Sustainability of Public Pension System in Aging China: An OLG Model Analysis

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Contents

1. Introduction
2. Model setup
3. Calibration and numerical analysis
4. Sustainability of public pension system
5. Conclusion
1. Introduction

The increase of dependency ratio and decrease of working age population, as results of aging, are adverse to economic growth (Razin et al., 2002; Muto et al., 2016).

China is facing a more intensifying aging trend than most developed countries in spite of its rapid development in the past 40 years, and its growth rate has declined from 9.7% in 2012 to 6.6% in 2018 and 6.0% in the 3rd quarter of 2019.

Public pension accounts of several provinces in China have ran into deficits.

In order to reduce the tax burden on the firms caused by aging, the Chinese government determined to cut the pension contribution rate from 28% to 24% in 2019.

Delaying of retirement age is also under extensive discussion.
Aging Population of China: Age 60/65 and over (%)

* National average, even higher for rural area
Question

Whether the performance of economy will be improved due to this policy change is still unknown. Moreover, the sustainability of public pension system is concerned because of the continuous increase in pension expenditure with aging.

Our work

In this paper, we construct an overlapping generation model, calibrated by the economy of China, incorporated with demographic change and educational investment to portray the public pension system in aging China.

Our findings

• The impact of pension contribution rate on disposable income per capita is negative, providing a theoretical explanation for China’s pension policy change.
• Policy simulations suggest that postponing legal retirement age from 60 to 62 can ensure the public pension system sustainability.
• Raising fertility cannot completely eliminate the deficit of the pension system.
2. Model setup

Consider a general equilibrium OLG economy, for it is widely used to depict aging and public pension system in some previous studies (Kotlikoff, 1996; Boldrin and Montes, 2005; Li and Lin, 2011).

**Three periods**: childhood, middle aged and old-aged.

- In the first period children do not take any decision.
- In the second period, the young are devoted to work and raising an exogenous number of children, \( n \), hence the population remains growth at a constant rate, namely \( N_t = nN_{t-1} \).
- The old-aged will spend a proportion of the third period to work and receive a pension when retired.
2.1 Individuals

The altruistic young adults are endowed with well-behaved preferences described by a utility function which depends on consumptions of the last two periods of life ($C_{y,t}, C_{o,t}$) and human capital ($h_{t+1}$) of their children. Then, households maximize expected lifetime utility:

$$U = \ln C_{y,t} + \beta \pi \ln C_{o,t} + \gamma n \ln h_{t+1}$$  \hspace{1cm} (1)

where $\beta$ is time discount factor, and $\gamma$ represents individual’s altruism on her child's human capital. Parameter $\pi \in [0,1]$ reflects the survival rate of the elderly. The individuals face the following budget constraints in the two periods of life:

$$C_{y,t} + nE_t + S_t = w_t h_t (1 - \tau_y - \tau_b)$$  \hspace{1cm} (2)

$$C_{o,t} = \theta w_{t+1} h_t (1 - \tau_y - \tau_b) + S_t \frac{(1+r_{t+1})}{\pi} + (\pi - \theta) P_{t+1}$$  \hspace{1cm} (3)

- $E_t$ is the private human capital investment per child
- $S_t$ represents private savings, $w_t$ and $r_t$ are the prices of human and physical capital.
- $\tau_y$ and $\tau_b$ represent the education tax rate and pension contribution rate
- $\theta$ is the proportion of working time, and $\theta < \pi$, then $\pi - \theta$ is the fraction of retirement time for the elderly.
- Pension payment: $P_{t+1} = \rho w_{t+1} h_t$, where $\rho$ is the pension replacement ratio.
2.2 Production

The production function is assumed to take a Cobb-Douglas form with constant returns to scale: \( Y_t = AK_t^\alpha L_t^{1-\alpha} \), where \( Y_t, K_t \) and \( L_t \) denote output, aggregate physical capital stock and labor supply, respectively.

In equilibrium, all markets clear. Market clearing on the capital market requires that savings of all the young people in period \( t-1 \) constitute the capital stock at the beginning of the period \( t \), namely

\[
K_t = N_{t-1}S_t
\]  

(11)

As the old people still spend a fraction of the third period for working, then the labor supply of the market is defined as

\[
L_t = N_t h_t + \theta N_{t-1} h_{t-1}
\]  

(12)

The representative firm chooses the optimal capital-labor ratio, \( k_t = K_t/L_t \), to maximize its profit function, then

\[
k_t = \frac{\pi S_t}{nh_t + \theta h_{t-1}}
\]

(13)

In equilibrium, the factor prices are determined as follows:

\[
1 + r_t = \alpha Ak_t^{\alpha-1}
\]

(14)

\[
w_t = (1 - \alpha)A k_t^\alpha
\]  

(15)
2.3 Government

The public pension system financed by the government runs a pay-as-you-go (PAYG) scheme. Then, the public pension fund in period $t$ is gathered from the entire working population, namely

$$P^1_t = N_t \tau_b w_t h_t + N_{t-1} \tau_b \theta w_t h_{t-1}$$

(16)

where $P^1_t$ denotes the resources of public pension fund. Only the retired elderly receive pensions:

$$P^2_t = N_{t-1} (\pi - \theta) P_{t+1}$$

(17)

where $P^2_t$ represents the expenditure of public pension. If we assume that the PAYG system runs at a balanced budget (Alders and Broer, 2005), then $P^1_t = P^2_t$, we have:

$$\rho = \frac{n \tau_b h_t + \tau_b \theta h_{t-1}}{(\pi - \theta) h_{t-1}}$$

(18)
2.3 Government

With aging trend, the PAYG system may not satisfy the balanced budget condition. Then, the deficit or surplus of the public pension fund account in period $t$ can be defined as $\Delta P_t = P_t^1 - P_t^2$. For simplicity, we convert $\Delta P_t$ into per capita form:

$$\frac{\Delta P_t}{N_t} = \tau_b w_t h_t + \frac{1}{n} \tau_b \theta w_t h_{t-1} - \frac{1}{n} (\pi - \theta) \rho w_t h_{t-1}$$  \hspace{1cm} (19)

The deficit or surplus of pension fund account will remain accumulating, and the accumulated deficit or surplus per capita in period $t$ is:

$$AP_t = AP_{t-1} + \frac{\Delta P_t}{N_t}$$  \hspace{1cm} (20)
2.3 Government

In addition, we assume that the public educational expenditure is the aggregation of the public human capital investment for the next generation in period $t$:

$$G_t = N_{t+1} g_t$$  \hspace{1cm} (21)

Resources of educational finance account are also gathered from the entire working population:

$$T_t = N_t \tau_y w_t h_t + N_{t-1} \tau_y \theta w_t h_{t-1}$$  \hspace{1cm} (22)

With balanced budget condition ($G_t = T_t$), we have the public human capital investment per capita:

$$g_t = \frac{1}{n} \left( \tau_y w_t h_t + \frac{\theta}{n} \tau_y w_t h_{t-1} \right)$$  \hspace{1cm} (23)
2.4 The dynamic equilibrium

In the competitive equilibrium, the following conditions will be satisfied: $k_{t+1} = k_t = k, w_{t+1} = w_t = w, r_{t+1} = r_t = r$ and $h_{t+1} = h_t = h$. The disposable wage income per capita can be defined as $y^w_t = \frac{N_t w_t h_t (1-\tau_y - \tau_b) + \theta N_{t-1} w_t h_{t-1} (1-\tau_y - \tau_b)}{N_t + \theta N_{t-1}}$, and in the steady state,

$$y^w_t = \frac{(n+\theta)wh(1-\tau_y - \tau_b)}{1+\theta n} \quad (24)$$

According to Eq. (24), $\frac{\partial y^w_t}{\partial \tau_b} < 0$, which means $y^w$ is negatively related to $\tau_b$. However, as $\frac{\partial g}{\partial \tau_y} > 0$ (Eq. (23)) and $\frac{\partial h}{\partial g} > 0$, thus $\frac{\partial h}{\partial \tau_y} > 0$, then $\frac{\partial y^w_t}{\partial \tau_y}$ is uncertain, which suggests that the impact of $\tau_y$ on $y^w$ is nonlinear.

In addition, according to the conditions of the equilibrium, the Eq. (18) can be simplified as:

$$\rho^* = \frac{n \tau_b + \tau_b \theta}{\pi - \theta} \quad (25)$$

where $\rho^*$ represents the balanced pension replacement ratio. From Eq. (25) we have $\frac{\partial \rho^*}{\partial n} > 0$ and $\frac{\partial \rho^*}{\partial \theta} > 0$. Therefore, the $\rho^*$ is positively related to $n$ and $\theta$. 
### 3. Calibration and numerical analysis

#### 3.1 Calibration

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Definition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha)</td>
<td>Output elasticity of physical capital</td>
<td>0.40</td>
</tr>
<tr>
<td>(\beta)</td>
<td>Time discount factor</td>
<td>0.74</td>
</tr>
<tr>
<td>(\gamma)</td>
<td>Preference of next generation's human capital</td>
<td>0.80</td>
</tr>
<tr>
<td>(A)</td>
<td>Total factor productivity</td>
<td>3.75</td>
</tr>
<tr>
<td>(B)</td>
<td>Technology of human capital accumulation</td>
<td>1</td>
</tr>
<tr>
<td>(\varepsilon)</td>
<td>Intellectual capacities at birth</td>
<td>1</td>
</tr>
<tr>
<td>(\sigma)</td>
<td>Elasticity of private human capital investment</td>
<td>0.2</td>
</tr>
<tr>
<td>(\eta)</td>
<td>Elasticity of public human capital investment</td>
<td>0.2</td>
</tr>
<tr>
<td>(\pi)</td>
<td>Survival time proportion in the third period</td>
<td>0.867</td>
</tr>
<tr>
<td>(\theta)</td>
<td>Retirement time in the third period</td>
<td>0.333</td>
</tr>
<tr>
<td>(\tau_b)</td>
<td>Pension contribution rate</td>
<td>0.28</td>
</tr>
<tr>
<td>(\tau_y)</td>
<td>Education tax rate</td>
<td>0.07</td>
</tr>
<tr>
<td>(n)</td>
<td>Number of children per adult</td>
<td>0.80</td>
</tr>
</tbody>
</table>
3.1 Calibration

• Although the total fertility rate in China was less than 1.5 in 2000 (Retherford et al., 2005), it has increased after the relaxing of the birth policy in 2013. Therefore, we assume the fertility rate per adult $n$ is equal to 0.8.

• According to the China Statistical Yearbook 2016 published by China National Bureau of Statistics, the average length of expected life in China is 76, then $\pi=\frac{76-50}{80-50} \approx 0.867$.

• We set a simple legal retirement age, namely 60, in spite of its difference between men and women in China, thus, $\theta=\frac{60-50}{80-50} \approx 0.333$.

• The legal pension contribution rate is 0.28 before 2019 in China, and is reduced to 0.24 in 2019. Therefore, we assume $\tau_b = 0.28$ in the numerical analyses and then $\tau_b = 0.24$ in the policy simulation to assess the sustainability of public pension system.

• As the ratio of public educational expenditure to GDP is more than 4% in recent years, the education tax rate can be calculated as $\tau_y = \frac{4%}{1-\alpha} \approx 0.07$. 
3.2 Numerical analysis

Defining $\phi_t^c = \frac{C_{y,t}}{wth_t(1-\tau_y-\tau_b)}$, $\phi_t^e = \frac{nE_t}{wth_t(1-\tau_y-\tau_b)}$ and $\phi_t^s = \frac{S_t}{wth_t(1-\tau_y-\tau_b)}$ denote the proportions of consumption, private human capital investment and savings in the in taxed income respectively, then $\phi_t^c + \phi_t^e + \phi_t^s = 1$. In the steady state, the follows conditions will be satisfied: $\phi_{t+1}^c = \phi_t^c = \phi^c$, $\phi_{t+1}^e = \phi_t^e = \phi^e$ and $\phi_{t+1}^s = \phi_t^s = \phi^s$.

<table>
<thead>
<tr>
<th>Variables</th>
<th>$\phi^c$</th>
<th>$\phi^e$</th>
<th>$\phi^s$</th>
<th>$r$(Annual)</th>
<th>$\rho$</th>
</tr>
</thead>
<tbody>
<tr>
<td>China (2015)</td>
<td>63.60%</td>
<td>7.83%</td>
<td>28.57%</td>
<td>5.00%</td>
<td>58.50%</td>
</tr>
<tr>
<td>Model</td>
<td>64.65%</td>
<td>8.27%</td>
<td>27.08%</td>
<td>5.48%</td>
<td>59.41%</td>
</tr>
<tr>
<td>Absolute error</td>
<td>1.05%</td>
<td>0.44%</td>
<td>-1.49%</td>
<td>0.48%</td>
<td>0.91%</td>
</tr>
<tr>
<td>Relative error</td>
<td>1.65%</td>
<td>5.62%</td>
<td>-5.22%</td>
<td>9.60%</td>
<td>1.56%</td>
</tr>
</tbody>
</table>

Note: The characteristic variables of the real economy in 2015 are calculated according to the China Statistical Yearbook 2016 published by China National Bureau of Statistics.
3.2 Numerical analysis

Figure 1 Disposable wage income per capita with different tax rates
3.2 Numerical analysis

Figure 2 Disposable wage income per capita with different tax rate combinations
4. Sustainability of public pension system

4.1 Postponing legal retirement age

In a defined pension replacement ratio, the resources of public pension may not afford the pension expenditure if the pension contribution rate $\tau_b$ drops. According to Eq.(25), the postponing of the legal retirement age, namely increasing $\theta$, will increase the optimal pension replacement ratio. Therefore, the legal retirement age is increased from 1 year to 5 years in the simulated scenarios to monitor the change of public pension account, depicted in Figure 3.

![Figure 3 public pension account balance: postponing the legal retirement age](image)
4.1 Postponing legal retirement age

• As is shown in Figure 2, the baseline scenario indicates the drop of pension contribution rate indeed result in deficit in public pension account.
• Postponing legal retirement age is an effective way to ensure the public pension account to operate sustainably, for the resources of public pension fund are expanded.
• In particular, determining the legal retirement age at 62 in China, as reported in Figure 2, is the minimum condition for the sustainability of public pension system.
4.2 Raising target fertility rate

Raising the target fertility rate aims to prevent the decline of the working population caused by aging, which will expand the source of the public pension fund as well. Thus, the fertility rate in the OLG model, namely \( n \), is assumed in the range of 0.8-1.05 to observe the change of public pension account, reported in Figure 4.

![Figure 4 public pension account balance: raising target fertility rate](image)

- **Figure 4 public pension account balance: raising target fertility rate**
4.2 Raising target fertility rate

• Raising target fertility rate, portrayed in Figure 3, is not an effective way to completely eliminate the deficit in public pension account, although it can delay the time of the ultimate deficit.

• The reason is that the population of the elderly who receive pensions will ultimately increase because of the raising in target fertility rate, which will expand the expenditure in public pension account.
5. Conclusion

• Although Chinese government reduces the pension contribution rate for the sake of economic stimulating, the sustainability of public pension system will be threatened.

• We focus on the balance of the public pension account through an OLG model, calibrated by the real economy in China.

• The numerical analyses indicate that the decline of pension contribution rate $\tau_b$ will lead to a higher disposable wage income per capita across all the educational tax $\tau_y$.

• Additionally, the policy simulations suggest that determining the legal retirement age at 62 in China is the minimum condition for the sustainability of public pension system. However, the deficit in public pension account will not be completely eliminated by raising target fertility rate.
Thank you!