

Chinese Age Pension System and Analysis

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ABSTRACT

Stochastic model checking is the extension and generalization of the classical model checking. Compared with classical model checking, stochastic model checking faces more severe state explosion problem, because it combines classical model checking algorithms and numerical methods for calculating probabilities. For dealing with this, we first apply symmetric assume-guarantee rule symmetric (SYM) for two-component systems and symmetric assume-guarantee rule for n-component systems into stochastic model checking in this paper, and propose a compositional stochastic model checking framework of probabilistic automata based on the NL* algorithm. It optimizes the existed compositional stochastic model checking process to draw a conclusion quickly, in cases the system model does not satisfy the quantitative properties. We implement the framework based on the PRISM tool, and several large cases are used to demonstrate the performance of it.

Keywords: *Stochastic model checking, assume-guarantee reasoning, symmetric assume-guarantee rule, learning algorithm, probabilistic automata*

1. INTRODUCTION

1.1. Background

Today's young people have been worried about whether the pension can guarantee the living standard of the working people since they are about 30 years old. From the pension measurement standard, that is, the replacement rate, we can see that the higher the income, the lower the substitution rate. Since most of the young people today are "moonlight clan", many people are not worried that the pension may not be enough to support the living standard when they are working, because they think that after retirement, the expenses will naturally decrease, and the pension can support the living standard. Han (2006) believes that many moonlight people have developed a relatively luxurious living habit. Once their income is reduced, it is difficult to ensure a normal living standard. According to Wu (2010), our pension replacement rate is about 60%, and the remaining 40% of the gap needs rich savings or investment to maintain the original living standard.

1.2. Study meaning

Due to the different statistical approaches and perspectives, pension replacement rate has many algorithms, such as target substitution rate, cross substitution rate and lifetime replacement rate. According to the existing research, the concept boundary of various types of pension replacement rate is very vague, because the concept is not clear, it is easy to appear the situation of being dressed up (Xue, et al 2020).

Therefore, this paper focuses on the calculation and prediction of pension replacement rate from the perspective of individuals. (Lin, 2013) believes that the pension replacement rate from an individual perspective can well reflect the relative level of the retiree's pension and the individual wage level before retirement. From the perspective of focus on individual pension replacement rate, we can predict whether the current pension policy can support the life of retirees, and maintain the quality of life after retirement in a stable and original state.

1.3. Chinese pension system development

Before the implementation of the pension reform system in China, the relevant national documents stipulated that after the labor force is old or has lost the ability to work, according to their contribution to the society, the insurance benefits shall be paid in the form of money on a monthly or one-time basis, which is mainly used to guarantee the basic life in the future [1].

The government document (1991) published stipulated the system of combining the basic pension insurance with the social supplementary pension insurance and the employee's personal savings pension insurance [2]. In 1971, the State Council further stipulated that under the principle of distribution according to work, enterprises should vigorously develop the difference of economic benefits and give full play to the role of commercial insurance.

The government document (2015) published by the State Council solved the contradiction between the two-track system for a long time. The State Council decided to divide staff into three parts, old staff, median staff, and new staff. For each different type of staff has different pension policies [3].

1.4 The Mechanism of the Chinese pension system

The Chinese pension account is formed by two parts: the personal account and the basic account. During working, employees pay 8% (individual contribution rate) of their payment base into the personal account which is invested in the age pension fund, and the interest is calculated annually. The payment base is determined by the salary level of each certain employee [4]. For people whose salaries are between 3 times and 60% of the average wage, their payment base is equal to their salaries. For people who have higher salaries than this range, the payment base is equal to the upper boundary. Similarly, for people who have lower salaries than this range, the payment base is equal to the lower boundary. This policy aims to guarantee people with low incomes the initiative to join the age pension and achieve the target of income redistribution (Zhang 2017). After retirement, retirees obtain the pension income monthly [5]. For the basic account, employers pay a part of employees' salaries into this account monthly. This proportion was 20% for 13 years, and was decreased to 16% in 2019. However, the pension income from this account is not determined by the balance. It is calculated by the average wage, the number of payment year, and employees' salary level. Once the balance is insufficient to afford the pension, the gap will be filled by the government budget.

The combination of these two accounts could ensure the principle 'pay more gain more'. In the meantime, the living standard after the retirement of people with low salaries could be ensured by this redistribution mechanism [6].

1.5 Current situation of the Chinese pension system

With the increase of the average lifetime and the decrease of the birth rate in these decades, the rapid aging of the population is unavoidable. According to Lin (2018), China has been in an aging society since 1999 and the aging coefficient is predicted to reach 16.83% after 2020. Though the two-child policy has been taken to reply to the increasingly serious situation, the aging of the population will be an ordinary state for China in the next generations. Therefore, the current age pension system has been challenged [7].

1.5.1 Measurement of the pension system

The replacement rate is the most common measure to evaluate the performance of a pension system. It evaluates the change of living standard after people retire. Commonly, whenever the replacement decreases to below 50%, the basic need in the life of retired people could not be satisfied.

For the whole system, the replacement is equal to the ratio of the average pension income to the average wage last year.

Unfortunately, a persistent decreasing trend in the average replacement rate could be found after 1997, which is smaller than the target replacement rate. It is estimated that the average replacement will stay around 45% for the long term [8], leading to a bad impact on the living standard of retired people (Lin 2013). More recent research shows that the average replacement rate will decrease to around 33% after 2050, seriously lowering the living standards of retired people (Zhou, et al 2020). Unless the retirement system has a major reform, the average replacement rate will hardly reach the target level.

For each person, the replacement rate is equal to the pension income in the first year after retirement divided by the salary the one obtains before retirement. This measure could be used to evaluate the reasonability of the pension system from a personal perspective [9].

1.5.2 Factors

According to the mechanism of the Chinese pension system, there are four factors that determine the replacement rate. Firstly, the personal account balance will be affected by the fund return. Assuming that the money is invested in cash and the equity market, it is determined by the annualized equity return and the 1-year interest rate provided by banks. Additionally, the pension income from the basic account is determined by the average wage and the number of the payment year. Finally, when calculating the replacement rate, the inflation rate should also be considered [10].

1.5.3 Reasons for the low replacement rate

Studies on this problem indicate some probable reasons for the low replacement rate. Cui (2017) points out that the low level of replacement rate is mainly due to the lack of adjustment mechanism, low pension growth rate, and the low payment period. Though the pension income increases by about 5% annually, the growth rate of the average wage could reach 9%, leading to a decrease in the replacement rate. Meanwhile, the minimum payment year is 15 years. The replacement rate of people who paid for their pension for only 15 years is extremely low, seriously impact their living standard.

1.5.4 Possible improvement proposed

For the problem of replacement rate, some researches propose potential improvements. The first one is to delay the mandatory retirement age. Now the retirement age is 60 for men and 55 for women. It is indicated that if the retirement age for both men and women increase to 65 gradually, the replacement rate will slightly increase (Yuan 2013). This paper also shows that the replacement will increase more sharply when the volatility of the investment return is high. In another study, Zhou (2020) also discusses the probability to increase the individual contribution rate

[11]. However, this study shows that if the target replacement rate is reached due to the increase of the individual contribution rate, residents' consumption and saving will be occupied heavily. Besides, Cui (2017) offers three proposals to improve the Chinese pension system. Firstly, a more comprehensive pension system such as multi-tier system should be built to improve the stability and sustainability of the Chinese age pension system. Additionally, the adjustment of pension income should depend on both price inflation, wage growth, and the accounts balance, which could guarantee the living standards of retired people. Finally, some parameters could be adjusted such as the floor of the payment base and the floor of the payment period. However, the effect estimation of these policy adjustments is not provided in this paper [12].

2. METHODOLOGY AND MODEL CALCULATION

2.1 The calculation of the pension income

Pension is one of the most important benefits of retirees in China. Under the implementation of the Chinese Pension system, pension system policy will provide people with life security after retirement. Because there will be some subtle differences in the specific pension policies of China's provinces and cities, this paper will use the data of Shenzhen to predict the future pension account amount and the replacement rate, then according to the predictive data to get some results and suggestions for the Chinese Pension system.

According to the policy, this paper does follow assumptions. Firstly, retirees must pay for pension account for at least 15 years. Secondly, retirees must reach legal age then retired. For male, the legal retirement age is 60 years old. For female, the legal retirement age is 55 years old.

The scope of pension payment is between 60% and 300% of the average wage of that year. Within this range, payment should be made according to a certain proportion. After retirement, retirees can get the pension monthly. The calculation method is as follows.

$$B_i = \begin{cases} 0.6W_i, & X_i \leq 0.6W_i \\ X_i, & 0.6W_i < X_i < 3W_i \\ 3W_i, & X_i > 3W_i \end{cases} \quad (1)$$

The current pension policy divides the pension into the social plan pension account and the personal pension account. This is the formula following:

$$SP(\text{Social plan account}) = \sum_{i=1}^m B_i * k_s * (1 + r_i)^{m-i} \quad (2)$$

$$PA_i(\text{personal pension account at year } i) = (PA_{i-1} + B_i * k_p) * (1 + r_i) \quad (3)$$

After retirement (which always 60 for male, 55 for female), the pension income at year i starting with the first year after retirement is

$$A_j = P_j(\text{Pension from personal account}) + S_j(\text{Pension from social plan})$$

$$= \frac{PA}{n} * 12 + \frac{(W_{j-1} + \lambda W_j)}{2} * m * 1\%, \quad (4)$$

where

$$\lambda = \frac{\sum_{i=1}^m \frac{B_i}{W_i}}{m}$$

X_i : personal wage at year i

m: years before retirement

B_i : base of payment at year i

W_i : average salary at year i

k_s : social payment rate, this rate keeps at 20% from 2003

k_p : personal payment rate, this rate keeps at 8% from 2005

λ : coefficient of wage

n: accounted number of months after retirement

2.2 Data processing

2.2.1 model parameters and their sources

Table 1 Parameters and sources

Variables	Notations	Index	Source
Average Wage	w(t)	Average wage of on-the-job staff in Shenzhen	National Bureau of Statistics
Short term interest rate	s(t)	1-year interest year	The people's Bank of China
Domestic equity total return	e(t)	SSE 50 Index E(t)	Tushare financial community

2.2.2 Average wage

For prediction of average wage in the next 40 years, the average wage of Shenzhen is used and this data is from 1979 to 2019.

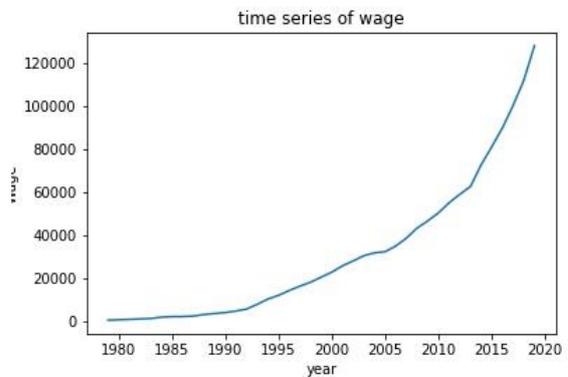


Figure 1 Time series of Average Wage

According to figure of time series of average wage, it can be seen that the historical data of average wage fits the curve of quadratic model (Yan Zhang, Li, Wang, 2016). Then I can use numpy in Python to do quadratic curve model to predict the future data, the prediction data can be described by the quadratic curve equation

$$W(t) = \beta_2 * t^2 + \beta_1 * t + \beta_0 + \varepsilon_w \quad (5)$$

where ε_w is the white noise (also called residual error), ε_w is an independent and identically distribution, the normal distribution specification $\varepsilon_w \sim N(0, \sigma^2)$, with the error variance σ^2 .

Table2 Calibration for the average wage

$W(t) = 100.89 * t^2 - 1468.94 * t + 6617.44 + \varepsilon_w$	(t=0 in 1979)
$\varepsilon_w \sim N(0, 5234.68^2)$	$R^2 = 0.975$

According to $R^2 = 0.975$, the result of predict average wage can be passed with 96% confidence, then the result is reliable.

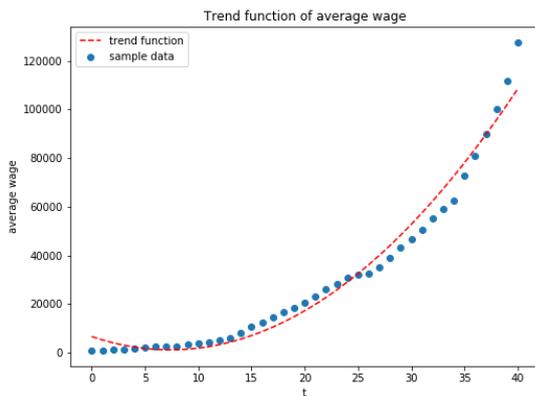


Figure 2 Trend function of Average Wage

2.2.3 Short term interest rate

The short-term interest rate refers to the bank interest rate in 1 year. Historical Data is from 1990 to 2019 which I got from The people’s Bank of China. This is the time series of short rate interest rate.

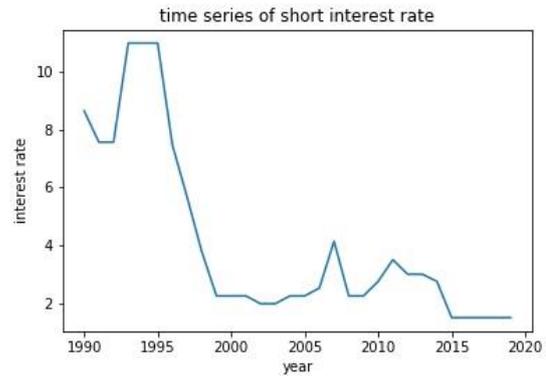


Figure3 Time series of the short-term interest rate

It could be seen that the short-term rate has a steady and mean-reverting pattern apart from extreme values before 1995, representing that it could be predicted by the autoregressive (AR) model. This model is commonly used to predict future values assuming that they are affected by the past. In this paper, we use the AR(1) model to simplify the problem. The autoregressive process of $s(t)$ is

$$s(t) = c_s + \varphi_s * s(t - 1) + \varepsilon_s(t) \quad (6)$$

where c_s is the constant term, φ_s is the correlation coefficient of the first lag term, and $\varepsilon_s(t)$ is the white noise, distributed as $N(0, \sigma_s^2)$.

Then the calibration of this equation is

$$s(t) = 0.0019 + 0.8955 * s(t - 1) + \varepsilon_s(t) \quad (7)$$

and $\sigma_s = 0.0116$.

According to the mean revering property of this process, the short-term interest rate is predicted to converge to

$$\alpha_s = \frac{c_s}{1 - \varphi_s} = 1.82\%$$

which is consistent with the actual situation.

2.2.4 Domestic Equity Total Return

Since the money in pension accounts are invested in many approached, the domestic investment environment should be considered as a factor affecting the pension income. In this paper, the equity market return is chosen to describe this factor. The time series of the equity return is as follow.

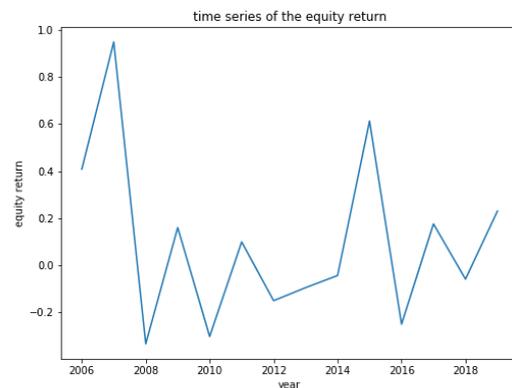


Figure 4 Time series of the equity return

Similar with the short-term interest rate, we use AR(1) model to predict the future performance of the domestic equity market. The annual return $e(t)$ satisfies

$$e(t) = c_e + \varphi_e * e(t - 1) + \varepsilon_e(t), \quad (8)$$

where c_e is the constant term, φ_e is the correlation coefficient of the first lag term, and $\varepsilon_e(t)$ is the residual, normally distributed as $N(0, \sigma_e^2)$.

By fitting data, the equation is determined as

$$e(t) = 0.0962 - 0.2314 * e(t - 1) + \varepsilon_e(t), \quad (9)$$

and $\sigma_e = 0.3441$.

Also, the mean-reverting level is

$$\alpha_e = \frac{c_e}{1 - \varphi_e} = 7.81\%$$

3. RESULT

Based on formula and variables in part 3, I assume two investment strategies which are conservative investment strategy and radical investment strategy to simulation the replacement rate for both male and female.

3.1 Strategy 1: Conservative Investment Strategy

For this strategy, I assume government puts 1/3 pension account into equity market and 2/3 money saves into bank. This following figure are for male, there is a linear relationship between the replacement rate and the start-working age. If people start working from 25 years old, the replacement rate after retirement is about 60%, however, if people start working from 45 years old, the rate is about 25%. This data shows that if people start working late, they will not be able to maintain their living standards after retirement. There is a decreasing trend for the replacement rate with increase of wage coefficient when fixed the age. The highest replacement rate is about 60% when people earn the 0.6 times of average wage per year, but if retirees earn 3 times of average wage before retirement, the replacement rate is about 40%. This figure shows the income redistribution function of pension system.

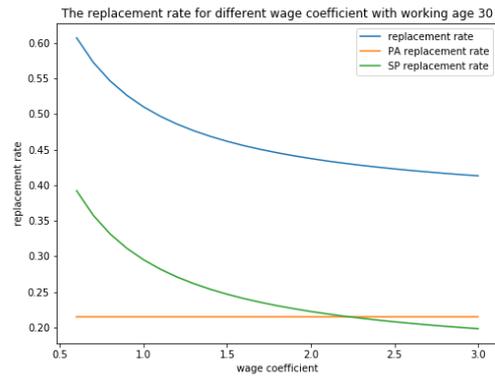
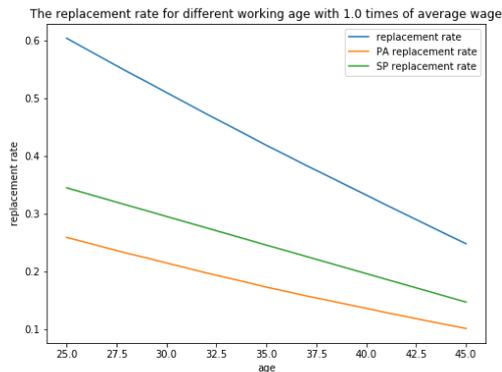


Figure 5 The replacement rate for male using the conservative investment strategy

For female, the trend of the replacement rate is as same as that of male. The highest replacement rate occurs for a woman start working at 25 with 0.6 times of average wage, at about 47%, whereas the lowest (24%) occurs for a woman paying her pension for 15 years with 3 times of average wage. From the second figure, it is shown that for a person who works for 30 years, a female has a 5% lower replacement rate than a man. In other words, women’s living standard is less ensured than men’s after retirement.

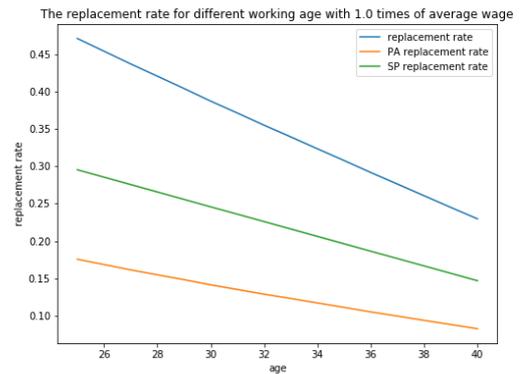
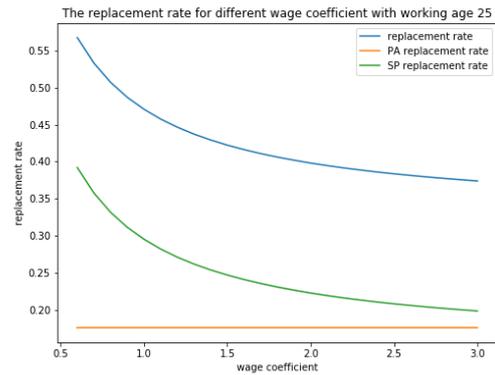


Figure 6 The replacement rate for female using the conservative investment strategy

For both male and female, the most part of pension income is from the social plan since the increase of annual payment from social plan is mainly affected by the growth rate of the average wage. When the average wage increases promptly, the social plan could ensure that the income of retirees will not fall behind that of employees.

3.2 Strategy 2: radical investment strategy

For this strategy, I assume that the money in personal accounts are invested in bank and equity market half and half.

Similarly, the first figure is for male. Compared with figure 4.1, a 5% increase in the replacement rate could be found. Since the income from the social plan is not dependent on the interest rate, so the replacement rate from this account keeps unchanged. For female, the adjustment in the investment strategy causes a slightly lower increase by around 3% in the replacement rate. The gap between the income from social plan and the personal account is reduced, since the personal account balance accumulates rapidly in equity market.

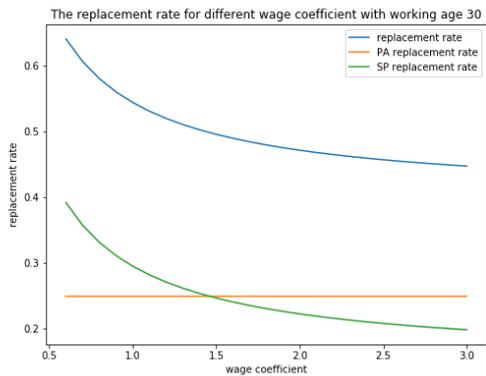
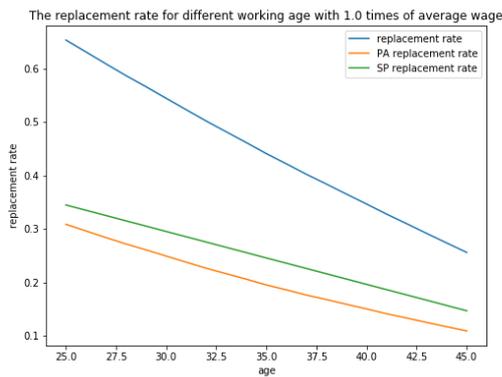


Figure 7 The replacement rate for male using the radical investment strategy

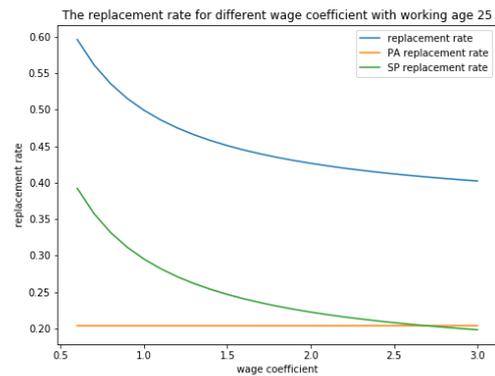
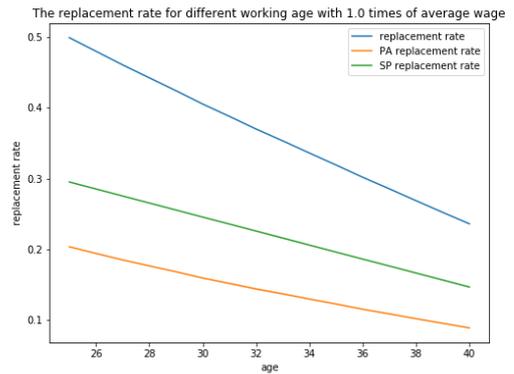


Figure 8 The replacement rate for female using the radical investment strategy

4. IMPROVEMENT METHODS

4.1 Improving the personal account payment rate

Due to the low replacement rate provided by PA (Personal Account), especially for women with short payment time, it is difficult to achieve the national goal of 24.2% (Xue, et al 2020). Therefore, the payment rate can be appropriately increased to improve the PA balance at retirement. However, government should pay attention to the fact that increasing the payment rate means reducing the disposable income before retirement, crowding out consumption and reducing the living standard before retirement to a certain extent, so it must be improved slightly. For example, PA payment rate could be improved to 8% or 10%.

I choose radical Investment Strategy (1/2 account into equity, 1/2 account into bank) to do assumption strategy simulation.

As is shown in the below figures, replacement rate of male who starts working age is 25 years old increases to over 70%, and for retirees who start working age is 45 years old, the replacement rate increases by about 5% compared with the currently personal account payment rate. A dramatic rise trend can be seen after the payment rate is improved. The

highest replacement rate is about 70% when people earn the 0.6 times of average wage per year, and the replacement rate of retirees who earn 3 times of average wage before retirement rises to about 53%. In general, the male replacement rate increases by about 7% after increasing the PA payment rate.

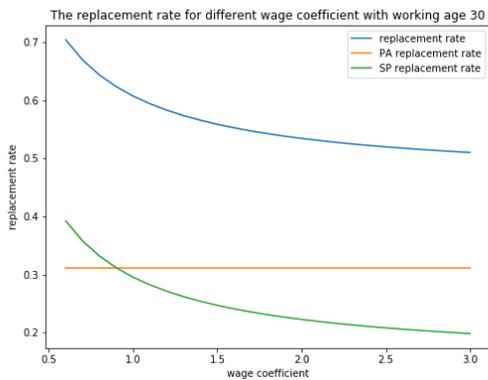
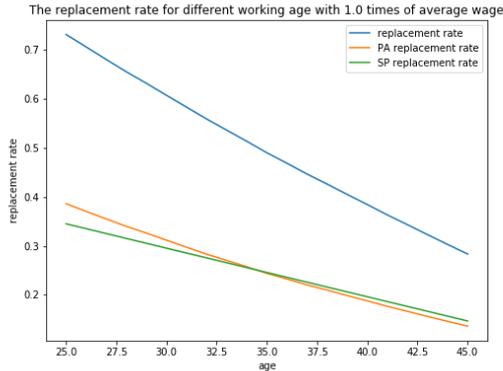


Figure 9 The replacement rate for male after increasing the rate of PA

It is manifest from below figures that after increasing the rate of PA payment, the overall female replacement rate has increased by about 5%.

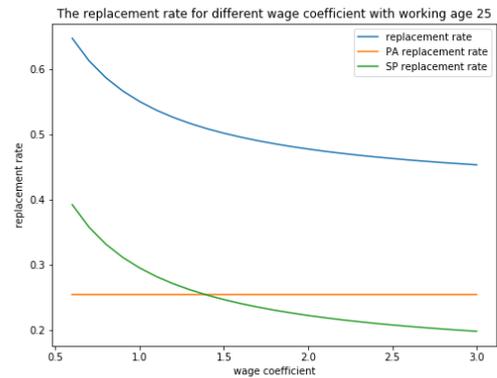
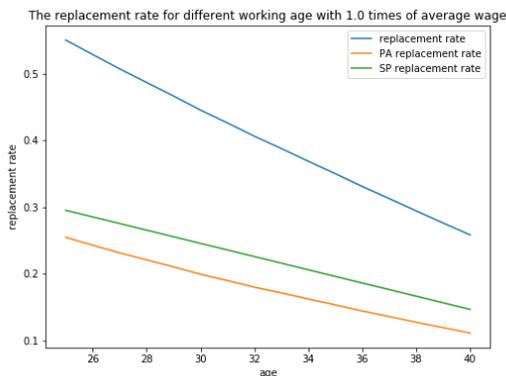
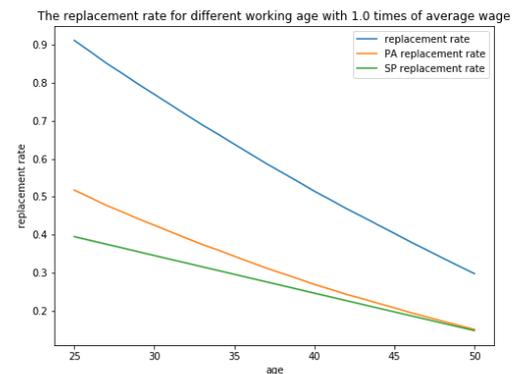


Figure 10 The replacement rate for female after increasing the rate of PA

4.2 Delaying retirement age

The male retires at 60 and the female retires at 55. This policy was established in 1978. However, with the increase of life expectancy and the aggravation of population aging, it is necessary to delay retirement. Refer to other developed countries, for example, the United States raised the retirement age for full pension from 65 to 67. The pension age in South Korea was adjusted from 60 to 61 in 2013 and will be raised to 65 in 2033. According to the statistics of more than 160 countries by the international labor organization, Chinese female workers retire at the age of 50, which is one of the countries with medium retirement age in the world. At present, discussions have been made to gradually increase the retirement age of both men and women to 65 in the next few years. Similarly, I use the radical investment strategy to do simulation and assume the retirement age is 65 years old for male and female, then result shows that no matter male or female, after delaying retirement to the age of 65 years old, the highest replacement rate can reach about 90%. This rate means that retirees can rely on pension account to maintain their original living standard after retirement, or even better.



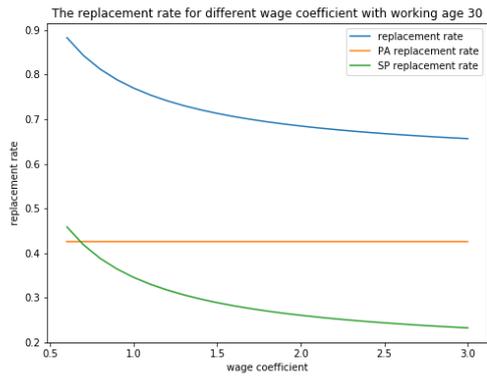


Figure 11 The replacement rate assuming retiring at 65

4.3 Strengthening the investment strategy of pension fund

Strengthen the research of fund investment strategy to ensure that the interest rate of personal account can be kept stable under various market conditions. Similarly, I assume personal account return can be maintained at 6% for a long period and use strategy 2 in part 4 to do simulation. As a result of the simulation, male's replacement rate increases by about 5% overall.

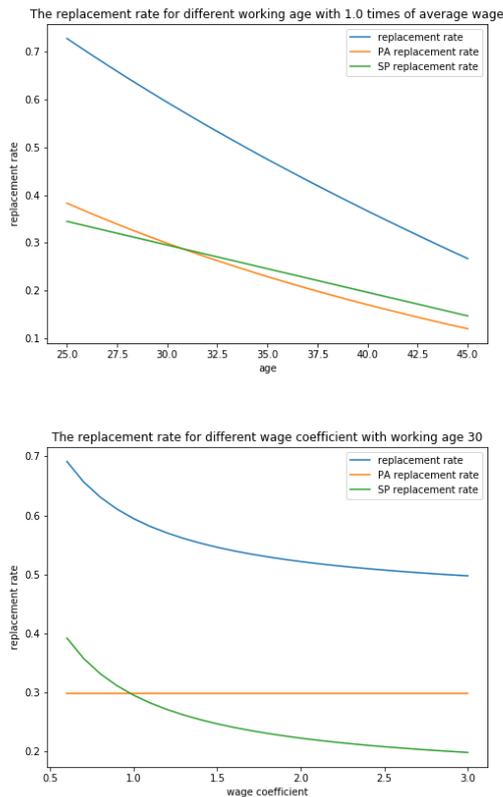


Figure 12 The replacement rate for male assuming the annual return of personal account is 6%

Under this strategy, female's replacement rate has increased more, about 7%, but the overall value is still lower than that of men.

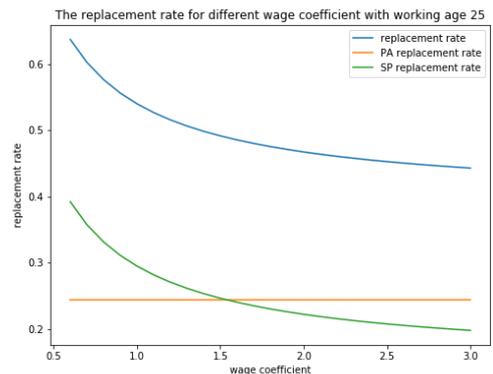
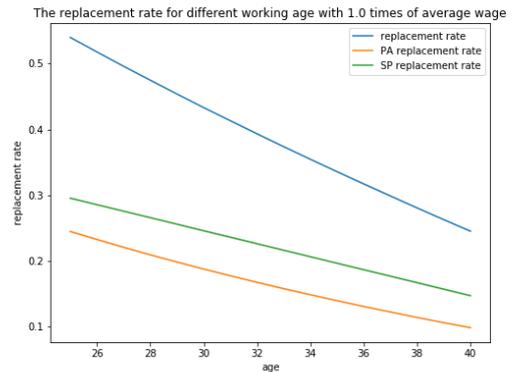


Figure 13 The replacement rate for female assuming the annual return of personal account is 6%

4.4 Increase the minimum payment period

For currently pension system, the replacement rate of men and women is less than 30% due to the payment time is the lowest 15 years, which seriously affects the living standard after retirement. The government can implement a new policy test to encourage more payment and raise the lower limit of payment time.

5. CONCLUSION

For Chinese currently pension system, retirees hardly maintain their original living standard after retirement especially for women who retire earlier. This paper focuses on simulating the replacement rate of all retirees under two investment strategies and get the result. In order to improve the replacement rate, this paper proposes four improved hypotheses and obtains a slightly increased replacement rate value. From the results, the best way to improve replacement rate is to delay retirement age to 65-year-old, which can reach about 90%.

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