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Stochastic Assessments of Urban Employees' Pension Plan of China

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Abstract: In the uncertain environment of population and economy; the pension plan for urban employees in China is under threat from various types of financial risk. This paper mainly builds a comprehensive risk assessment system to evaluate the solvency sustainability of the urban employees' pension plan of China. Specifically, we forecast annual accumulative net asset; actuarial balance; and potential support ratio for the next seventy years. To account for the impact of demographic uncertainty on long-term finances, stochastic simulations are used to estimate the probability distribution of relative risk indicators. Moreover, we integrate the Lee–Carter model into the population projection. According to the median projection, the public pension fund will have a gap in about 35 years; and the cash flow will be negative about 25 years later. Furthermore, under the existing policy, the burden of insured employees will increase rapidly. Delayed retirement could relieve the coming solvency risk, but it does not fundamentally resolve the solvency problem in the long run.

Keywords: pension plan; solvency sustainability; actuarial balance; potential support ratio; stochastic simulation; probability forecast

1. Introduction

The financial risk of the pension plan has been extensively studied by academics and social security agencies, and especially, the longevity risk brought about by population aging has become a worldwide issue. The population of China is aging more rapidly than other countries and the accumulated pension debt becomes larger and more widespread each year [1]. To improve the solvency of the public pension plan, the Chinese government has introduced a two-child family planning policy and a delayed retirement policy. However, because of the uncertainty regarding future demographic developments, the exact timing and structure of related policy reforms depend on the quantitative analysis of the whole social security system. Thus, accurate risk assessments of old-age security system are fundamental to avoid the shocks of demographic structure and economic transition. Furthermore, the stochastic projections of long-term finances of the pension plan could also optimize the design of the old-age security system and enhance the solvency sustainability.

In order to make a more comprehensive decision, administrators are not only required to project the long-term outcomes of risk indicators, but also required to quantify the uncertainty of these indicators as much as possible. For instance, consider a scenario where one pension plan will maintain sustainability for the next fifty years, but that there is a 25% probability that the plan is expected to be insolvent for the next twenty years; for another scenario, it has a positive cumulative balance for the next forty five years, but there is a 20% probability that the plan has a negative cumulative balance for

the next twenty years. By comparing the uncertain financial status of the two pension systems, it is clear that the first pension system needs more urgent reforms to maintain financial sustainability [2]. According to the actuarial factors, the uncertainty of the pension plan is classified into four categories: demographic structure, economic factors, employee retirement behavior, and changes in economic structure (technological innovation, globalization of trade and capital, and macroeconomic feedback on economic and demographic structures), while the retirement behavior of workers and economic structure are more difficult to model stochastically [3]. Thus, stochastic assessments of the pension fund play a double role: first, they present percentile distribution of future financial outcomes helping to deal with uncertain risks; second, to avoid frequent adjustment of policy, they highlight the need for long-term sustainable alternatives.

In recent years, stochastic assessments of the pension fund have been investigated by many researchers and social security administrations using Monte Carlo simulation techniques [4–6], which is an increasingly important area in applied actuarial science. As an alternative to scenario analysis, actuarial scholars began to explore the application of stochastic simulation in the projection of demographic uncertainty since the 1980s [7]. According to Lee and Anderson (2003), the stochastic simulation method makes it possible to generate predictive distributions that can give a probabilistic interpretation to the actuarial outcome [3]. In addition, Lee and Carter established the stochastic mortality model, the Lee–Carter model, which was then integrated into the actuarial framework of the U.S. Social Security Administration [8]. Building on this work, Lee and Carter combined time-series models of productivity growth and interest rates to stochastic forecasts of the long-run financial status of the OASDI fund [9]. Alho et al., 2008 measured the sustainability of the pension plan in a stochastic environment, and more importantly they investigated how demographic uncertainty can be addressed through policy initiatives [10]. Tian and Zhao (2016) stochastically forecasted the contributions, expenditures and cumulative balance of the basic pension and evaluated the effect of the delay of retirement of pension sustainability [6]. In addition, simulation techniques can also be used to assess the effect of pension reform within the macroeconomic model [11,12]. However, few studies have investigated the financial risk of the pension plan of China, especially for the liquidity risk and aging risk under stochastic environment. Based on earlier works [4–6], this study is designed to forecast the relative risk indicators within the stochastic actuarial framework of social pooling account. The structure of this paper is as follows. Section 2 introduces the solvency situation of the public pension fund of China. Section 3 describes the basic methods. Analysis of solvency risk is analyzed in Section 4. Section 5 analyzes the risk indicators under the delayed retirement scenario. Section 6 provides the conclusions.

2. The Solvency Situation of Urban Employees' Public Pension Fund in China

According to the accumulated assets of the pension system, the financing mode of pension funds can be divided into three types: pay-as-you-go, partial accumulation (partial funded system) and complete accumulation (funded system). In order to cope with the reform of the market economy system of China, the pension insurance for urban employees has transformed into a partial funded system, which is jointly contributed to by the state, enterprise and employees. Thus, the urban employee's pension fund has two accounts: the social pooling account and the individual account, for which enterprises contribute about 20% of total taxable wages to the social pooling account and employees themselves contribute 8% of payroll to the individual account [13]. As affected by the aging process of population, the public pension plan is facing solvency risk in the near future. Figure 1 shows the historical tendency of accumulated net asset of the social pooling fund. It can be seen that the scale of China's basic pension has been expanding. The cumulative size of the social pooling pension fund has increased from 0.22 trillion yuan in 2003 to 3.85 trillion yuan in 2016, and the scale of annual revenue and expenditure has also increased by nearly 10 times. However, in the case of excluding financial subsidies, the fund's cash flow in 2014 was negative for the first time, and the growth of annual revenue was relatively slower than annual payment.

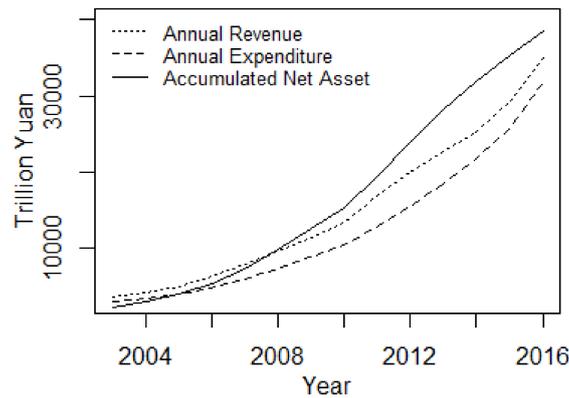


Figure 1. Historical finances of social pooling fund (2003–2016). Source: Statistical bulletin (2003–2016) on the development of human resources and social security [14].

Figure 2 presents the growth rate of annual revenue, annual expenditure, and accumulated net asset. It is noteworthy that the gap between the growth rate of revenue and expenditure shows a trend of increasing year by year. The growth rate of the cumulative pension fund also shows a downward trend, which means that with the aging of population, the fiscal gap of the public pension fund is only a matter of time.

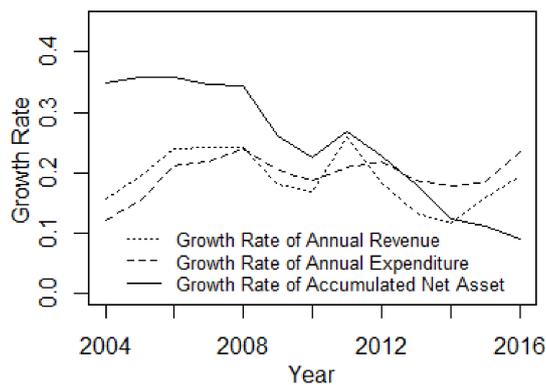


Figure 2. Growth rate of historical finances (2004–2016). Source: Statistical bulletin (2003–2016) on the development of human resources and social security [14] and the author's own calculations.

In order to increase the income of investment, on 1 April 2015, the State Council of China's executive meeting decided to appropriately expand the scope of pension fund investment, expand the pension fund investment to local government bonds, equity investment, trust loan investment, interbank deposit certificate and so on [15]. In this context, we need to pay more attention to the impact of economic crisis. When the economic crisis happens, the agents' wage will decline, the unemployment rate will increase, and the rate of return will be lower, which will directly lead to the reduction of the income of the pension fund. However, governments often hesitate to reduce pension benefits [16]. Thus, the sustainability of the pension system will become even less sustainable in the context of an economic crisis.

3. Method

3.1. Modelling Demographic Variables

The basic demographic inputs, varied stochastically, in the analysis of long-term projections are age-specific fertility and mortality. Considering the characteristic of age–sex specific mortality, we use

the classical Lee–Carter (LC) approach combined with the statistical extrapolation equation to project future mortality. The age-specific fertility is then predicted using time-series equations. In addition, long-held assumption underlying the time-series models is that the probability distribution of annual random shocks can be approximated with normal distribution.

3.1.1. Lee–Carter Approach for Mortality Forecasting

The LC method [8], also known as principal-components-based model, was proposed by Lee and Carter (1992). The model can be expressed as follows:

$$\ln(m_{x,t}) = a_x + b_x k_t + \varepsilon_{x,t} \varepsilon_{x,t} \sim i.i.d N(0, \sigma_\varepsilon^2) \quad (1)$$

$$\sum_x b_x = 1, \sum_{t=t_1}^{t_n} k_t = 0 \quad (2)$$

where: $m_{x,t}$ denotes central mortality rate aged x in calendar year t ; $a_x = (1/T) \sum_t \ln(m_{x,t})$ denotes age-specific parameter, reflecting the constant age pattern of log mortality rates averaged across years; b_x denotes the sensitivity of the age factors on time parameter k_t ; k_t denotes time-varying intensity index of mortality, measuring the speed of mortality change over time; $\varepsilon_{x,t}$ denotes random error term, satisfying the assumption of independent identically distributed. In order to ensure a unique solution of parameter estimation for the bilinear multiplicative constructed model, the identifying constrains are chosen as model (2).

In the stage of parameter estimation, firstly we estimate a_x through historical mortality data for which age separate into 19 unit groups (0–4, 5–9, 10–14, . . . , 80–84, 85–89, 90+). Secondly, we use singular value decomposition (SVD) to estimate parameters b_x and k_t , which is consistent with Lee and Carter (1992). The SVD method is implemented by decomposing the matrix $\ln(m_{x,t}) - a_x$, which can be expressed as:

$$\text{SVD}[\ln(m_{x,t}) - a_x] = USV' \quad (3)$$

By using the constraints (2), the preliminary fitted results of b_x and k_t are estimated as:

$$\vec{b}_x = \vec{u}_1^T / \left(\sum_x u_{x,1} \right) \quad (4)$$

$$\vec{k}_t = s_1 \left(\sum_x u_{x,1} \right) \vec{v}_1 \quad (5)$$

where \vec{u}_1 is the first column of singular vector U , and \vec{v}_1 is the first column of singular vector V' . Singular vectors U and V' , decomposed from the matrix $\ln(m_{x,t}) - a_x$, denote the characteristic of age composition and time index, and s_1 denotes the first singular value of diagonal matrix S . Thirdly, time-series equation is used to forecast k_t based on the historical data decomposed in the second procedure. According to Akaike information criterion (AIC), the extrapolated equation of k_t for females is in accordance with ARIMA (0,1,1) process:

$$k_t^* = -1.02 + k_{t-1}^* + \varepsilon_t - 0.6684\varepsilon_{t-1} \quad \varepsilon_t \sim N(0, 0.72) \quad (6)$$

Index k_t for male data is estimated according to an ARMA (3,0,0) process:

$$k_t^* = -0.6675 + 0.0517k_{t-1}^* + 0.2917k_{t-2}^* + 0.6566k_{t-3}^* + \varepsilon_t \quad \varepsilon_t \sim N(0, 0.75) \quad (7)$$

The expected future values of k_t are forecasted by solving the estimated equation forward through time, and the probability distributions of future forecasts are generated by Monte Carlo simulations. The future mortality can be finally calculated as:

$$\hat{m}_{x,t} = (\hat{\sigma}^2/2) \exp(a_x + \hat{b}_x k_t) \quad (8)$$

3.1.2. Time-Series Modelling of Age-Specific Fertility

In this subsection we constructed time-series equations of age-specific fertility. The Bayesian forecasting method could give an accurate projection [17], but that is not consistent with the stochastic actuarial framework of the U.S. Social Security Administration and Congressional Budget Office [4,18], which we used as a benchmark. Seven groups of age-specific fertility are estimated using ARIMA models involving one or two autoregressive variables with a moving-average term of annual fluctuations. Table 1 shows time-series equations of fertility for each age group, and the principle of uncertainty prediction is consistent with mortality projection.

Table 1. Estimates of Time-Series Equations for age-specific fertility.

Age Range	Estimates of Fertility Time-Series Equations	σ (Residual)
15–19	$f_t = 0.9466f_{t-1} + 0.0534f_{t-2} + \varepsilon_t - 0.7666\varepsilon_{t-1}$	2.23
20–24	$f_t = 4938f_{t-1} + 0.1816f_{t-2} + 0.3246f_{t-3} + \varepsilon_t$	16.11
25–29	$f_t = 0.7109f_{t-1} + 0.2891f_{t-2} + \varepsilon_t - 0.6467\varepsilon_{t-1}$	20.91
30–34	$f_t = 1.0977f_{t-1} - 0.0977f_{t-2} + \varepsilon_t - 0.6941\varepsilon_{t-1}$	7.63
35–39	$f_t = 0.4154f_{t-1} + 0.5846f_{t-2} + \varepsilon_t + 0.3584\varepsilon_{t-1}$	3.64
40–44	$f_t = 0.2170f_{t-1} + 0.7830f_{t-2} + \varepsilon_t + 0.5967\varepsilon_{t-1}$	1.73
45–49	$f_t = 1.8836 + 1.2225f_{t-1} - 0.5236f_{t-2} + \varepsilon_t$	0.96

3.2. Matrix Modeling of Population Projection

Cohort Component Method has been used in the past to project the structures of populations [19–21]. A major advantage of this method is that it can forecast populations by constructing an age-classified transition matrix, also known as Leslie matrix. To construct the transition matrix, firstly, we model iterative equations that encompass the demographic elements as:

$$P_{s+1,t+5}^m = P_{s,t}^m \times p_{s,t}^m \quad (9)$$

$$P_{s+1,t+5}^f = P_{s,t}^f \times p_{s,t}^f \quad (10)$$

$$P_{0,t+5}^f = \sum_{s=15}^{49} (P_{s,t}^f \times 5b_{s,t}^f) \quad (11)$$

$$P_{0,t+5}^m = \sum_{s=15}^{49} (P_{s,t}^f \times 5b_{s,t}^m) \quad (12)$$

$$b_{s,t}^m = w/(w+1) \cdot F_{s,t} \quad (13)$$

$$b_{s,t}^f = 1/(w+1) \cdot F_{s,t} \quad (14)$$

where $P_{s,t}$ denotes the population of age class s in year t ; p denotes the survival rate of an age-sex class; $b_{s,t}^m$ denotes the age specific fertility rate of baby boys in year t ; $b_{s,t}^f$ denotes the age specific fertility rate of baby girls in year t ; $F_{s,t}$ denotes age specific fertility rate in year t ; w denotes the sex ratio at birth. The indexes m , f , t , and s denote male, female, time, and age. Based on the assumption of a five-year cycle, the women of childbearing age will experience five reproductive opportunities. So, the number

of births per year ($b_{s,t}$) needs to be adjusted to the number of births in five years ($5b_{s,t}$) in the transition equation [22]. Because most of the members in the social pooling pension scheme are employees of state-owned enterprises, the migration rate of these employees can be neglected in the long run. These equations can be conveniently written in matrix form as:

$$\begin{bmatrix} P_{0,t+5} \\ P_{1,t+5} \\ \vdots \\ P_{n-1,t+5} \end{bmatrix} = \begin{bmatrix} 5b_{0,t} & 5b_{1,t} & 5b_{2,t} & \dots & 5b_{n-2,t} & 5b_{n-1,t} \\ p_{0,t} & 0 & 0 & \dots & 0 & \dots \\ 0 & p_{1,t} & 0 & \dots & 0 & \\ 0 & 0 & p_{2,t} & 0 & \vdots & \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & & & & p_{n-2,t} & \end{bmatrix} \cdot \begin{bmatrix} P_{0,t} \\ P_{1,t} \\ \vdots \\ P_{n-1,t} \end{bmatrix} \quad (15)$$

or in more compactly form:

$$P_{t+5} = L_t \times P_t \quad (16)$$

The population of urban insured employees is calculated on the basis of the projected age-sex specific population. The forecasted model of insured employees can be represented as follows:

$$P_{a,t} = \left(\sum_{20}^{59} P_{s,t}^m + \sum_{20}^{54} P_{s,t}^f \right) \times c_t \times j_t \times m_t \quad (17)$$

The population of beneficiaries comprise new arrivals reached retirement age and survived retirees in previous years, which can be calculated as follows:

$$P_{b,t} = \left(P_{60,t}^m + P_{55,t}^f \right) \times c_t \times j_t \times m_t + \left(\sum_{60}^{90+} P_{s,t-1}^m + \sum_{55}^{90+} P_{s,t-1}^f \right) \times c_{t-1} \times j_{t-1} \times m_{t-1} \quad (18)$$

where $P_{a,t}$ denotes the population of insured employees in year t ; $P_{b,t}$ denotes the population of the pension beneficiaries in year t ; c_t denotes the urbanization rate of population in year t ; j_t denotes the ratio of urban employment in year t ; m_t denotes the coverage ratio of urban employee's pension plan in year t . The indexes m, f , and s refer to male, female and age respectively.

3.3. Actuarial Indicators of Financial Risk

W. Cheng et al., 2004 proposed various types of financial measures to assess the actuarial status of the combined OASDI Trust Funds under the U.S. pension plan's financing approach: (1) annual actuarial balances, income rates, and cost rates; (2) potential support ratio; (3) trust fund ratio; and (4) open group unfunded obligation [4]. For any given year, the annual actuarial balance equals the income rate minus the cost rate, and the time at which the annual balance changes from positive to negative values should be paid more attention. The potential support ratio, i.e., the comparison of workers to beneficiaries, could monitoring shocks in aging risk of the pension plan. The trust fund ratio is the ratio of the asset at the beginning of the year to the total outgo during that year, which is a useful indicator of the adequacy of the financial resources. The open group unfunded obligation is a summary indicator measuring the size of any shortfall in present-value discounted dollars. Similarly, based on the financing mode of China's social pooling account, we use three actuarial indicators to measure the financial risk: the accumulated net asset, annual actuarial balance, and potential support ratio. These measures could assess the fiscal gap, liquidity risk, and aging risk of a DB pension scheme in a comprehensive way. The accumulated net asset at the end of a given year is numerically equal to the asset at the beginning of the year, plus payroll taxes, plus interest income, less scheduled benefits,

less transition debt, and the administrative expenses are neglected in the long run. The actuarial model of accumulated net asset can be expressed as:

$$T_t = (I_t - E_t - TPD_t) + T_{t-1} * (1 + r)$$

where: TPD_t denotes the total transition pension debt in year t ; I_t denotes the contributions from payroll tax in year t ; E_t denotes the scheduled benefits in year t ; T_t denotes the accumulated net asset in year t . The actuarial model of I_t and E_t can be expressed as:

$$I_t = C_t * W_t * P_{t,a} \quad (19)$$

$$E_t = R_t * W_t * P_{t,b} \quad (20)$$

For the purpose of measuring the expected pattern of cash flow, annual actuarial balance is modeled as:

$$AB_t = (I_t - E_t - TPD_t) / (W_t * P_{t,a}) \quad (21)$$

For the purpose of measuring the burden placed on the working population by the retirees, potential support ratio is modeled as:

$$PSR_t = P_{t,a} / P_{t,b} \quad (22)$$

where: C_t denotes contribution ratio of taxable payroll in year t ; W_t denotes average wage of urban employee in year t ; $P_{t,a}$ denotes population of insured employee in year t ; R_t denotes replacement ratio of the social pooling pension in year t ; $P_{t,b}$ denotes population of the pension beneficiaries in year t ; r denotes interest rate of the social pooling fund in year t ; AB_t denotes the actuarial balance in year t ; PSR_t denotes the potential support ratio in year t .

3.4. Data and Actuarial Assumptions

For using the actuarial models given in the previous three subsections, it is necessary to explain data source and make assumptions about model parameters based on the pension system.

- (1) Initial population: The matrix model of population projection uses age-sex specific population data of 2013 as the initial population vector. The data can be obtained from China population and employment statistics yearbook [23].
- (2) Entry age: The legal age of employment in China should be more than 16. Similar to previous study [24], we suppose the entry age for insurance is 20 over the long term.
- (3) Normal retirement age: In the current legal provisions, male workers retire at the age of 60, female workers retire at the age of 50, and female staff managers retire at 55 [6,25]. But with the implementation of policy for gradually suspending the retirement age of employees, the retirement age will be delayed. Thus, the retirement age is set to be 60 for men and 55 for women.
- (4) Sex ratio at birth: According to the National Population Development Plan (2016–2030), the future objective of gender ratio is set to be 112 at year 2020 and 107 at year 2030 [26]. With the reduction of gender preference, the gender ratio of Chinese urban infants is supposed to be 107 boys to 100 girls.
- (5) Contributed rate: According to the State Council (2005) document No. 38, the contributed rate of social pooling fund is set to 20 percent of taxable payroll in the evaluation period [13].
- (6) Coverage rate: In the light of development of human resources and social security 13th Five-Year plan, the coverage rate of plan will reach 90 percent. The coverage rate of urban employee's pension plan is set to increase year by year to 90 percent in the evaluation period.
- (7) Urbanization rate: According to the data released by the National Bureau of Statistics, the urbanization rate of the population has increased from 17.92 percent in 1978 to 56.10 percent

in 2015. The urban development report of China indicates that the urbanization rate of China will increase to more than 75 percent by 2050. Hence, the urbanization rate is set to increase year by year to reach 75 percent.

- (8) Urban employment rate: According to the Statistical Yearbook of China, the ratio of urban employment in the past year has remained at around 85%. Thus, this paper assumes that the future urban employment rate will remain at this level in the prediction interval.
- (9) The social pooling replacement rate: According to the State Council (2005) document No. 38, the total replacement rate of an urban employee contributed payroll tax for more than 35 years is set to 59.2 percent of social average wage, and the social pooling replacement rate is set at 35 percent of social average wage [13].
- (10) Return rate: Referring to past study [8] and recent changes, we assume that the interest rate under the benchmark scenario is 0.03.

4. Stochastic Assessments of Relative Financial Risk Indicators

In this section we assess the financial risk of the pension plan by projecting the long-term actuarial indicators stochastically. To present uncertainty of these financial measurement, time-series uncertainty bands are delineated using percentiles of the forecasts, and the results illustrated here are all based on 5000 stochastic simulations.

4.1. Stochastic Assessment of Accumulated Net Asset

The annual cumulative asset (or fiscal gap when it is negative) is a common measure to evaluate pension fund's solvency. Figure 3 illustrates the stochastic projection by showing 'fan chart' of the annual accumulated net asset: a time series simulated probability distribution for the years 2018 to 2088.

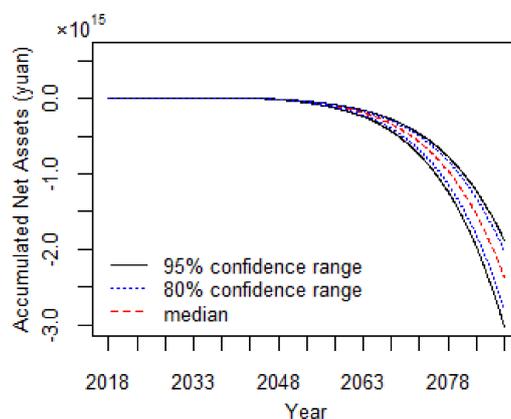


Figure 3. The projected percentile curves of accumulated net asset. Source: Own calculation and design based on R and China data.

For any given year, these lines represent the percentile distribution of accumulated net asset based on all simulated results. The median line (50th percentile) for each year is the cumulative asset for which half of the simulated outcomes are higher and half are lower for that year. The other trend lines delineate the 95-percent, 80-percent confidence intervals expected for future cumulative net asset. It can be seen that the accumulated net asset will increase slowly in the early stage and then decrease rapidly after 2033, and the range of uncertainty increases as time continues. Table 2 gives confidence intervals of cumulative assets range from 2018 to 2088. As shown in the first two columns, there is a 95-percent probability that the social pooling pension fund will be exhausted between years 2043–2048. Under the existing policy environment, the social pooling system will experience a heavy burden in 2088.

Table 2. Confidence Intervals for accumulated net assets of the projection year 2018–2088 (trillion)
Source: Own calculation based on R and China data.

Year	95% Confidence Range		80% Confidence Range		Median	Mean	s.d.
2018	4.43	4.44	4.43	4.43	4.43	4.43	1.62×10^{-3}
2023	6.07	6.12	6.08	6.11	6.09	6.09	1.56×10^{-2}
2028	8.41	8.56	8.44	8.54	8.49	8.49	4.39×10^{-2}
2033	9.73	10.10	9.79	10.03	9.91	9.91	0.109
2038	8.88	10.36	9.15	10.12	9.63	9.63	0.434
2043	2.25	7.27	3.13	6.38	4.79	4.77	1.46
2048	−17.01	−4.09	−14.87	−6.44	−10.64	−10.63	3.76
2053	−57.41	−28.23	−52.32	−33.38	−42.88	−42.88	8.47
2058	−126.09	−65.39	−115.21	−76.10	−95.66	−95.79	17.6
2063	−240.58	−122.18	−220.77	−142.31	−182.01	−181.94	34.6
2068	−436.28	−206.73	−398.79	−249.04	−325.03	−324.34	66.7
2073	−752.24	−341.79	−689.22	−417.79	−557.68	−554.43	1.20×10^2
2078	−1234.01	−552.10	−1133.82	−680.81	−920.21	−910.92	2.00×10^2
2083	−1963.06	−870.33	−1807.37	−1076.94	−1470.01	−1450.61	3.21×10^2
2088	−3025.56	−1305.51	−2790.65	−1649.59	−2270.59	−2234.26	5.04×10^2

4.2. Stochastic Assessment of Annual Actuarial Balance

Annual actuarial balance is used to monitor the expected cash flow of the pension fund. As shown in model (21), this indicator could reflect the liquidity risk of the pension fund. The results obtained from 5000 stochastic simulations of annual actuarial balance are set out in Figure 4. The outer solid lines represent the upper and lower bound of the 95 confidence interval and the inner dashed lines represent the upper and lower bound of the 80 confidence interval. In general, there is a decreasing trend in the forecast period. As with the cumulative net asset projections, the uncertainty regarding the actuarial balance increases as time progresses, and the uncertainty concerning the actuarial balance projections is larger than the uncertainty concerning the cumulative asset projections.

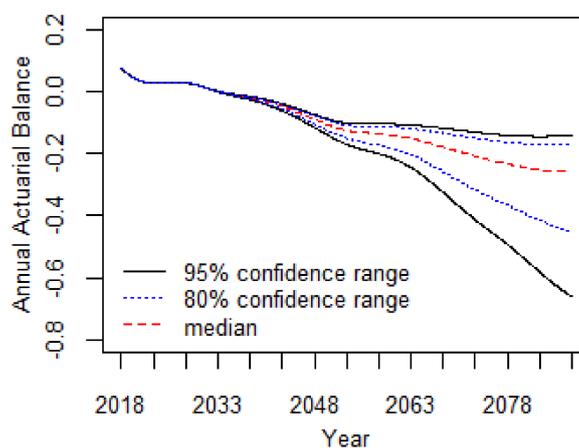


Figure 4. The projected percentile curves of annual actuarial balance (% of payroll). Source: Own calculation and design based on R and China data.

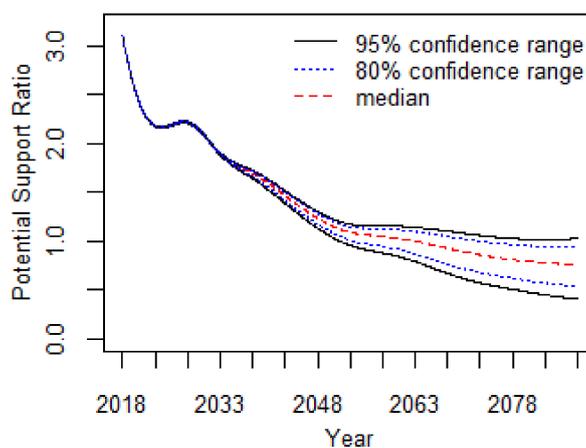
Table 3 shows confidence intervals for annual actuarial balance in the projection year. As described by the data, the expected annual balance first becomes negative between years 2028–2033, and the cash flow will remain negative thereafter if contributions are collected as scheduled. The projected value in 2088 indicates that in order to balance the income and expenditure, nearly four times taxable wage will be used to improve the deteriorated cash flow.

Table 3. Confidence Intervals for annual actuarial balance of the projection year. Source: Own calculation and design based on R and China data

Year	95% Confidence Range		80% Confidence Range		Median	Mean	s.d.
2018	0.075383	0.075688	0.075433	0.075632	0.07553	0.075531	7.76×10^{-5}
2023	0.026665	0.028059	0.026915	0.027809	0.02735	0.027356	0.000354
2028	0.027938	0.029892	0.028263	0.029523	0.028875	0.028893	0.000494
2033	-0.00047	0.002568	2.19×10^{-5}	0.001989	0.000991	0.001006	0.000777
2038	-0.02614	-0.0117	-0.02324	-0.01396	-0.01851	-0.01859	0.003659
2043	-0.06197	-0.03145	-0.05633	-0.03627	-0.04582	-0.0461	0.007786
2048	-0.1156	-0.06014	-0.10462	-0.06866	-0.0854	-0.08619	0.014085
2053	-0.17023	-0.07985	-0.15091	-0.09237	-0.11883	-0.12069	0.022888
2058	-0.20048	-0.07562	-0.17301	-0.09173	-0.1275	-0.13058	0.032021
2063	-0.24456	-0.07072	-0.20317	-0.09172	-0.14067	-0.14499	0.044723
2068	-0.32493	-0.0695	-0.25824	-0.09612	-0.1637	-0.17181	0.065755
2073	-0.41357	-0.07195	-0.31719	-0.10434	-0.18857	-0.2025	0.089838
2078	-0.49315	-0.07495	-0.36625	-0.11045	-0.20807	-0.22794	0.112879
2083	-0.58198	-0.07198	-0.41439	-0.11056	-0.22254	-0.25016	0.143976
2088	-0.66239	-0.06359	-0.44998	-0.10496	-0.22578	-0.26092	0.176715

4.3. Stochastic Assessment of Potential Support Ratio

Compared with the dependency ratio, potential support ratio can evaluate how many workers are needed to support retirees in the social pooling pension system, and it can also be used to analyze fertility policy adjustment, labor market and insured ratio. As reported by the annual report on the development of social insurance in China 2015, the ratio of insured workers to beneficiaries has fell from 2.97 in 2014 to about 2.87 in 2015, which means that less than three employees raise up one elderly in the social pooling system. Figure 5 shows the time-series uncertainty bands for the potential support ratio produced by stochastic simulations.

**Figure 5.** The projected percentile curves of potential support ratio. Source: Own calculation and design based on R and China data.

The two extreme lines in the figure illustrate the range of a 95 percent confidence interval, and the internals are shown for 80-percent confidence range. It can be seen that the potential support ratio will undoubtedly decrease, and this trend indicates that the PAYG-mode social pooling pension system requires more labors to pay for the increasing retirement. As with the projections of actuarial balance, the uncertainty regarding the ratio increases as time progresses, and the uncertainty concerning the potential support ratio is also less than the uncertainty concerning the actuarial balance projections. According to the decline rate of the ratio, the projection period 2018–2023 has a faster rate of decline than the period 2028–2088, and possible reason to explain this phenomenon may be attributed to the

retirement of baby boomers. Table 4 shows confidence intervals for the potential support ratio in the projection year. As can be seen, the dependency burden of workers in the pension system will increase year by year. Furthermore, it is alarming to note that each worker would afford a retiree's pension benefit after forty years if there are no other improvements. While it may be possible to reduce tax burden by expanding the coverage of old-age insurance, the employees are still facing an increasing payroll tax, especially from population aging.

Table 4. Confidence Intervals for potential support ratio 2018–2088. Source: Own calculation and design based on R and China data.

Year	95% Confidence Range		80% Confidence Range		Median	Mean	s.d.
2018	3.10945	3.118086	3.110851	3.116494	3.113611	3.113644	0.002204
2023	2.172967	2.192129	2.176384	2.188667	2.182335	2.182424	0.004854
2028	2.207609	2.235412	2.21218	2.230084	2.220849	2.221124	0.007035
2033	1.882788	1.914331	1.887838	1.908253	1.897854	1.898029	0.008064
2038	1.642543	1.755201	1.663965	1.736208	1.699935	1.699841	0.028576
2043	1.385562	1.568494	1.416325	1.536583	1.476993	1.476635	0.046629
2048	1.131954	1.373179	1.172689	1.329793	1.251899	1.251366	0.061287
2053	0.956134	1.264857	1.008603	1.210517	1.11018	1.10929	0.078235
2058	0.879054	1.277324	0.943726	1.206746	1.074957	1.074686	0.101637
2063	0.78928	1.296217	0.870382	1.202888	1.030029	1.033604	0.129188
2068	0.667377	1.299924	0.764521	1.183047	0.96324	0.969851	0.1614
2073	0.570588	1.287346	0.676906	1.150322	0.900967	0.908694	0.183949
2078	0.504966	1.273002	0.618137	1.127438	0.85774	0.866228	0.19812
2083	0.447586	1.286874	0.569677	1.126997	0.828336	0.838052	0.215241
2088	0.405848	1.327825	0.538482	1.147676	0.822016	0.8345	0.236383

5. Scenario Analysis

Through the simulated results of the fourth section, it is clearly that the pension plan of China are facing financial risk in the near future. To improve the solvency of the pension plan, the usual practice is to delay retirement age or improve pension fund yield. According to the third session of the 18th Conference of the Chinese Communist Party, the government decided to postpone the retirement age in progressive steps. This section we present two scenarios to examine the impact of postponing retirement age on the risk indicators. The baseline scenario assumes that the employees retire at the existing benchmark age, while the delayed retirement scenario supposes that the retirement age is raised from 55 to 60 for women and from 60 to 65 for men.

Since the accumulated net asset and annual actuarial balance depend on the potential support ratio, so we first examine impact of postponing retirement age on potential support ratio. As presented in Figure 6, the potential support ratio in both scenarios will experience a downward trend. The potential support ratio in the baseline scenario decreases from 3.11 in 2018 to 0.82 in 2088. While in the delayed retirement scenario, the potential support ratio decreases from 6.45 in 2018 to 1.35 in 2088. With the implementation of the delayed retirement policy, the predicted value of potential support ratio will increase by two times on average during the horizon 2018–2048. It can be seen clearly that the burden of the insured employees will be relieved to a great extent.

Next, we analyze the projection of accumulated net asset in the baseline and delayed retirement scenarios. Figure 7 provides the median projections of accumulated net asset in two scenarios. We can see that the accumulated net asset in both scenarios will increase slowly and then decrease. The difference is that the baseline accumulated net asset will peak in 2033, while the accumulated net asset in delayed retirement scenario will peak in 2068. Moreover, the decline rate of accumulated net asset in the delayed retirement scenario is lower than the baseline case. According to the median projection, the pension plan will become unsustainable in 2048 in the baseline scenario, while the pension plan in the delay retirement scenario will be unsustainable in 2083.

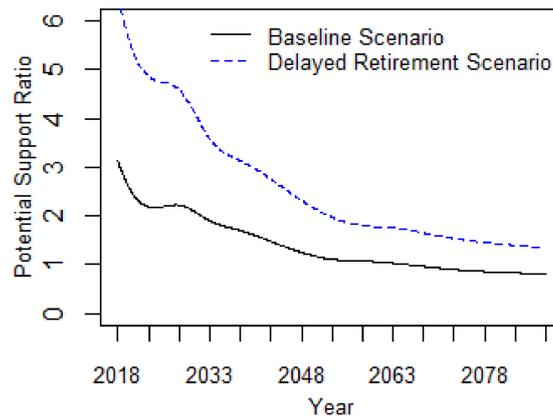


Figure 6. Scenario analysis of potential support ratio.

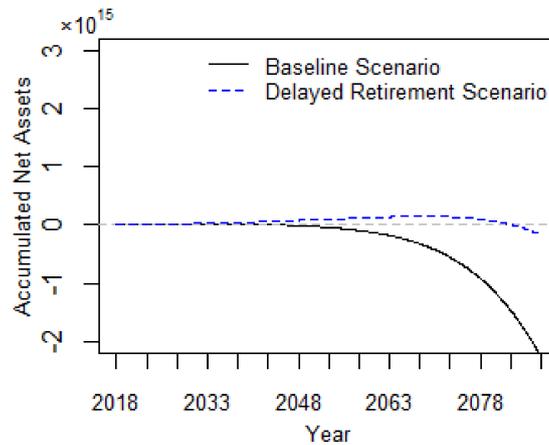


Figure 7. Scenario analysis of accumulated net assets.

Thirdly, we examine impact of postponing retirement age on annual actuarial balance. As presented in Figure 8, the median projection of annual actuarial balance in both scenarios will experience a downward trend. According to the simulated results, the baseline actuarial balance will be negative in 2038, while in delayed retirement scenario the actuarial balance will be negative in 2063. Evidently, the delayed retirement policy can effectively improve the cash flow pattern of the pension plan.

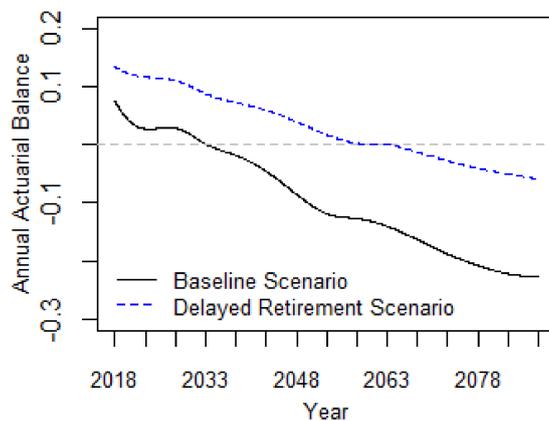


Figure 8. Scenario analysis of annual accumulated balance.

6. Conclusions

The uncertainty derived from vital demographic rates makes it difficult to project financial outcomes exactly. In the stochastic actuarial framework proposed by the U.S. Security Administration, we construct a comprehensive risk assessment system to monitor the financial risk of the pension plan in China. From the illustrated results, it is clear that the stochastic assessments give more accurate and transparent outcomes in the long-term projection. The risk assessments indicate that the public pension fund of China is facing a gap in the end of valuation period, and the median deficit would attain 2270 trillion yuan. Furthermore, with the rapidly process of population aging, the insured workers will bear more pressure of retirement, and the pension fund would also experience a liquidity risk since the expected cash flow tend to be negative after 2033. The scenario analysis indicates that the delayed retirement policy can greatly reduce the financial risk in the medium-term, but the pension plan still faces financial risks in the long run. In general, the solvency of social pooling pension fund is not optimistic, and sustainable policies need to be implemented to improve the solvency of the pension fund. The innovation of this research is that we extend the risk assessment to monitor the trends of liquidity risk and dependency burden in the long term. Moreover, in the stochastic simulation of the population module, we propose Lee–Carter model to forecast the age-specific mortality. The adoption of Lee–Carter model could effectively reduce the generations of random number and error during simulation process.

However, it should be noted that the study has examined uncertainty derived only from demographic variables, and this will underestimate the degree of uncertainty in the projection. Moreover, we do not consider the impacts of macroeconomic conditions, family insurance, and healthcare. In the uncertain environment, the rate of economic growth is key for the sustainability of the pension system. During the period of economic growth, the rate of wage growth and the rate of return on assets will increase, and the pension plan will be greatly improved. But, in the economic downturn, the pension plan will face a heavy financial burden. Because of the uncertainty of system reform and the deterioration of family insurance due to the one-child policy [27–29], households tend to increase the precautionary savings, thus causing an increase in the savings rate. The high saving rate has funded capital accumulation which in turn has been the primary driver of China’s economic growth [30]. Other factors that affect pension plan include sex ratio and health care [31,32], and it is clear that our research needs to further explore the impacts of these factors. Notwithstanding its limitation, the study does suggest that the quantification of demographic uncertainty is beneficial to formulate reasonable policies related to birth control and retirement.

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References

1. James, E. How can China solve its old age security problem? The interaction between pension, SOE and financial market reform. *Comp. Econ. Soc. Syst.* **2003**, *1*, 53–75. [[CrossRef](#)]
2. CBO’s Long-Term Modeling Group. *Uncertainty in Social Security’s Long-Term Finances: A Stochastic Analysis*; Congressional Budget Office, Congress of the United States: Washington, DC, USA, 2001.
3. Lee, R.D.; Anderson, M.W. Tuljapurkar, S. Stochastic forecasts of the social security trust fund. *SSRN Electron. J.* **2003**. [[CrossRef](#)]
4. Cheng, A.W.; Miller, M.L.; Morris, M.; Schultz, J.P.; Skirvin, J.P.; Walder, D.P. *A stochastic Model of the Long-Range Financial Status of the Oasdi Program*; Office of the Chief Actuary, U.S. Social Security Administration: Baltimore, MD, USA, 2004.

5. Liu, X.; Zhang, Y.; Fang, L.; Li, Y.; Pan, W. Reforming China's pension scheme for urban workers: Liquidity gap and policies' effects forecasting. *Sustainability* **2015**, *7*, 10876–10894. [[CrossRef](#)]
6. Tian, Y.; Zhao, X. Stochastic forecast of the financial sustainability of basic pension in China. *Sustainability* **2016**, *8*, 46. [[CrossRef](#)]
7. Alho, J.M.; Spencer, B.D. Uncertain population forecasting. *J. Am. Stat. Assoc.* **1985**, *80*, 306–314. [[CrossRef](#)] [[PubMed](#)]
8. Carter, L.R.; Lee, R.D. Modeling and forecasting U.S. sex differentials in mortality. *Int. J. Forecast.* **1992**, *8*. [[CrossRef](#)]
9. Lee, R.; Tuljapurkar, S. Uncertain demographic futures and social security finances. *Am. Econ. Rev.* **1998**, *88*, 237–241.
10. Alho, J.M.; Jensen, S.E.H.; Lassila, J. *Uncertain Demographics and Fiscal Sustainability*; Cambridge University Press: Cambridge, UK, 2008; pp. 224–315.
11. Lassila, J.; Valkonen, T. Uncertain demographics and pension policy. *Rev. Econ.* **2008**, *59*, 913–926. [[CrossRef](#)]
12. Auerbach, A.J.; Lee, R. Welfare and generational equity in sustainable unfunded pension systems. *J. Public Econ.* **2011**, *95*, 16–27. [[CrossRef](#)] [[PubMed](#)]
13. The State Council of China. Available online: http://www.gov.cn/zhuanti/2015-06/13/content_2878967.htm (accessed on 30 March 2018).
14. Ministry of Human Resources and Social Security of the People's Republic of China. Available online: <http://www.mohrss.gov.cn/SYrlzyhshbzb/zwggk/szrs/tjgb/> (accessed on 19 February 2018).
15. The State Council of China. Available online: http://www.gov.cn/zhengce/content/2015-08/23/content_10115.htm (accessed on 22 February 2018).
16. Fedotenkov, I.; Meijdam, L. Crisis and pension system design in the EU: International spillover effects via factor mobility and trade. *Economist* **2013**, *161*, 175–197. [[CrossRef](#)]
17. Schmertmann, C.; Zagheni, E.; Goldstein, J.R.; Myrskylä, M. Bayesian forecasting of cohort fertility. *J. Am. Stat. Assoc.* **2014**, *109*, 500–513. [[CrossRef](#)]
18. CBO's Long-Term Modeling Group. *Quantifying Uncertainty in the Analysis of Long-Term Social Security Projections*; Congressional Budget Office, Congress of the United States: Washington, DC, USA, 2005.
19. Thomas, J.R.; Clark, S.J. More on the cohort-component model of population projection in the context of HIV/AIDS: A Leslie matrix representation and new estimates. *Demogr. Res.* **2011**, *25*, 39–101. [[CrossRef](#)] [[PubMed](#)]
20. Tian, F. Demographic probabilistic forecast method and its application. *Northwest Popul. J.* **2011**, *5*, 9–13.
21. Pânzaru, C. On the sustainability of the Romanian pension system in the light of population declining. *Procedia Soc. Behav.* **2015**, *183*, 77–84. [[CrossRef](#)]
22. Zhao, Y.; Bai, M.; Liu, Y.; Hao, J. Quantitative analyses of transition pension liabilities and solvency sustainability in China. *Sustainability* **2017**, *9*, 2252. [[CrossRef](#)]
23. National Bureau of Statistics of the People's Republic of China. Available online: <http://www.stats.gov.cn/tjsj/ndsj/2014/indexch.htm> (accessed on 12 September 2017).
24. Wang, X.; Mi, H. Pension deficit: Scope, methodology and measurement. *J. Quant. Tech. Econ.* **2013**, *10*, 49–62.
25. Yang, D.U.; Wang, M. *Demographic ageing and employment in China*; ILO Employment Working Paper; No. 57; Employment Sector, International Labor Office: Geneva, Switzerland, 2010.
26. The State Council of China. Available online: http://www.gov.cn/zhengce/content/2017-01/25/content_5163309.htm (accessed on 19 October 2017).
27. Curtis, C.C.; Lugauer, S.; Mark, N.C. Demographics and aggregate household saving in Japan, China, and India. *J. Macroecon.* **2017**, *51*, 175–191. [[CrossRef](#)]
28. Curtis, C.C.; Lugauer, S.; Mark, N.C. Demographic Patterns and Household Saving in China. *AEJ Macroecon.* **2015**, *7*, 58–94. [[CrossRef](#)]
29. Song, Z.M.; Storesletten, K.; Wang, Y.; Zilibotti, F. Sharing high growth across generations: Pensions and demographic transition in China. *AEJ Macroecon.* **2015**, *7*, 1–39. [[CrossRef](#)]
30. Lugauer, S.; Mark, N.C. The role of household saving in the economic rise of China. *SSRN Electron. J.* **2013**. [[CrossRef](#)]

31. Wei, S.-J.; Zhang, X.B. The competitive saving motive: Evidence from rising sex ratios and savings rates in China. *J. Political Econ.* **2011**, *119*, 511–564. [[CrossRef](#)]
32. Imrohoroglu, A.; Zhao, K. The Chinese saving rate: Long-term care risks, family insurance, and demographics. *J. Monet. Econ.* **2018**. [[CrossRef](#)]



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