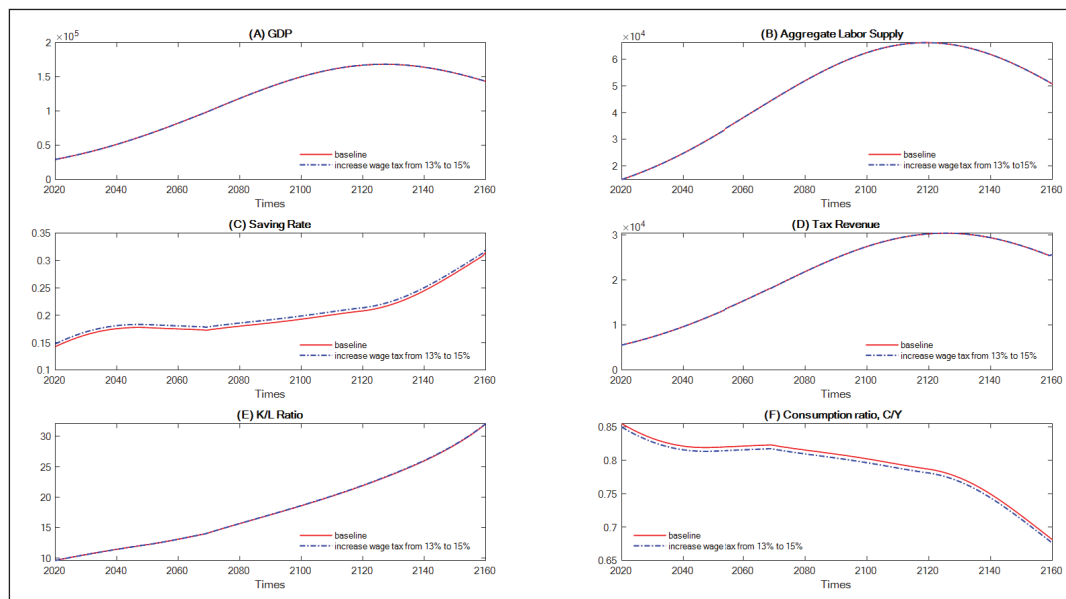


Figure 10. The Effects of Tax Reform: Increase Wage Income Tax by 2%

Source: Simulation results prepared by the authors.

to 15 percent, and (d) extending the mandatory retirement age and cutting the replacement ratio, a combination of (a) and (b). Figures 11–12 illustrate the pension reform simulation results.

Simulation Results of Tax Reform

We consider tax reforms that include an increase in the current VAT tax rate from 13 percent to 15 percent or an income tax reform that raises wage income tax rates from 13 percent to 15 percent. The simulation results from these two reform experiments show very similar results. Neither reform alters aggregate labor supply, GDP, or the capital ratio considerably. They also do not improve the aggregate tax revenue significantly (Tax Revenue in Panel D). However, both tax reforms alter consumption and saving behavior. These reforms have negative impacts on the consumption ratio and a positive impact on the saving rate. The effect of the wage income tax on the consumption rate, C/Y , and the saving rate is slightly larger than that of the consumption tax. Perhaps this difference is because the consumption tax applies only to consumption expenditure, while the wage tax affects income before consumption. Though these reforms do not yield remarkable impacts on the other variables of interest in this study, these two reforms do reduce households' disposable income and induce savings such that people save more for the future. Tax revenue does not change too much with these two tax reforms, possibly implying that Ricardian equivalence holds for the Chinese economy.

Simulation Results for Pension Reform

In the four pension reform exercises, we investigated the reform effects on GDP, labor supply, saving rate, consumption ratio, capital–labor ratio, and pension benefits to GDP ratio. Of these six variables, GDP and capital–labor ratio relate to current and future macroeconomic performance, while the saving rate and labor supply are important policy variables for the short- and long-run economic growth. The consumption ratio reflects the current material welfare of all generations, whereas the pension benefits to GDP ratio concerns the welfare of the retirees in the economy. In general, the simulations of the four pension reform schemas produce more prominent effects on the macroeconomy than do the tax reforms.

The immediate effect of extending the mandatory retirement age by one year (Figure 11) is an increase in labor supply, which raises the productive power of the economy and hence GDP growth. In the first few years of the reform effect, there is a sudden increase in the labor force, which leads to a reduction in the capital–labor ratio. The latter effect of this reform on the capital–labor ratio depends on the effects on saving behaviors. Extending mandatory retirement increases the working life of older workers and raises income for the affected older workers. The result is an increase in consumption and hence a reduction in savings. The simulated scenarios for the saving rate and consumption ratio, compared to that of the baseline scenarios, reveal these changes. Since people save less, the increase in capital slows down. However, as the society “gets old,” there is a smaller working-age population available for hire. The dynamics of less saving and a smaller labor force causes the capital–labor ratio to converge to the baseline scenarios (Panel E, Figure 11). Both the saving rate and consumption ratio converge to the baseline scenarios. The most prominent effect of this reform is that it releases the pressure on pension outlays in the pension system. The ratio of pension benefits, defined as the total pension payment to the retirees to the GDP ratio moves significantly below the ratio of the baseline model. This result implies an improvement to the sustainability of the pension system, though a reduction in the welfare of retirees.

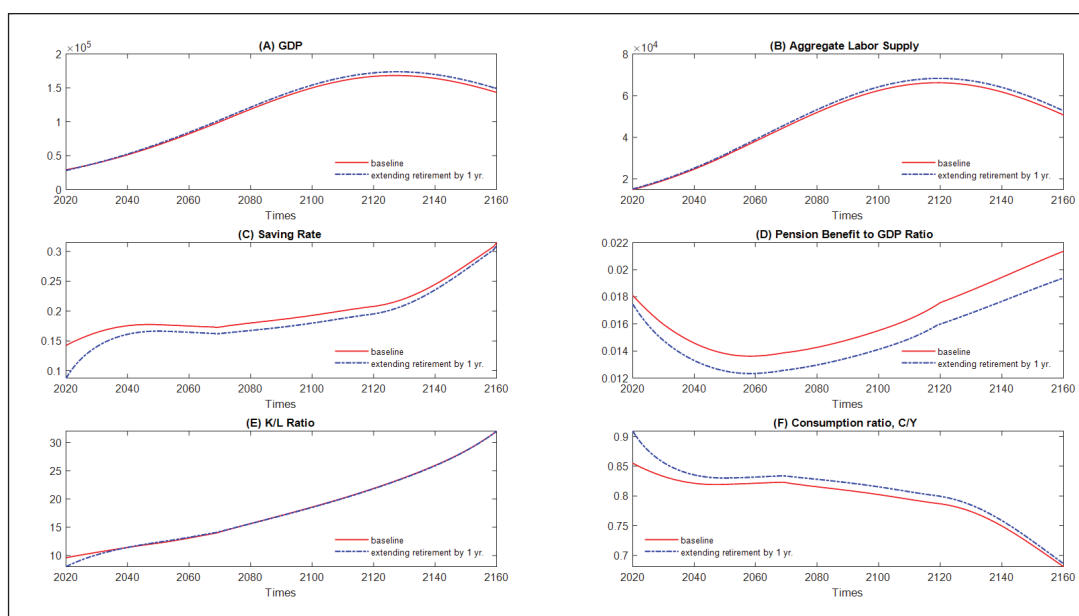


Figure 11. The Effects of Pension Reform: Extending the Mandatory Retirement Age

Source: Simulation results prepared by the authors.

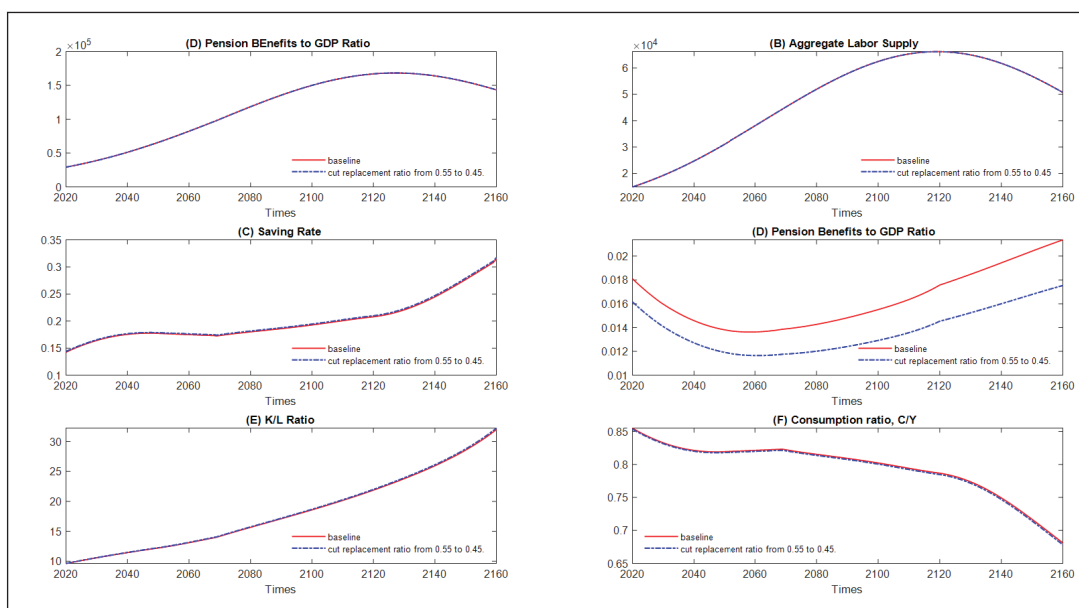


Figure 12. The Effects of Pension Reform: Cutting the Replacement Ratio

Source: Simulation results prepared by the authors.

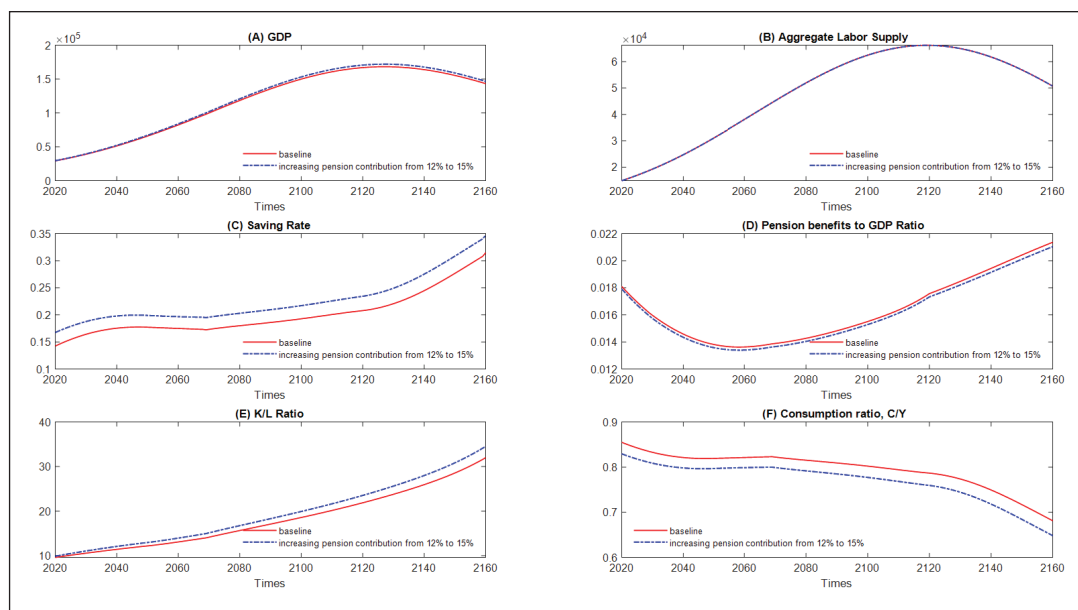


Figure 13. The Effects of Pension Reform: Increasing Contributions

Source: Simulation results prepared by the authors.

The second simulation of pension reform is to cut the replacement ratio of retirees (Figure 12). This policy reform has a direct impact on the retirees' pension incomes and an indirect effect on the lifetime income of the working-age population. The overall effect of this policy reform on national saving/consumption depends on the reactions of both working and retired generations to this reform. In this simulation, we observe only a slightly lower consumption ratio and a slightly higher saving ratio in the Chinese economy. The labor supply is not affected, and GDP remains fairly stable. The only noticeable change is on the pension benefit-to-GDP ratio variables (Panel D). The lower this ratio, the lower the total claimed pension benefits to the current GDP ratio. We also notice that the distances between the simulated and baseline scenarios are more noticeable than those for the extended retirement age case.

A third reform is an increase in the contribution rate of wages of the current working-age population. Like the other two reforms in the previous simulations, this reform seeks to improve the sustainability of the pension system. Unlike the aim of the other two reforms to reduce outlays, this reform aims to increase pension revenue. The simulation results (Figure 13) indicate that this reform has only a slight impact on aggregate labor supply yet has significant impacts on saving and consumption behaviors. The consumption ratio is stably below the baseline scenarios and the saving ratio is permanently higher than that of the baseline scenarios. The result is an ever-increasing capital-labor ratio, though this increase yields only a slight increase in GDP because the positive effect of the increase in the capital-labor ratio offsets the negative effect of reduced consumption.

Concerning the goal of this reform (improving the sustainability of the pension system), we note that this reform is the least effective among the policies discussed in this section because it only reduces the disposable income of the current working generations and has no effect on the benefits of retirees. Although this reform has the least effect on reducing tension in the pension system, it has the most remarkable impacts on saving and consumption in the aging economy.

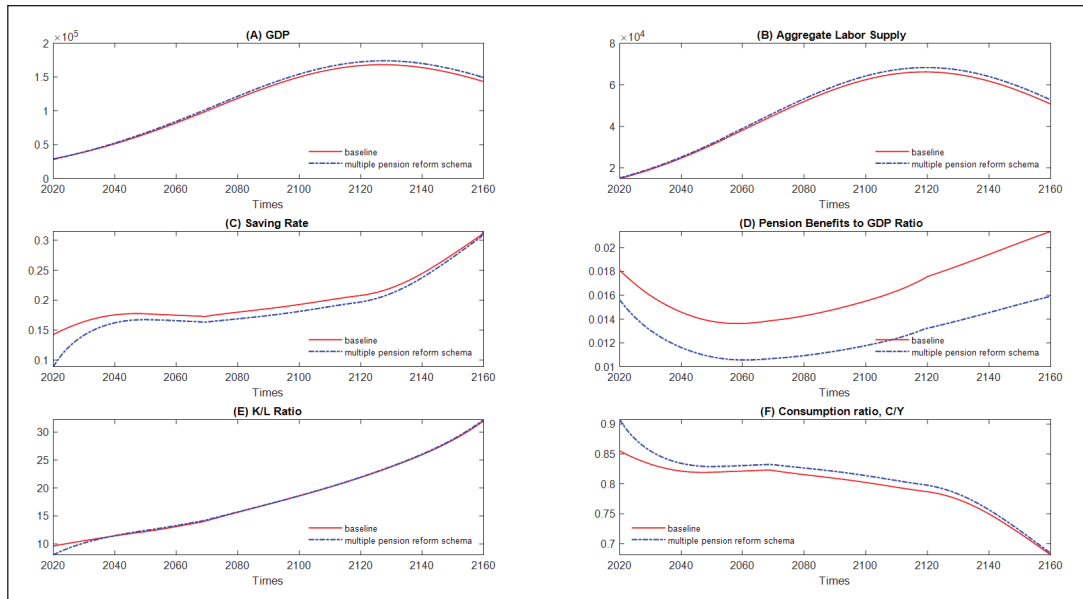


Figure 14. The Effects of Pension Reform: Combination of Multiple Reforms

Source: Simulation results prepared by the authors.

The last policy simulation combines multiple reforms: extending the mandatory retirement age by one year and cutting the replacement ratio from 55 percent to 45 percent. Comparing the simulation results from the single-reform programs, this reform provides a much more apparent improvement in the financial situation of the pension system (Panel D, Figure 14). The effects of this joint reform on the macroeconomy are the combined effects of both single reforms. This joint reform retains the features of the individual reforms on the saving rate, consumption ratio, capital–labor ratio, labor supply, and output. The combined reform has an amplified effect on the improvement to the financial health of the pension system, reducing the pension outlays to make the system more sustainable. The reduction in the pension benefits to GDP ratio is the smallest of all reform measures discussed in this article. This drastic reduction means a big cut in the pension benefits of retirees. Therefore, the financial sustainability of the pension system is maintained at the cost of cutting old-age benefits.

Conclusions

Findings

This study develops a four-sector, multigenerational OLG model to investigate the impacts of population aging on China's economy. This model assumes that a young adult enters the labor market at the physical age of 18 and retires at the age of 60. The physical age of 18 corresponds to age 1 in the model, so that at any time 42 working-age generations coexisted in the model. An agent has a life of up to 60, corresponding to a physical age of 78 in the real world. We plugged the population projection on China

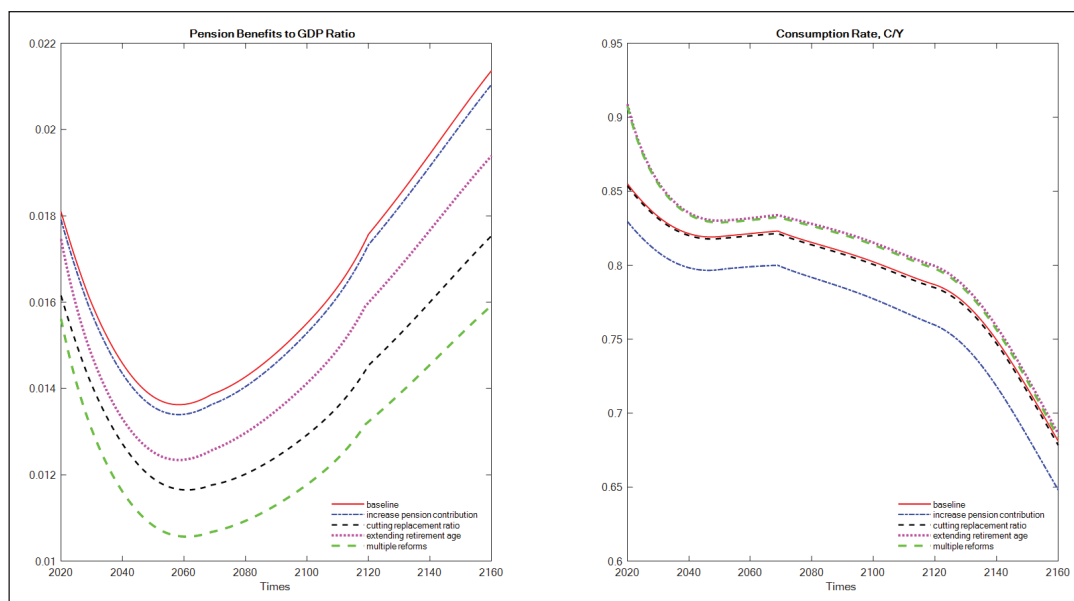


Figure 15. A Comparison of Pension Reform Effects

Source: Simulation results prepared by the authors.

made by the UN into the model and emulate other socioeconomic conditions in China to set the model parameters. We use MATLAB for model estimation and policy simulations.

Population aging is an irreversible demographic transition process that results from declining fertility and increasing longevity. This aging demographic transition leads to an increasing share of old-age dependent people and a decreasing share of the working-age population. This demographic aging impacts future economic growth and the sustainability of the fiscal, social welfare, and health care systems.

The computational results from this study indicate that population aging in China would inevitably lead to a decrease in its national output resulting from a shrinking working-age population and increasing old-age dependency. Technological progress may mitigate the adverse effects on economic growth in an aging economy, but it is incapable of checking the adverse effects resulting from the decline in the labor force. To improve the welfare of people in a fast-aging China, we propose and simulate six policy measures to enhance the sustainability of the fiscal and pension systems. These six policy measures consist of two tax reform policies and four pension reform policies. Neither of the tax reform policy increases (increasing the consumption tax or wage income tax) could yield significant improvements to national tax revenues in China. The only effect is that both tax reforms generate distortionary effects on consumption and savings and have no obvious effects on employment and output.

Although the tax reform we considered here does not significantly improve fiscal sustainability in China, the four pension reform simulations yield some meaningful results. A pension reform program may affect the welfare of the current working-age generation, retirees, or both. We summarize the findings from the pension reform in Figure 15. The left panel in Figure 15 compares the effects of pension reform on the sustainability of the current pension system in China. A reform measure that reduces the pension benefits to GDP ratio implies an improvement in the sustainability of the pension

system. Considering this, we note that reform with the combined measures of extending the mandatory retirement age and cutting the replacement ratio has the most significant positive effect on pension sustainability. On the other hand, an increase in the contribution rate has the least effect on pension sustainability but has the most significant effect on changing the saving rate and consumption ratio in the economy.

Regarding people's consumption welfare, we compare the effects of the different pension reform programs on the economy's consumption rate, C/Y . Of the four pension reform programs, those related to the extension of the mandatory retirement age would improve the material welfare of the consumption ratio in the economy. The program that cuts the replacement ratio has a mildly negative effect on C/Y . An increase in the contribution rate affects the working-age population's disposable income and has the most adverse effects on C/Y . Policymakers who aim to improve pension sustainability should carefully choose a program that balances generational equity, integrated welfare, and sustainability.

Issues for Future Discussion

Although the use of the OLG model used in this study of the aging economy in China is a common practice, there are still some settings that require improvement. The first limitation is that our model is a closed economy setting. However, as we discussed in the introduction, economic growth in China is highly related to its growth in international trade. In the future, we should expand the model to investigate the open economy aspects of issues related to an aging economy like China. Furthermore, most studies treat the population as exogenously given. This practice limits the interaction between economic factors, population structure, fertility, family formation, intergenerational income transfers, and so on. Any improvement in this matter may yield better conclusions than those from the current study.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Notes

1. Unless otherwise specified, the phrase "population projection" in this study refers to the medium variant projection in the *2019 Revision of World Population Prospects*. <https://population.un.org/wpp/>
2. All population data cited in this section were retrieved from Health Nutrition and Population Statistics, the World Bank. <https://databank.worldbank.org/source/health-nutrition-and-population-statistics#>
3. Life expectancy is based on the 2019 vital statistics released by the World Bank. The reported life expectancy at birth is 76.704 for 2018. <https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=CN>
4. The current pension age in China is 60 for men, 55 for female civil servants, and 50 for female workers. There will be a gradual extension of the mandatory retirement age. The current study uses 60 as the mandatory retirement age.
5. The survival probability is calculated from the "China Life Insurance Mortality Table (2010–2013)" issued by the Supervision and Administration of Full-Time Insurance Agencies, China Banking and Insurance Regulatory Commission. <http://bxjg.circ.gov.cn/web/site0/tab5216/info4054990.htm> (in Chinese).
6. The CHFS is a nationally representative survey in China on household finance conducted by Survey and Research Center of Southwestern University of Finance and Economics. This survey has been conducted four

rounds in 2011, 2013, 2015, and 2017 respectively. The survey collects microlevel information on individual and household assets, including housing, business assets, financial assets, and other household assets. The survey also collects information on household age, income, expenditures, and socioeconomic status. Gan et al. (2014) provided an informative introduction on CHFS sampling design and survey methodology; Zhang (2016) introduced several studies based on CHFS.

7. To obtain the age-specific income for each individual age, we first calculate the mean income for each age group from the CHFS2017 to obtain a series of mean age-income profiles for different ages. We then normalize this age-income series with mean income of the 18-year-old group. In the final stage, we estimated the life cycle labor efficiency equation with this normalized mean age-income series and obtained Equation (4).
8. It is admissible that the bequest motive is an important cultural factor that affects saving decision for people in China. A current popular bequest practice for the Chinese parents is to make inter vivos transfer, not to transfer assets after they passed away. That is, parents help their heirs with housing install payment, purchase cars or precious gifts for son/daughter's marriage. This inter vivos transfer drains the parents' savings and such transfer does not match the notion of bequest mentioned in the conventional bequest model. Moreover, this inter vivos transfer involves an implicit cultural norms of bilateral obligations between the two generations involved; the young generation is expected to payback and support the old generation in the future. Given this inter vivos practice and the implicit bilateral gift-exchange obligations, the overall effect of such bequest will be canceled out for the economy as a whole. We thus make a simple proposition of "no bequest" in this study. Extending the current model to incorporate sophisticated bequest motive would be an agenda for our future work.
9. In the spirit of the PAYG pension system, the replacement ratio (ζ) adjusts to balance the aggregate pension contribution and aggregate outlays. However, in practice, the replacement ratio is fixed in the short run. Whenever a pension deficit occurs, the government must manage a fund to balance it.
10. See Chinese VAT rates. <https://www.avalara.com/vatlive/en/country-guides/asia/china/chinese-vat-rates.html>
11. The TFP growth rate is a calculation made by the authors based on the *rtfpna* series (TFP at constant national prices, 2011 = 1) in PWT9.1. For the discussion of data in PWT9.1, see Feenstra et al. (2015). Although TFP growth is not necessarily equals to technological progress, in the Cobb–Douglas production total factor productivity growth is used as a synonym for technological progress. We use TFP as a proxy of technological progress. Although in the artificial intelligence (AI) era there could be jumps in technological advancement, population aging may lead to a decline in the labor productivity and restructuring of industrial production and goods markets due to the change in age-related consumption patterns. The latter case may reduce the immediate applicability of AI technology. As a result, we set a conservative TFP growth rate in the baseline model.

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