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Will Ending the One-Child Policy and Raising the Retirement Age Enhance the Sustainability of China's Basic Pension System?

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Abstract: The sustainability of China's Basic Pension System (CBPS) has been challenged by the ageing of the population and the decline in economic growth. This article establishes a Markov model for CBPS to examine whether the reforms, including ending the one-child policy and raising retirement the age, will shrink the negative income–expenditure gap. We find that the negative income–expenditure gap will destroy CBPS in the future in the absence of fiscal transfer or reform. Ending the one-child policy will increase the number of contributors and then reduce the gap in the short term but will worsen the gap in the long term. Raising the retirement age will have several positive effects overall while increasing expenditures in certain periods. The contributions of this article are describing CBPS in detail and establishing a precise model to analyze the effectiveness of reforms.

Keywords: China's Basic Pension System (CBPS); Markov model; ending one-child policy; raising retirement age

1. Introduction

After several decades of development and reforms, China has established a three-pillar old-age security program comprising China's Basic Pension System (CBPS), Supplementary Pension System, and Personal Saving. Sponsored by the Government, CBPS plays the most important role because of the history of the planned economy. CBPS contains several sub-systems for different groups of people: an urban employees' basic pension system for workers in urban areas, an urban residents' basic pension system for workers who are not employed, and a rural residents' basic pension system for people in rural areas (now urban residents and rural residents are combined in the urban and rural residents' basic pension system). The urban employees' basic pension system was the benchmark system, which began in 1997 and included all employees in China (see [1]). Therefore, it is the focus of this article.

A mixed scheme was designed for China's urban employees' basic pension system, comprising a public account and a private account, for example [1–3]. The public account holds funds from the pay-as-you-go plan contributed by all employers at a rate of 20% (the ratio was decreased to 16% to reduce the burden of employers in 2019) of employees' wages and benefiting all the retirees. The benefit for public accounts is calculated at the base of an individual's history of contributions (related to the historical wages) and the average wages in retirement, awarding 1% for 1 year's contribution. The private account holds the funded plan contributions by individuals at a rate of 8% of wages and benefiting the individuals after retirement. The benefit for private accounts is calculated by dividing the planned periods from individuals' cumulative value at retirement.

China's urban employees' basic pension system does not work very well because there was no fiscal transfer into the start-up fund at the outset, but the system paid benefits to retirees at that time (see [2]). Consequently, the money in the private account was embezzled. With the aging of the population, a gap appeared and has grown. In the 2000s, the problem was not apparent because of the high economic growth, thus providing ample public revenue and millions of subsidies. In fact, the government awarded large bonuses to retirees by increasing their public account benefits during 2005 to 2015 (the annual average growth rate was above 10% during 2005 to 2015).

Alarm bells rang in the early 2010s. The sustainability of China's urban employees' basic pension system was eroded by the population's aging, particularly the sudden reduction in new labor because of the one-child policy beginning in 1978. In addition, economic growth has continued to decline, thus resulting in a decrease in fiscal subsidies. Therefore, there is an understanding that the income–expenditure gap not is inevitable and reforms are necessary, for example [1,2,4,5].

The government issued several measures quickly. The one-child policy was ended in 2016, and couples are now allowed to have two children (see [6]). In addition, the compulsory retirement age will be increased by 5 years gradually over the course of several years, to 65 and 60 for males and females (see [7]). In addition, parts of stated-owned assets have been transferred to China's urban employees' basic pension system, thereby allowing the assets' return to complement the benefits. Furthermore, a disbursement mechanism allows surplus provinces to subsidize provinces with deficits.

Will these measures enhance CBPS sustainability? The third measure will help because the transfer will result in cash inflow, whereas the fourth measure will not help because it is only a rebalancing among provinces. However, what about ending the one-child policy and raising the retirement age? This is an interesting question because of its details: CBPS income and expenditure are not actuarial-balanced. Therefore, there may be a surplus or a deficit for each individual, and the surplus or the deficit may accumulate if the number of contributors increases. Furthermore, raising the retirement age will shorten the benefit period but increase the benefit level. Thus, whether the expenditure will decrease is unclear.

This article established a Markov model to simulate CBPS cashflows according to detailed rules and then analyzed the impacts of population policies and reforms on the sustainability of CBPS. We found that first, the negative income–expenditure gap will destroy CBPS in the future if there is no outside transfer or reform; second, ending the one-child policy will increase the number of contributors and reduce the gap in the short term but will worsen the gap in the long-term; and third, raising the retirement age will have some positive effects overall while increasing the expenditures in certain periods.

The remainder of the article is organized as follows. The Section 2 reviews the literature and summarizes the innovations of this article. The Section 3 establishes an actuarial model of cash inflow and expenditure, assuming that the contribution is not always continuous and the contributor could take early retirement. The Section 4 calibrates the parameters in the model. The Section 5 tests the model and parameters with the data from 2009 to 2015, forecasts CBPS cashflows from 2018 to 2058, and then discusses how policies and reforms affect the cashflows. The Section 6 describes the conclusions.

2. Literature Review

The prediction of income and expenditure for pension systems has attracted substantial interest. Some official models have been established to forecast the impacts of reform on sustainability. For example, the Office of the Chief Actuary of the US Social Security Administration has built an actuarial model (the OCA Stochastic Model, OSM) to forecast the income and expenditure of the US Social Security Fund in the next 75 years. The Congressional Budget Office also predicts the cashflows with a micro-stochastic model. A special report on the short-term and long-term cashflows of Social Security Funds in the UK has been released by the Government Actuary's Department. Unfortunately, similar modeling is not conducted in China, although many researchers have made attempts to do so, for example [1–3].

The aging of the population has led to many studies of the pension system's sustainability; ref. [8] has proposed the Aaron condition, based on the Samuelson model, in which intergenerational equilibrium for a pay-as-you-go pension system occurs when the growth rates of the population and wages exceed the interest rates. However, the pension system will inevitably have a deficit because of the low fertility rate in an aging society, for example [9–11]. Using an OLG model to calculate the gap in Slovenia, ref. [12] has shown that the gap increases as the population ages, and ref. [13] believes that pension system reforms are essential to solving the aging problem, e.g., delaying retirement and increasing the fertility rate and the contribution rate. Delayed retirement is generally accepted to enhance a pension system's sustainability: see [14–16]. In addition, on the basis of an endogenous fertility model, ref. [17] has suggested that a pension system's sustainability will be enhanced if the fertility rate is increased; ref. [18] have claimed that financial sustainability of unfunded pension systems will be eroded by population ageing and analyzed the impact of immigration flows on the financial sustainability, taking Spain as a test case.

Some studies have focused on the sustainability of CBPS. For an aging population with a pay-as-you-go system, ref. [1] have claimed that CBPS will have a current deficit in 2025 if there are no reforms; ref. [9] believes that the income and expenditure will be balanced if the compulsory retirement age is 65 years; ref. [4] analyzes the sustainability of China's basic pension fund under two macroeconomic scenarios and indicates that China's present basic pension system faces insolvency crisis; ref. [6] has claimed that if more than 54% of qualified couples have a second child, the accumulated deficit of pension insurance fund will not appear before 2090; ref. [19] has suggested that China's pension plan is expected to finish the transition in 2081. Postponing the retirement age will delay the peak time of debt, but the total debt will increase substantially. Ref. [20] has assessed the effects of rates on enterprises' incentive to participate in CBPS. The findings suggest that a lower contribution rate motivates enterprises to participate in CBPS and increases the fund's revenue; ref. [21] explores the financial self-balancing ability of the individual accounts of China's urban enterprise employees' pension plan and indicates that the self-balancing ability of individual accounts will be improved if a stochastic bookkeeping rate is adopted; ref. [5] studies the effect of poverty alleviation policy on the sustainability of China's basic pension funding for urban and rural residents in the short term (2020–2025) and medium term (2025–2050) and suggests that the sustainability of the fund will inevitably face challenges.

Various aspects of CBPS have been studied, but some problems have yet to be solved. No micro-stochastic actuarial model has been developed for CBPS. Although many models have been established for CBPS, they do not consider break-off and early retirement. Moreover, CBPS is not a standard pay-as-you-go system, and it includes many additional bonuses. Existing studies have ignored the particularities of CBPS, thus potentially resulting in ineffectiveness in delaying retirement and increasing the fertility rate.

Our article introduces CBPS, describes a Markov actuarial model built to predict the income and expenditure of CBPS in the future, and discusses the impact of delaying retirement and increasing fertility rate.

3. Model and Assumption

3.1. Population Model

3.1.1. Markov Model for Contributors and Retirees

Figure 1 shows the state space and the transitions for the contributors and the retirees.

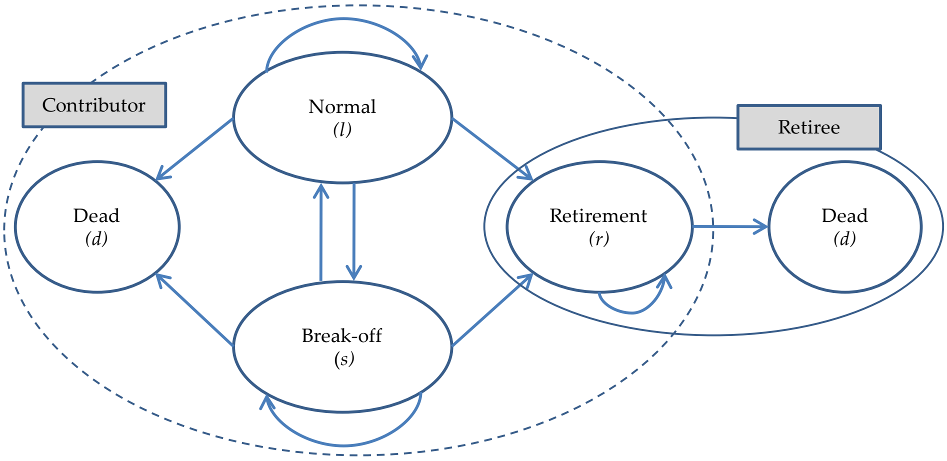

Figure 1. Markov model for contributors and retirees.

All CBPS participants are divided into two groups: contributors and retirees. There are four states for each contributor: "normal" describes the state in which the contributor contributes to CBPS (including the contribution of the employer and employee). "Break-off" describes the state in which the contributor belongs to CBPS but does not contribute to the system, for example, because of unemployment. Break-off is a serious problem for CBPS, and the official data show that the break-off rate is 20%. However, a break-off contributor can re-contribute to CBPS. "Dead" and "retirement" are two absorbing states. Although there are compulsory retirement ages for men and women, many contributors have reason to apply for retirement before the compulsory age. Early retirement is taken by 40% of men and 50% of women. There are two states for each retiree: "retirement" and "dead". "Retirement" means that the retiree is alive and receives pension from CBPS.

According to the state transition diagrams, it is easy to construct the transition probabilities matrix for the contributor, i.e.,

$$P_x(t) = \begin{pmatrix} p_x^{ll}(t) & p_x^{ls}(t) & p_x^{lr}(t) & p_x^{ld}(t) \\ p_x^{sl}(t) & p_x^{ss}(t) & p_x^{sr}(t) & p_x^{sd}(t) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{1}$$

where $P_x(t)$ denotes the matrix of an x-year-old contributor at period t and $p_x^{ij}(t)$ denotes the probability of an x-year-old contributor transitioning from state i to state j at period t.

The matrix for the retiree is

$$Q_x(t) = \begin{pmatrix} q_x^{rr}(t) & q_x^{rd}(t) \\ 0 & 1 \end{pmatrix} \tag{2}$$

where $Q_x(t)$ denotes the matrix of an x-year-old retiree at period t and $q_x^{ij}(t)$ denotes the probability of an x-year-old retiree transitioning from state i to state j at period t.

For simplicity, we assume that the Markov models are time homogeneous. Thus, the transition probabilities depend only on age. Therefore,

$$P_x = \begin{pmatrix} p_x^{ll} & p_x^{ls} & p_x^{lr} & p_x^{ld} \\ p_x^{sl} & p_x^{ss} & p_x^{sr} & p_x^{sd} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \; Q_x = \begin{pmatrix} q_x^{rr} & q_x^{rd} \\ 0 & 1 \end{pmatrix}$$

3.1.2. The Number of Participants in the Future

We forecast the number of participants in the future on the basis of the present population structure and the transition probability matrix.

Participants in the future comprise two groups. The first is those who have already participated in CBPS at period 0. Let LA_x^i denote the number of contributors who are x years old and are in state i, and let LR_y denote the number of retirees who are y years old. The second is those who enter CBPS afterward. We assume that all new participants are c years old and contribute to CBPS at the beginning. Let $NLA_c(t)$ denote the number of new participants at period t.

With those assumptions, the expected number of "normal" contributors at period t is:

$$\sum_{x=x_s}^{x_f} LA_x^l \cdot {}_t p_x^{ll} + \sum_{x=x_s}^{x_f} LA_x^s \cdot {}_t p_x^{sl} + \sum_{k=1}^{t} NLA_c(k) \cdot {}_{t-k} p_c^{ll} \tag{3}$$

where x_s and x_f represent the minimum and maximum age of the contributor, respectively.

The expected number of "retirement" retirees at period t is

$$\begin{aligned} &\sum_{y=y_s}^{y=y_f} LR_y \cdot {}_t q_y^{rr} + \sum_{x=x_s}^{x=x_f}\left[LA_x^l \cdot \sum_{t_r=1}^{t} P(R_x^l = t_r)_{t-t_r} q_{x+t_r}^{rr}\right] + \sum_{x=x_s}^{x=x_f}\left[LA_x^s \cdot \sum_{t_r=1}^{t} P(R_x^s = t_r)_{t-t_r} q_{x+t_r}^{rr}\right] \\ &+ \sum_{k=1}^{t}\left[NLA_c(k) \cdot \sum_{t_r=k}^{t} P(R_c(s) = t_r)_{t-t_r} q_{c+t_r-k}^{rr}\right] \end{aligned} \tag{4}$$

where $P\left(R_x^l = t_r\right)$ (or $P(R_x^s = t_r)$) denotes the probability of an x-year-old "normal" (or "break-off") contributor retiring at period t_r, $P(R_c(s) = t_r)$ denotes the probability of new participants at period s retiring at period t_r, and y_s and y_f represent the minimum and maximum ages of retirees, respectively.

3.2. Inflow Model of CBPS

CBPS specifies that the contribution base is an individual's average wage in the previous year. However, if a person's wage exceeds 300% of the social average wage, the contribution base is restricted to 300% of the social average wage, and if a person's wage is less than 60% of the social average wage, the contribution base is restricted to 60% of the social average wage. In addition, we assume that there is no difference in wages for people at the same age. The individual contributes λ (8%) of the contribution base to the private account, while the employer contributes η (20%) of the base to the public account. Therefore, the cash inflows for the public account TIN^t and the private account PIN^t at period t are:

$$TIN^t = \sum_{x=x_s}^{x=x_f} (\eta B_{x+t}^t \cdot LA_x^l \cdot {}_t p_x^{ll}) + \sum_{x=x_s}^{x=x_f} (\eta B_{x+t}^t \cdot LA_x^s \cdot {}_t p_x^{sl}) + \sum_{k=1}^{t} (\eta B_{c+t-s}^t NLA_c(k) \cdot {}_{t-k} p_c^{ll}) \tag{5}$$

$$PIN^t = \sum_{x=x_s}^{x=x_f} (\lambda B_{x+t}^t \cdot LA_x^l \cdot {}_t p_x^{ll}) + \sum_{x=x_s}^{x=x_f} (\lambda B_{x+t}^t \cdot LA_x^s \cdot {}_t p_x^{sl}) + \sum_{k=1}^{t} (\lambda B_{c+t-s}^t NLA_c(k) \cdot {}_{t-k} p_c^{ll}) \tag{6}$$

respectively, where B_x^t is the contribution base of an x-year-old contributor at period t.

Either TIN^t or PIN^t contains three parts. The first part of the inflow is contributed by those who are "normal" at the beginning and are "normal" at period t. The second part is contributed by those who are "break-off" at the beginning and are "normal" at period t. The third part is contributed by those who entered in CBPS from period 1 to period t and are "normal" at period t.

3.3. Expenditure Model of CBPS

CBPS specifies that the expenditure of the private account includes individual pensions and unfinished amounts in the plan-month, and the expenditure of the public account includes the public pension, individual pension out of the plan-month, and the funeral favor, a bonus covering the funeral expenses of retirees. The structure of expenditures is shown in Figure 2.

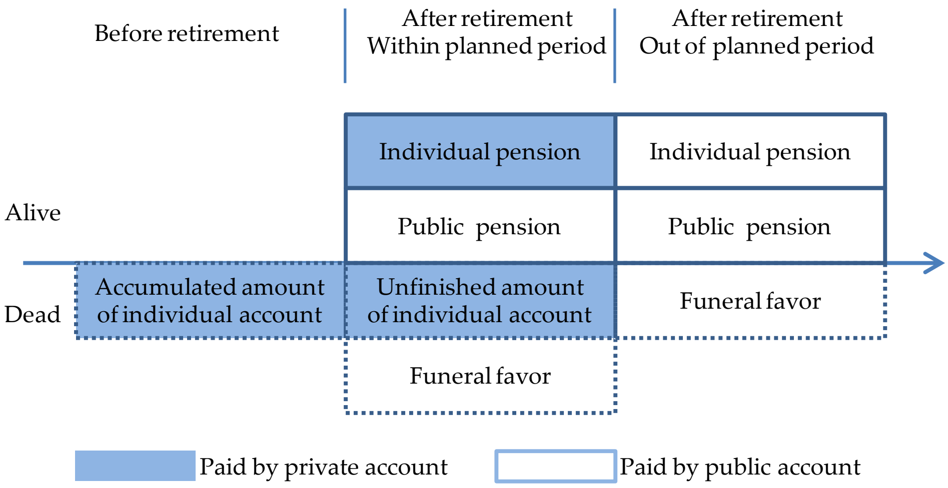

Figure 2. The expenditure structure of China's Basic Pension System (CBPS).

In addition, the retirees at period t come from three groups of people:

- Type I: those retired at period 0;
- Type II: those employed at period 0;
- Type III: those who will join CBPS from period 1 to period t.

3.3.1. Expenditure Models for Type I

For participants in type I, their benefits at period 0 have already been determined. Therefore, we take the living status and the growth rate of public pension into consideration. The expenditures of the private account and public account for type I are as follows.

$$PRC^t = \sum_{y=y_s}^{y_f} \left[{}_t q_y^{rr} \cdot AVP_y \cdot (1 - I_{\{t>G_y\}}) + {}_{t-1} q_y^{rr} q_{y+t-1}^{rd} \cdot AVP_y \cdot \max(G_y - t, 0) \right] \cdot LR_y \tag{7}$$

$$TRC^t = \sum_{y=y_s}^{y_f} \left[{}_t q_y^{rr} \cdot AVB_y \cdot \prod_{s=1}^{t} (1+\alpha_s) + {}_{t-1} q_y^{rr} q_{y+t-1}^{rd} \cdot D \cdot \prod_{s=1}^{t} (1+\beta_s) + {}_t q_y^{rr} \cdot AVP_y \cdot I_{\{t>G_y\}} \right] \cdot LR_y \tag{8}$$

where ${}_t q_y^{rr}$ denotes the survival probability of retirees from y years old to $y + t$ years old, AVP_y and AVB_y are the average individual pension and public pension of y-year-old participants at period 0, respectively, $I_{\{\cdot\}}$ is the indicator function, G_y is the average remaining years in the planned period, α_t denotes the growth rate of the public pension at period t, D is the funeral favor, and β_t is the growth rate of the funeral favor at period t.

3.3.2. Expenditure Models for Type II

Among participants in type I, the benefits are partially determined by their contribution history but still depend on their contributions in the future. Therefore, we must forecast their benefits on the basis of assumptions regarding their wages and status. Before that, we will review the rules of CPBS. CPBS specifies that the individual pension equals the accumulated amount of an individual's private account divided by the length of the planned period, which is set by the government, i.e.,

Individual pension = accumulated amount of private account/length of planned period
In addition, the public pension is calculated as follows:
Public pension = (years of contribution/100) × . . .
(Average wage of individual contribution + average wage of all employees)/2

With these specifications, the expenditures of the private account and public account for type II are as follows:

$$PLC^t = \sum_{i=l,s}\left\{\sum_{x=x_s}^{x=x_f}\left[LA_x^i \cdot \sum_{t_r=1}^{t} P(R_x^i = t_r)PLC_x^{t,t_r,i} + LA_x^i \cdot P(T_x^i = t)PA_x^{t,i}\right]\right\} \quad (9)$$

$$TLC^t = \sum_{i=l,s}\left\{\sum_{x=x_s}^{x=x_f}\left[LA_x^i \cdot \sum_{t_r=1}^{t} P(R_x^i = t_r)TLC_x^{t,t_r,i}\right]\right\} \quad (10)$$

where $P\left(R_x^i = t_r\right)$ is the probability that an i-status x-year-old individual retires at period t_r, $P\left(T_x^i = t\right)$ is the probability that an i-status x-year-old individual dies at period t, $PLC_x^{t,t_r,i}$ and $TLC_x^{t,t_r,i}$ are the expenditures at period t of the private account and public account for an i-status x-year-old individual who retires at period t_r, and $PA_x^{t,i}$ is the accumulated amount in the private account for an i-status x-year-old individual at period t. $PLC_x^{t,t_r,i}$ is calculated by

$$PLC_x^{t,t_r,i} = {}_{t-t_r}q_{x+t_r}^{rr} PLC_x^{t_r,i}\left(1 - I_{\{t-t_r \geq g(x+t_r)\}}\right) + {}_{t-1}q_{x+t_r}^{rr} q_{x+t_r+t-1}^{rd} PAS_x^{t,t_r,i} \quad (11)$$

$$PLC_x^{t_r,i} = \frac{\sum\limits_{k=0}^{t_r} (1+r)^{t_r-k}\lambda B_{x+k}^k{}_k p_x^{il} + PAY_x^i(1+r)^{t_r}}{g(x+t_r)} \quad (12)$$

$$PAS_x^{t,t_r,i} = PLC_x^{t_r,i}\max(g(x+t_r) - (t-t_r), 0) \quad (13)$$

where $PLC_x^{t_r,i}$ is the individual pension of an i-status x-year-old individual who retires at period t_r, $g(x+t_r)$ is the length of the planned period for those who retired at age $x+t_r$, PAY_x^i is the accumulated amount at period 0 of an i-status x-year-old individual, and $PAS_x^{t,t_r,i}$ is the unfinished amount at period t for an individual account of an i-status x-year-old individual who retires at period t_r.

$TLC_x^{t,t_r,i}$ is calculated by

$$\begin{aligned} TLC_x{}^{t,t_r,i} &= {}_{t-t_r}q_{x+t_r}^{rr} \cdot TLC_x{}^{t_r,i} \cdot \prod_{s=t_r}^{t}(1+\alpha_s) + {}_{t-1}q_{x+t_r}^{rr} q_{x+t_r+t-1}^{rd} \cdot \\ & D \cdot \prod_{s=1}^{t}(1+\beta_s) + {}_{t-t^r}q_{x+t_r}^{rr} \cdot PLC_x^{t_r,i} \cdot I_{\{t-t_r \geq g(x+t_r)\}} \end{aligned} \quad (14)$$

$$\begin{aligned} TLC_x{}^{t_r,i} &= \overline{W}^{t_r-1} \times z_x^{equ,i} \times n_x^{equ,i} \times 1\% + \overline{W}^{t_r-1} \times z_x^{real92-98,i} \times n_x^{real92-98,i} \times 1\% \\ &+ 1\% \times 0.5(\overline{W}^{t_r-1} + \overline{W}^{t_r-1} \times (z_x^{real99-08,i} + EZ_x^{real09-16,i} + EZ_x^{real17-t_r,i}) \\ &\times (n_x^{real99-08,i} + EN_x^{real09-16_r,i} + EN_x^{real17-t_r,i}) \end{aligned} \quad (15)$$

where $TLC_x{}^{t_r,i}$ is the public pension of an i-status x-year-old individual who retires at period t_r and Equation (15) is the calculation of $TLC_x{}^{t_r,i}$.

$PA_x^{t,i}$ is calculated by

$$PA_x^{t,i} = \sum_{k=0}^{t}(1+r)^{t-k}\lambda B_{x+k}^k{}_k p_x^{il} \quad (16)$$

3.3.3. Expenditure Models for Type III

The expenditure models for new participants (type III) are similar to those for type II, except that the participants are aged c at period s instead of x at period 0. Therefore, we omit the explanations for these formulas. The expenditures of the private account and public account for type III are as follows.

$$PLNC^t = \sum_{s=1}^{t}\left[NLA_c(s) \cdot \sum_{t_r=s}^{t} P(R_c(s) = t_r)PLC_c^{t,t_r}(s) + NLA_c(s) \cdot P(T_c^d(s) = t)PA_c^t(s)\right] \quad (17)$$

$$TLNC^t = \sum_{s=1}^{t}\left[NLA_c(s)\cdot\sum_{t_r=s}^{t}P(R_c(s)=t_r)TLC_c^{t,t_r}(s)\right] \tag{18}$$

where

$$PLC_c^{t,t_r}(s) = {}_{t-t_r}q_{c+t_r-s}^{rr}PLC_c^{t_r}(s)(1-I_{\{t-t_r\geq g(x+t_r)\}}) + {}_{t-1}q_{c+t_r-s}^{rr}q_{c+t_r-s+t-1}^{rd}PAS_c^t(s) \tag{19}$$

$$PLC_c^{t_r}(s) = \frac{\sum\limits_{k=s}^{t_r}(1+r)^{t-k}\lambda B_{c+kk-s}^k p_c^{ll}}{g(c+t_r-s)} \tag{20}$$

$$PAS_c^t(s) = PLC_c^{t_r}(s)\max(g(c+t_r-s)-(t-t_r),0) \tag{21}$$

$$PA_c^t(s) = \sum_{k=s}^{t}(1+r)^{t-k}\lambda B_{c+kt-s}^k p_c^{ll} \tag{22}$$

and

$$TLC_c{}^{t,t_r}(s) = {}_{t-t_r}q_{c+t_r-s}^{rr}\cdot TLC_c{}^{t_r}(s)\cdot\prod_{m=t_r}^{t}(1+\alpha_m) \tag{23}$$

$$TLC_c{}^{t_r}(s) = 1\%\times 0.5(\overline{W}^{t_r-1}+\overline{W}^{t_r-1}\times EZ_x^{reals-t_r})\times EN_x^{real09-t_r} \tag{24}$$

3.4. Balance Model of CBPS

With the population model, inflow model, and expenditure model, the balance models at period t for private account and public account are

$$TB^t = TIN^t - TRC^t - TLC^t - TLNC^t \tag{25}$$

$$TP^t = PIN^t - PRC^t - PLC^t - PLNC^t \tag{26}$$

4. Calibration

4.1. Participants in the Future

The population structure in the future depends on the population structure at period 0 and the mortality and fertility rates. Let L_y^t denote the population of y-year-old people at period t. Then, $L_0^{t+1} = n_t\sum\limits_y L_y^t$ and $L_{y+1}^{t+1} = L_y^t\cdot p_y$, where n_t is the fertility rate of the total population, and p_y is the probability of an individual y years old surviving to y + 1 years old. Therefore, we must estimate the population structure at period 0 and the mortality and fertility rates.

We calculate the population structure at period 0, $\{L_y^0\}$, according to the tabulation of the 2010 Population Census of China.

We must estimate a national life table because one is not currently available. According to the China Life Insurance Mortality Table (2010–2013) and the actual population and fertility rate issued by the China National Bureau of Statistics, the actual mortality rate is 1.2 times that in Table 1, China Life Insurance Mortality Table (2010–2013). The comparison of the actual population and the estimated population is shown in Table 1.

Table 1. Comparison of the actual population and estimated population in China from 2010 to 2018.

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Actual population	13,409	13,474	13,540	13,607	13,678	13,746	13,827	13,901	13,954
Estimated population	13,328	13,406	13,482	13,560	13,632	13,715	13,788	13,838	13,908
Accuracy rate	99.4%	99.5%	99.6%	99.7%	99.7%	99.8%	99.7%	99.6%	99.7%

Estimating the fertility rate in the future in China is highly difficult. The one-child policy was issued in 1978, and couples were allowed to have only one child. However, the policy was ended in 2016, and a new policy allows couples to have two children. The reform of the one-child policy has attracted great interest. At the beginning of the new policy, many studies claimed that the total fertility rate would increase rapidly in the short term, e.g., [22,23]. However, those expectations did not come true. According to data from China National Bureau of Statistics, the total fertility rate was 1.094, which is the lowest in the history of China. In this study, we sought to examine the impact of the increasing population on the sustainability of CBPS. Therefore, we assume that the fertility rate will increase in the short term and then decline in the long term. According to the data from a population sample survey released by the National Bureau of Statistics, we assume a fertility rate of 1.4 from 2019 to 2022 and 1.25 after 2022.

With these assumptions, the population will increase first and then decrease after the 2038 peak, as shown in Figure 3.

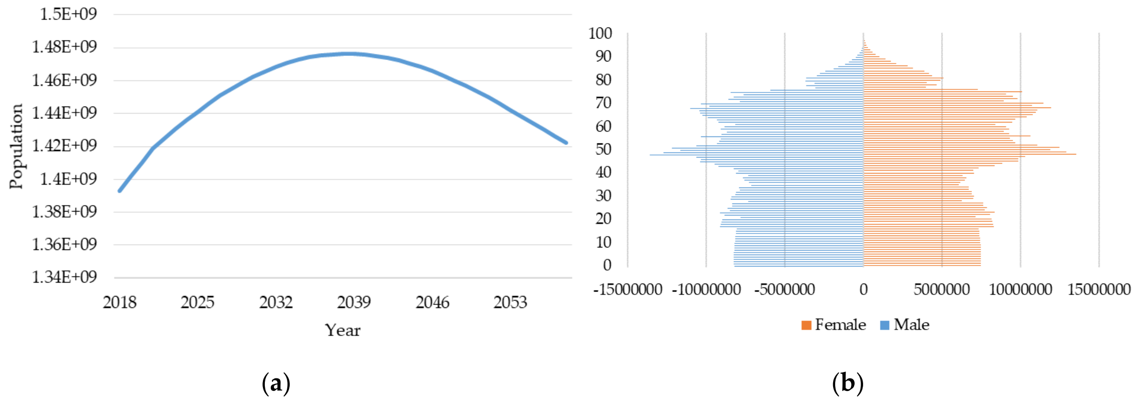

Figure 3. The future population in China. (**a**) The population in China (2018–2058). (**b**) The population structure in China (2038).

As described before, only employees participate in CBPS, and the populations who join in CBPS must be estimated.

Step 1: estimating the structure of populations that have already joined CBPS. We obtained the number of contributors and retirees from the China Labor Statistical Yearbook 2018. From the unpublished social security database of Beijing, we obtained the proportions of participants of all ages. Then, we estimated the number of participants of all ages in China, which are LA_x^i and LR_y at period 0.

Step 2: estimating the numbers of new participants in all periods. We assumed that the number of new participants is the product of the new workforce, urbanization rate, and employment rate. The numbers of the new workforce come from the population in China. According to the China National Population Development Plan (2016–2030), the urbanization rate in 2030 will be 70%. Given that the urbanization rate in 2018 was 58.52%, we assume that the urbanization rate will increase 1% per year from 2019 to 2030 and then remain unchanged after 2030. In addition, the unemployment rate in China was between 4% and 4.3% from 2002, according to the China National Bureau of Statistics. Thus, we assume that the unemployment rate in the future will be 4.14%, and the employment rate will be 95.86%.

Step 3: estimating the transition probability matrix. We collected the unpublished social security database of Beijing, stratified the data by age and status, and then estimated the probabilities (Appendix A).

4.2. Wages

Following [24], we assume the following rules for wages:

- $W_{x+t}^{t} = W_{x}^{t} e_{x+t}$. The human capital e_{x+t} determines the difference in wages of individuals who are x years old and x + t years old in the same period.
- $W_{y}^{t} = W_{y}^{t-1}(1+\varepsilon)$. The wages of individuals of the same age increase ε per year.

Therefore, we have $W_{x+t}^{t} = W_{x}^{0} e_{x+t}(1+\varepsilon)^{t}$, where e_{x+t} and ε will be estimated.

According to the unpublished social security database of Beijing, we calculated the average wages for all ages and then obtained e_{x+t}, which is shown in Figure 4.

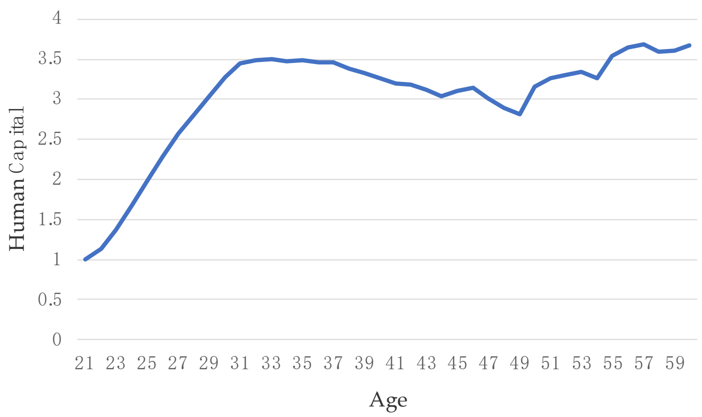

Figure 4. Human capital for all ages (e_x= 1).

The average growth rate of wages ε reached to 13.83% during 2000–2014. However, the subsequent growth rate will not be as high because of the decline of economic growth in China. According to [2], we assume that $\varepsilon = 7.7\%$ for 2018–2020, $\varepsilon = 6.6\%$ for 2021–2025, and $\varepsilon = 5.7\%$ for 2026–2068.

4.3. Parameters in CBPS

We assume that the age of the youngest employees is 21, and the maximum age of retirees is 100, according to the social security database of Beijing. CBPS specifies an individual contribution rate of 8% and an employer contribution rate of 20% (the employer contribution rate has been decreased to 16% to reduce the employer's burden and promote the development of the private sector in China. However, the policy is temporary because of the large CBPS gap. Therefore, we still assume 20% but perform a sensitivity test for the parameter.). The length of the planned period depends on the age at which the participant retires; for example, the length of the planned period for an individual retiring at 60 years is 139 months (approximately 12 years). Appendix B shows the relationship between the length of the planned period and age.

Official documents regulated the interest rate of the private account in 2017, and the interest rate was above 8%. We assume an interest rate of 8.13% after 2017, according the Annual Report of National Council of Social Security Funds. Before 2017, the money in the private account was embezzled. The return of the private account was not recovered and for bookkeeping purposes was considered to have accrued at the lowest interest rate. Therefore, we assume that the interest rate was 2.84% before 2017.

The public pension increases every year after individuals retire. The increases are a bonus to retirees to ensure that the standard of living of retirees is not affected by inflation. However, the growth rate of the public pension was much higher than the inflation rate during 2006–2015, reaching 10% per year. However, the growth rate began to fall in 2016 and was 6.5%, 5.5%, 5%, and 5% in 2016, 2017, 2018, and 2019, respectively. Therefore, we assume a 5% future growth rate.

The funeral favor, another bonus, differs among provinces. For example, the funeral favor is 5000 CNY in Beijing and four times the average wage in Chengdu. According to [25], we assume that the funeral favor is 60% of the national average wage.

All parameter values are shown in Table 2.

Table 2. Parameter values.

Description	Value
Mortality rate	1.2 times the value in Table 1, China Life Insurance Mortality Table (2010–2013)
Fertility rate	The fertility rate is 1.4 from 2019 to 2022 and 1.25 after 2022
Population structure at period 0	The tabulation on the 2010 Population Census of China
Urbanization rate	The urbanization rate in 2018 was 58.52%, which will increase 1% per year from 2019 to 2030 and then remain unchanged.
Unemployment rate	4.14%
Average growth rate of wages	7.7% for 2018–2020, 6.6% for 2021–2025, and 5.7% after 2025
Interest rate	2.84% before 2017 and 8.13% after 2017
Funeral favor	60% of the national average wage
Public pension growth rate	5% after 2018

5. Model Testing and Policy Analysis

5.1. Model Testing

We used the data from 2009 to 2017 to test our model to ensure that the model, parameters, and codes are correct. The comparison of the actual data and simulated data is shown in Table 3.

Table 3. Comparison of actual data and simulated data (2009–2017).

(0.1 Billion CNY)	Actual Income [1]	Simulated Income	Ratio	Actual Expenditure	Simulated Expenditure	Ratio
2009	9534.0	10,924.7	114.59%	8894.4	8965.7	100.80%
2010	11,110.0	12,211.2	109.91%	10,554.9	10,888.1	103.20%
2011	13,956.0	14,199.8	101.75%	12,765.0	13,249.9	103.80%
2012	16,467.0	16,184.8	98.29%	15,561.8	16,049.5	103.10%
2013	18,634.0	18,324.3	98.34%	18,470.4	19,644.0	106.40%
2014	20,434.0	20,844.6	102.01%	21,754.7	23,435.2	107.70%
2015	23,016.0	23,617.4	102.61%	25,812.7	28,030.7	108.60%
2016	26,768.0	27,158.3	101.46%	31,853.8	32,310.4	101.40%
2017	33,403.0	31,453.2	94.16%	38,051.5	37,027.4	97.30%

[1] Data source: China Labor Statistical Yearbook 2018; the actual income does not contain the subsidies.

Table 3 shows that our model fits CBPS well. The error rate of income is 4.62% and that of expenditure is 4.19%. Our model appears to be reliable.

5.2. Forecasting

Taking 2017 as period 0, we predict the income and expenditure of CBPS from 2018 to 2058. The results are shown in Table 4.

Table 4. Income and expenditure forecasting of CBPS (2018–2058).

(0.1 Billion CNY)	Income	Expenditure	Gap in Single Year
2018	35,288.4	42,417.6	−7129.2
2023	59,106.1	80,415.9	−2,1309.8
2028	88,826.7	152,188.6	−6,3361.8
2033	126,820.4	274,725.0	−147,904.7
2038	177,121.9	459,464.7	−282,342.9
2043	246,078.1	729,378.4	−483,300.3
2048	336,225.5	1,076,058.5	−739,833.0
2053	452,095.0	1,534,990.1	−1,082,895.1
2058	617,958.4	2,093,026.2	−1,475,067.9

Table 4 shows that the contributions are less than the benefits every year from 2018, and CBPS is unsustainable if there are no reforms or external transfers. In addition, the gap grows in the future.

As there is a positive accumulated balance at the end of 2017, the accumulated balance will not become negative in 2018. The accumulated balances from 2018 to 2028 are shown in Table 5.

Table 5. Accumulated balance of CBPS (2018–2028).

	Accumulated Balance (0.1 Billion CNY)
2018	40,323.2
2019	34,605.7
2020	26,469.1
2021	14,911.0
2022	−769.2
2023	−22,079.0
2024	−49,565.3
2025	−83,610.6
2026	−125,697.6
2027	−177,370.3
2028	−240,732.2

Table 5 shows that the accumulated balance of CBPS will become negative in 2022, and the deficit is 76.9 billion CNY. Subsequently, the deficits grow, reaching 24,073.2 billion CNY in 2028, which is 27% of the GDP in 2018.

5.3. Policy Analysis

5.3.1. The Decline in Employer Contribution Rate

As described before, the government decreased the employer contribution rate from 20% to 16% in 2019, to ease employer burden and promote economic growth. However, this change is not beneficial for the unsustainable CBPS. There is no doubt that the deficits will become larger than before. The results are shown in Figure 5.

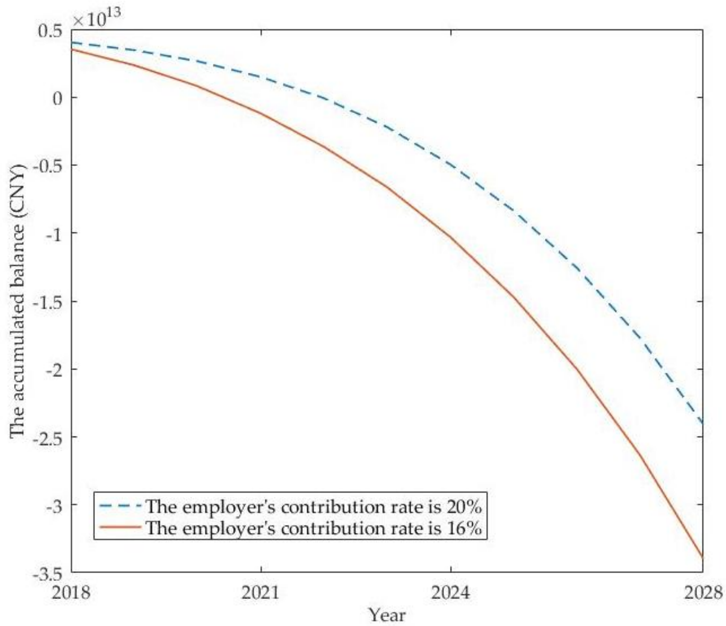

Figure 5. Accumulated balance when the employer contribution rate is decreased to 16%.

As expected, the deficits grow. Owing to the decrease in the employer contribution rate from 20% to 16%, the time at which the accumulated balance will become negative becomes 2021 instead of 2022. In addition, the deficit will be 1192.8 billion CNY, instead of 76.9 billion CNY.

However, the impact of the decline in the employer contribution rate may be substantial. The decline will increase employer profit and then increase the wages and employment rate, which in turn, will increase the income of CBPS. However, this topic is beyond the scope of our article.

5.3.2. The End of One-Child Policy

China is getting older faster than anywhere else worldwide. Ending the one-child policy was one measure taken to alleviate the aging problem. Simultaneously, an increase in fertility rate will also enhance the sustainability of CBPS, according to the experience of other countries. Here, we study the impact of ending the one-child policy on the sustainability of CBPS.

We examine three situations:

- High fertility rate: 2 from 2019 to 2022 and 1.8 after 2022.
- Moderate fertility rate (baseline situation): 1.4 from 2019 to 2022 and 1.25 after 2022.
- Low fertility rate: 1.4 from 2019 to 2022 and 1.1 after 2022.

Changes in fertility will affect the income and expenditure of CBPS for more than 100 years. Therefore, we must extend the prediction period from 2018–2057 to 2018–2107. The results are shown in Figure 6.

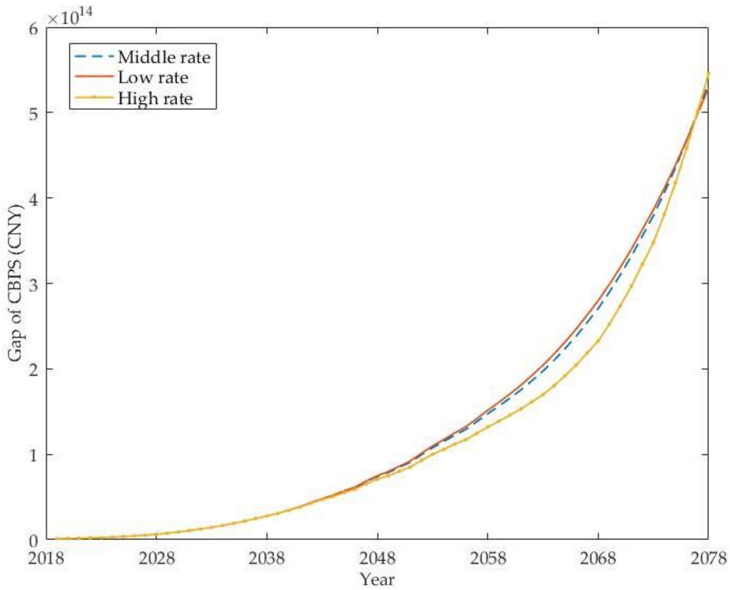

Figure 6. CBPS gap with different fertility rates (2018–2078).

Figure 6 shows that fertility rate have no effects in the short term because the new generation does not participate in CBPS until 2038. After these individuals are employed and contribute to CBPS during 2038–2078, the income will increase, and the gap between expenditure and income will decrease if the fertility rate increases. Therefore, the increase in fertility rate will also enhance the sustainability of CBPS in the short to medium term.

However, Figure 6 shows that the sustainability will substantially decrease when the new generation retires. This conclusion is contrary to those of many other researchers, who have claimed that the increase in fertility rate will enhance the sustainability of CBPS at all times, e.g., [6]. The reason for this discrepancy is that CBPS is not actuarially balanced. In other words, every participant receives more than his/her contributions, as shown in Table 6. Therefore, CBPS has a greater deficit if there are more participants.

Table 6. The actuarial present value of the benefits and contributions of a male participant who enters the system in 2018 (assuming an interest rate of 7%).

Entry Year	Contributions (CNY)	Benefits (CNY)
2018	61,710	79,420

In conclusion, ending the one-child policy may enhance the sustainability of CBPS in the short to medium term but will erode the sustainability of CBPS in the long term.

5.3.3. The Increase in Retirement Age

Raising the retirement age is another way to enhance the sustainability of the pension system. China also issued a delayed retirement policy specifying that the retirement age will increase 1 year every 2 years, and the final compulsory age will be 65 for men and 60 for women. We consider the policy as the experimental group and the baseline situation as the control group. The results are shown in Figure 7.

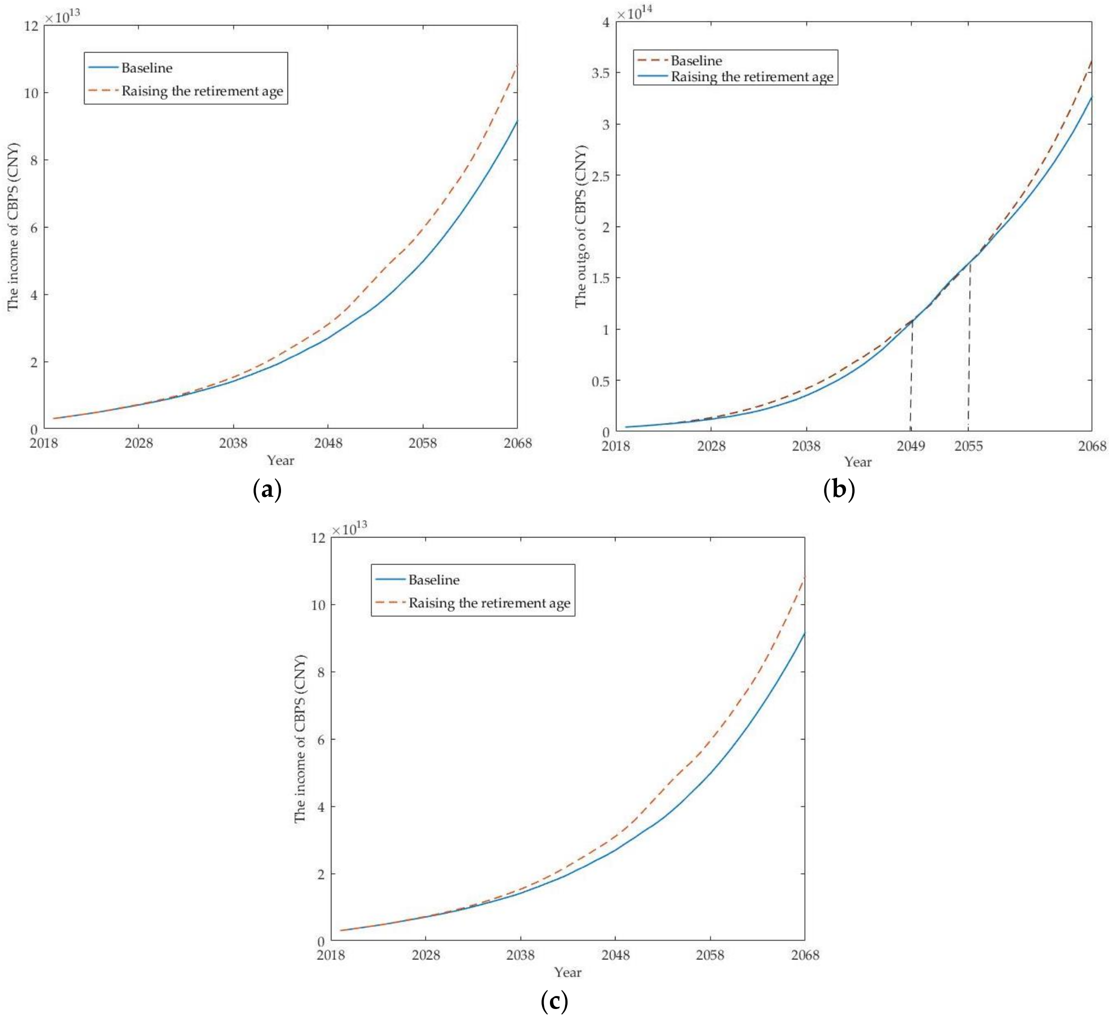

Figure 7. Income and expenditure of CBPS with different retirement ages. (**a**) The income of CBPS (2018–2068). (**b**) The expenditure of CBPS (2018–2068). (**c**) The gap of CBPS (2018–2068).

Figure 7 shows that the income will increase because individuals will contribute longer if the retirement ages are increased. However, the change in expenditure is slightly more than we expected. We expected that the expenditure would decrease if the retirement age increased. Although this is true in most years, the expenditure increases between 2049 and 2055, although the gap decreases in all years because of delayed retirement.

We sought to determine why the expenditure increases between 2049 and 2055. Taking a male participant who enters the system in 2018 as an example, we calculated the actuarial present value of his total contributions and benefits with different retirement ages. The results are shown in Figure 8. Although delayed retirement results in a delay in pension payment for part of the working staff, the amount of pension payment for this part of the insured staff will increase in the future, thus potentially leading to an increase in the total amount of pension funds paid in the future, and in contrast, increasing the pressure on pension funds to pay.

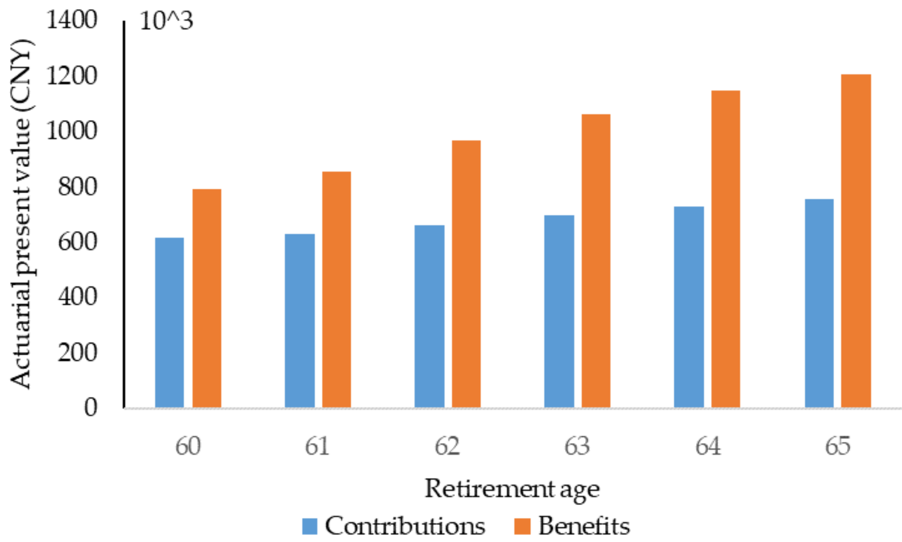

Figure 8. The actuarial present value of the benefits and contributions of a male participant who enters the system in 2018 with different retirement ages (assuming an interest rate of 7%).

5.3.4. Comprehensive Analysis

There are interactions if the above policies are simultaneously affected. Therefore, we comprehensively analyzed the effects of the decline in employer contribution rate, the end of the one-child policy, and the increase in retirement age. The results are shown in Figure 9.

Figure 9 shows that the income will increase if all policies go into effect simultaneously. There will be many more participants because of the ending of the one-child policy. All participants will contribute for longer times because of delayed retirement. Although the income will decrease because of the decline in the employer contribution rate, it will be offset by the increases resulting from the other two policies.

However, the change in expenditure is not consistent. The impacts on expenditure of ending the one-child policy and increasing the retirement age are opposite. Moreover, the decline in the employer contribution rate does not affect the expenditure. Therefore, the expenditure will decrease because of fewer participants, whereas the expenditure will increase when the population exceeds a threshold, which will occur in 2078.

The changes in income and expenditure determine the gap. Our results show that the gap will shrink before 2088 and subsequently increase rapidly.

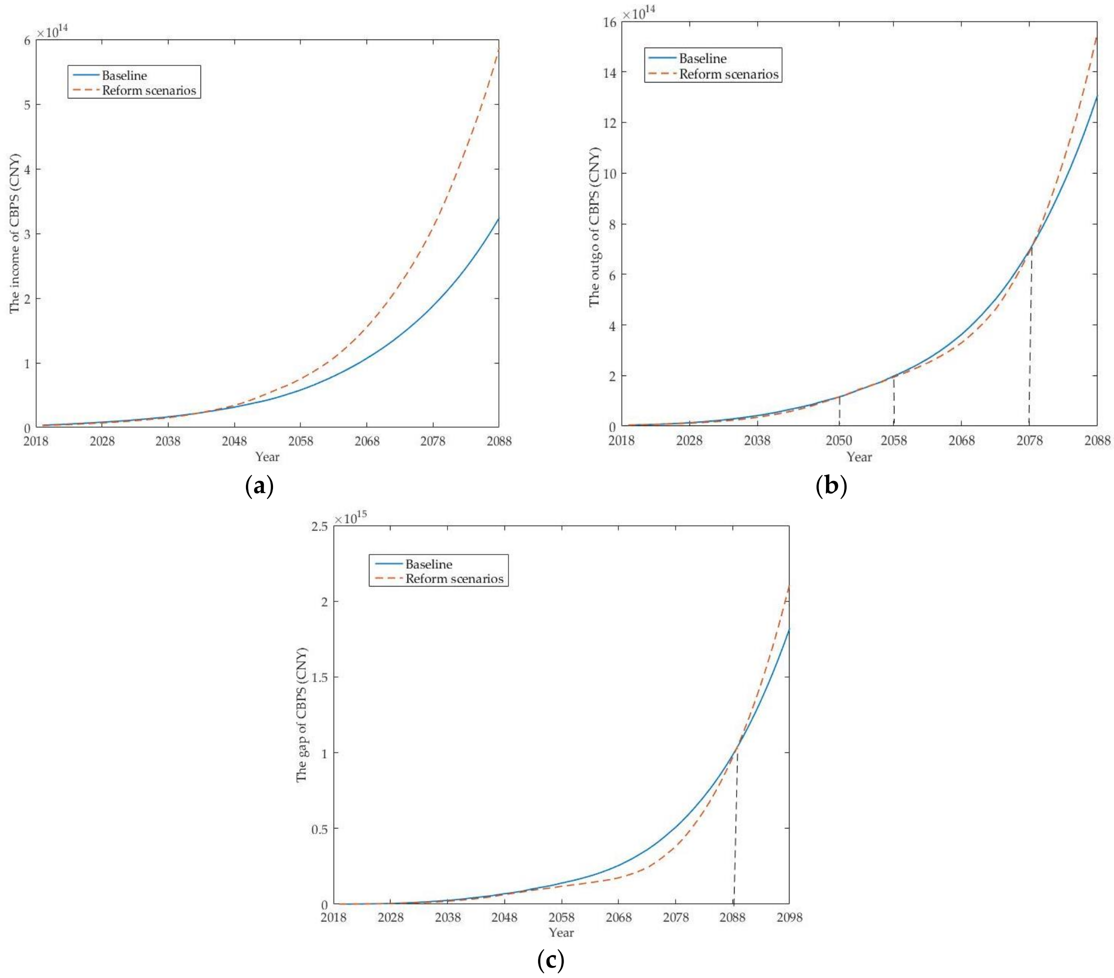

Figure 9. Income and expenditure of CBPS with reforms. (**a**) The income of CBPS (2018–2088). (**b**) The expenditure of CBPS (2018–2088). (**c**) The expenditure of CBPS (2018–2098).

6. Conclusions

This article describes CBPS and discusses the effectiveness of reforms on its sustainability. It provides a description of the pension system in China. In addition, a Markov actuarial model, which had not previously been developed for China, was established and verified for CBPS.

This article found that: (1) The contributions are less than the benefits every year from 2018, and the accumulated balance will be negative from 2022. (2) Ending the one-child policy may enhance the sustainability of CBPS in the short to medium term but will erode the sustainability of CBPS in the long term. (3) Raising the retirement age will shrink the gap of CBPS although the expenditure increases in a certain period. (4) Comprehensively, the gap will shrink before 2088 and subsequently increase rapidly if all of the policies are implemented.

From the above results, we believe that CBPS will not be sustainable in the long term if there are no subsidies or other financial transfers, even with delayed retirement and the increase in fertility. Moreover, the rise in fertility will shrink the gap of CBPS in the medium to short term but will increase the gap in the long term. In addition, raising the retirement age may not help, because the benefits depend on the length of contributions. It is the system itself that is not sustainable. In other words, the system is not actuarially balanced, by giving everyone extra money. Therefore, thorough reform is necessary to make the system self-financed, such as the methods to calculate the benefits of the public and private account.

There are two limitations of the article. Firstly, there are a lot of parameters and assumptions when forecasting the future cashflows of CBPS. Because of the uncertainties in future, the actual parameters and assumptions may be different with the settings in the paper. Secondly, the implementation of some reforms will not only directly affect the sustainability of CBPS but also have indirect impacts by changing macroeconomic variables. It is an interesting topic for future works. In addition, our model can also be applied to projecting the cashflows of other pension systems.

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

Appendix A

Table A1. The transition probability matrix of contributors.

Age	ll	ls	lr	ld	sl	ss	sr	sd
21	0.85463	0.14527	0.00000	0.00010	0.75794	0.24043	0.00000	0.00163
22	0.87759	0.12232	0.00000	0.00009	0.78286	0.21565	0.00000	0.00149
23	0.88040	0.11952	0.00000	0.00008	0.77670	0.22153	0.00000	0.00177
24	0.86935	0.13054	0.00000	0.00011	0.73936	0.25817	0.00000	0.00247
25	0.86049	0.13940	0.00000	0.00011	0.69870	0.29815	0.00000	0.00315
26	0.86177	0.13810	0.00000	0.00013	0.64215	0.35340	0.00000	0.00445
27	0.86705	0.13282	0.00000	0.00013	0.59016	0.40370	0.00001	0.00613
28	0.87679	0.12304	0.00000	0.00016	0.55109	0.44093	0.00000	0.00798
29	0.88109	0.11874	0.00001	0.00017	0.52666	0.46534	0.00004	0.00796
30	0.88877	0.11102	0.00000	0.00021	0.50992	0.48211	0.00000	0.00797
31	0.89559	0.10421	0.00002	0.00018	0.49817	0.49361	0.00008	0.00814
32	0.90243	0.09739	0.00002	0.00016	0.49603	0.49378	0.00008	0.01010
33	0.90865	0.09106	0.00005	0.00023	0.50305	0.48558	0.00021	0.01116
34	0.91690	0.08278	0.00012	0.00019	0.49749	0.48979	0.00049	0.01222
35	0.92598	0.07361	0.00011	0.00030	0.50250	0.48356	0.00047	0.01347
36	0.93114	0.06832	0.00022	0.00032	0.49364	0.48995	0.00100	0.01542
37	0.93625	0.06316	0.00025	0.00034	0.49680	0.48432	0.00116	0.01772
38	0.93906	0.06015	0.00037	0.00041	0.49965	0.47797	0.00179	0.02059
39	0.94039	0.05864	0.00050	0.00047	0.49556	0.47992	0.00261	0.02191
40	0.93309	0.06574	0.00068	0.00049	0.49382	0.47941	0.00360	0.02316
41	0.93850	0.06011	0.00082	0.00057	0.50950	0.46298	0.00445	0.02307
42	0.94005	0.05820	0.00113	0.00062	0.50980	0.45816	0.00625	0.02579
43	0.93781	0.06039	0.00120	0.00060	0.50734	0.45419	0.00726	0.03121
44	0.93427	0.06333	0.00157	0.00083	0.48147	0.46866	0.01078	0.03910
45	0.83349	0.07278	0.09273	0.00099	0.27621	0.27516	0.42243	0.02619
46	0.91394	0.06067	0.02438	0.00101	0.40522	0.39219	0.15931	0.04328
47	0.93032	0.06133	0.00724	0.00112	0.45130	0.43657	0.05695	0.05517
48	0.93977	0.05364	0.00540	0.00119	0.45080	0.44098	0.04425	0.06396
49	0.94059	0.05373	0.00394	0.00175	0.43647	0.46080	0.03496	0.06777
50	0.65188	0.05800	0.28844	0.00167	0.09661	0.12411	0.75741	0.02187
51	0.90594	0.06468	0.02752	0.00186	0.31975	0.41671	0.18588	0.07767
52	0.92773	0.06163	0.00879	0.00184	0.34389	0.49763	0.06597	0.09250
53	0.92894	0.06080	0.00789	0.00237	0.32010	0.51606	0.06332	0.10052
54	0.91843	0.07275	0.00667	0.00215	0.30672	0.53597	0.05690	0.10040
55	0.50985	0.05435	0.43390	0.00189	0.05214	0.09147	0.83271	0.02368
56	0.84429	0.05271	0.10077	0.00223	0.19373	0.29432	0.42343	0.08851

Table A1. *Cont.*

Age	ll	ls	lr	ld	sl	ss	sr	sd
57	0.92097	0.04898	0.02684	0.00322	0.26167	0.43847	0.16313	0.13673
58	0.94414	0.03671	0.01598	0.00317	0.25210	0.50030	0.10868	0.13892
59	0.94620	0.04017	0.00969	0.00394	0.24076	0.53257	0.07314	0.15352
60	0.03196	0.04342	0.92153	0.00310	0.00617	0.04715	0.92728	0.01940
61	0.17245	0.18253	0.64166	0.00336	0.03069	0.35778	0.42889	0.18263
62	0.53000	0.14500	0.32000	0.00500	0.03488	0.63081	0.09302	0.24128
63	0.58182	0.11818	0.30000	0.00000	0.03795	0.64286	0.07366	0.24554
64	0.55556	0.13889	0.30556	0.00000	0.02609	0.74348	0.09565	0.13478
65	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	1.00000	0.00000

"l", "s", "r", "d" denote "Normal", "Break-off", "Retirement" and "Dead", respectively. And "ij" denotes the 1-year transition probability from state i to state j. For example, "ll" denotes the the 1-year transition probability from Normal to state Normal.

Table A2. The transition probability matrix of retirees.

Age	rr	rd	Age	rr	rd
41	0.97575	0.02425	71	0.96806	0.03194
42	0.98830	0.01170	72	0.96310	0.03690
43	0.98209	0.01791	73	0.95697	0.04303
44	0.97702	0.02298	74	0.95318	0.04682
45	0.99574	0.00426	75	0.94776	0.05224
46	0.99525	0.00475	76	0.94279	0.05721
47	0.99395	0.00605	77	0.93871	0.06129
48	0.99497	0.00503	78	0.93138	0.06862
49	0.99320	0.00680	79	0.92154	0.07846
50	0.99722	0.00278	80	0.91088	0.08912
51	0.99533	0.00467	81	0.90527	0.09473
52	0.99519	0.00481	82	0.89749	0.10251
53	0.99543	0.00457	83	0.88268	0.11732
54	0.99436	0.00564	84	0.86553	0.13447
55	0.99508	0.00492	85	0.85774	0.14226
56	0.99310	0.00690	86	0.83706	0.16294
57	0.99223	0.00777	87	0.81914	0.18086
58	0.99153	0.00847	88	0.79904	0.20096
59	0.99092	0.00908	89	0.78832	0.21168
60	0.99163	0.00837	90	0.77597	0.22403
61	0.98948	0.01052	91	0.73368	0.26632
62	0.98779	0.01221	92	0.71470	0.28530
63	0.98577	0.01423	93	0.71448	0.28552
64	0.98497	0.01503	94	0.68311	0.31689
65	0.98356	0.01644	95	0.67688	0.32312
66	0.98134	0.01866	96	0.65587	0.34413
67	0.97979	0.02021	97	0.70186	0.29814
68	0.97593	0.02407	98	0.56842	0.43158
69	0.97566	0.02434	99	0.46429	0.53571
70	0.97087	0.02913	100	0.00000	1.00000

"l", "s", "r", "d" denote "Normal", "Break-off", "Retirement" and "Dead", respectively. And "ij" denotes the 1-year transition probability from state i to state j. For example, "ll" denotes the the 1-year transition probability from Normal to state Normal.

Appendix B

Table A3. The relationship of the length of planned period and the age.

Retirement Age	The Length of Planned Period (in Months)	Retirement Age	The Length of Planned Period (in Months)
40	233	53	180
41	230	54	175
42	226	55	174
43	223	56	164
44	220	57	158
45	216	58	152
46	212	59	145
47	208	60	139
48	204	61	132
49	199	62	125
50	195	63	117
51	195	64	109
52	185	65	101

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