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Prediction and Improvement of Pension Replacement Rate and Sustainability under Delayed Retirement Policy in Shaanxi, China

Xinqi Xie

Xi'an Jiaotong University, Xi'an 710000, China.

Abstract: In this study, the researcher predicted the sustainability and replacement rate of the pension in Shaanxi, China from 2023 to 2050 with population and average wage prediction, comparing that under delayed retirement policy and without delayed retirement policy. He also studied the improvement measures of pension in Shaanxi. In terms of population prediction, the researcher used the grey model by allelic substitution method and the Leslie population mode. The proportion of the elderly population in Shaanxi will continue to rise, reaching 30% in 2050. In terms of average wage prediction, the researcher found a linear relationship between it and GDP per capita in Shaanxi and used the Logistic regression to predict it. The average wage in Shaanxi will rise from $14,345 in 2021 to $43,939 in 2050. Based on these, the researcher found that the sustainability of Shaanxi's pension will continue to decline, reaching break-even in 2030. And the replacement rate keeps going up. The delayed retirement policy would extend the pension break-even to 2035 and also rise the replacement rate by about 5%.

Keywords: Pension; Elderly People; Leslie's Population Model; Grey Prediction; Actuarial Models

1. Introduction

In recent years, the aging trend of the world population has become more and more serious. The income and living standard of the elderly population have also attracted the attention of the world, for which the pension system needs to be modified. People care two aspects of pension: replacement rate (i.e., the ratio between the employee's pension at the beginning of retirement and the pre-retirement wage) and sustainability.

Three changes are taking place to the pension in China in. Firstly, the increasing elderly population, which is tensing the pension. Secondly, the swiftly raising average wage brings uncertainty to pension payment and issuance. Last but not least, is the delayed retirement policy. It's significant to do research to estimate and improve the pension. The researcher studied Shaanxi pension as an example.

2. Research methods

2.1 Population age distribution prediction

For population prediction, the researchers used the Leslie population model. The reason for choosing this model is that it can predict the population of different ages[1]. The working population and retired population can be predicted by this.

Leslie population model

$$\boldsymbol{X_0} = [x_0, x_1, x_2, \ldots, x_n]^T \qquad (4\text{-}1)$$

Vector is the female population in year . is the female population of -year-old. The upper age is set to 100.

$$\boldsymbol{L_w} = \begin{bmatrix} a_0 & a_2 & \cdots & a_{n-1} & a_n \\ sw_0 & 0 & \cdots & 0 & 0 \\ 0 & sw_2 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & sw_{n-1} & 0 \end{bmatrix} \qquad (4\text{-}2)$$

In the Leslie matrix , is the female infant fertility rate of the -year-old female, and is the survival rate of the -year-old female. Therefore, the female population of any year can be inferred from and the Leslie matrix through the equation (4-3).

$$\boldsymbol{X_n = L_w{}^n X_0} \quad (4\text{-}3)$$

Similarly, the male population can be modeled. It's just that the fertility rate in the male Leslie matrix is zero[2].

Fertility prediction by grey prediction by allelic substitute method

Fertility rate changes over the years, influenced by numerous factors, which makes the change of it very complex and nonlinear. Grey prediction by allelic substitute method can adapt to this.

The known time series of fertility rates is $X^0 = [X^0(1), X^0(2), \ldots, X^0(n)]$. The cumulative sequence is: $X^1 = [X^1(1), X^1(2), \ldots, X^1(n)]$, $X^1(k) = \sum_{i=1}^{k} X^0(i)\ (k = 1,2,\ldots,n)$.

We can predict the fertility rate in t+1 year with the equation:

$$\hat{X}^1(t+1) = [X^0(1) - \frac{u}{a}]e^{-at} + \frac{u}{a}.$$

The coefficients are calculated by the least square method.

In the subsequent prediction, the researchers constantly update [1]. So the new data is predicted only by several data in front of it to improve the precision.

2.2 Average wage prediction

Predict the average wage through the GDP

The Logistic regression with the Sigmoid function is consistent with the GDP growth, which increases fast in the developing period but slows down in the developed stage[3]. The researcher took it to predict average wage through the linear relation between GDP per capita and average wage.

The equation of the Logistic regression:

$$y = \frac{1}{a+be^{-ct}} \quad (4\text{-}4)$$

The value of is calculated by $\lim_{n\to\infty} y = \frac{1}{a}$. According to China's current economic goals, the limit of is the average wage of a moderately developed country.

Actuarial model for Shaanxi pension

Using China's official method of calculating personal pensions, the researcher built the actuarial model for the Shaanxi pension[4]. is the expenditure of the pension a year and is the income of it a year. is the personal contribution ratio and is the enterprise contribution ratio. Now is 8% and is 16% in Shaanxi.

$$PE = \frac{Average\ wage\ last\ year\ \times\ t}{100} \times Population\ aged\ i$$

$$+ \sum_{i=60}^{100} \frac{\sum_{j-t}^{j} j - (i-60)w_j\ pr}{139} \times Male\ population\ aged\ i$$

$$\times Average\ wage\ in\ the\ year\ of\ age\ j$$

$$+ \sum_{i=55}^{100} \frac{\sum_{j-t}^{j} j - (i-55)w_j\ pr}{170} \times Female\ population\ aged\ i$$

$$\times Average\ wage\ in\ the\ year\ of\ age\ i$$

$$PI = Average\ wage\ this\ year \times (pr + er) \quad (4\text{-}5)$$

The researcher defines a sustainability coefficient (s) by equation (4-6).

$$S = \frac{Total\ pension\ payment\ in\ a\ year}{Total\ pension\ issuance\ in\ a\ year} - 1 = \frac{PI}{PE} - 1 \quad (4\text{-}6)$$

2.3 Improve the pension

The researcher uses the multi-objective nonlinear programming model to find the highest replacement rate and sustainability coefficient by adjusting the pension contribution ratio.

Questionnaire

The researcher makes a questionnaire to collect the acceptance degree of pension regulation, and willingness to pay the pension. The questionnaire is made by https://www.wjx.cn/.

3. Results

3.1 The population and average wage prediction

The prediction of population age distribution and average wage is shown in the figures.

Population prediction

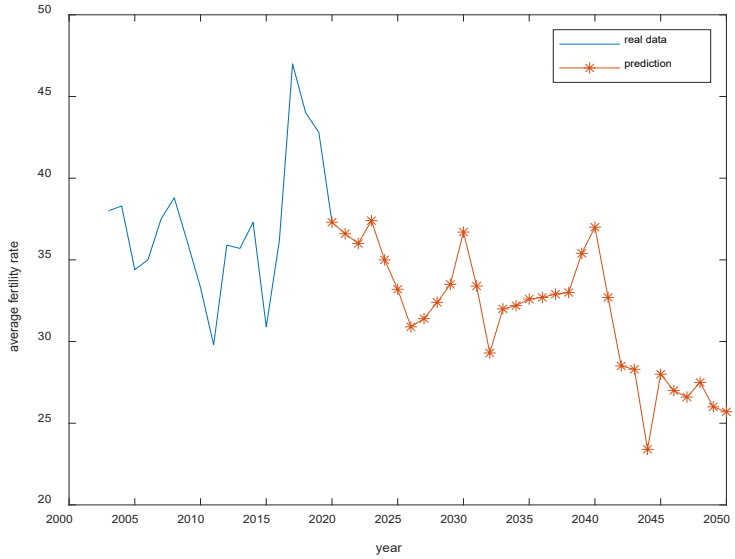
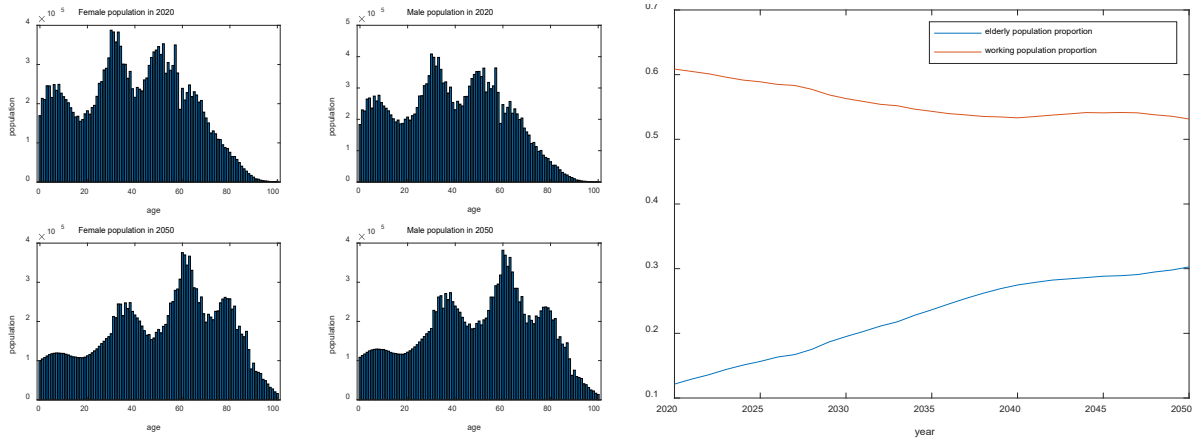


Figure 1: Shaanxi average fertility rate prediction.

Figure 1 shows the average fertility rate in Shaanxi predicted by the grey prediction by allelic substitute method. It will decline with fluctuation in the future.



(a) (b)

Figure 2: Population age structure change.

Figure 2 (a) shows the population age distribution change in detail, and Figure 2 (b) shows the elderly population changing trend. It is

increasing over time.

Average wage prediction

Source	SS	df	MS	Number of obs	=	44
				F(1, 42)	=	21879.74
Model	3.2607e+10	1	3.2607e+10	Prob > F	=	0.0000
Residual	62590954.8	42	1490260.83	R-squared	=	0.9981
				Adj R-squared	=	0.9980
Total	3.2669e+10	43	759746854	Root MSE	=	1220.8

averagewage	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
GDPPer	1.161153	.00785	147.92	0.000	1.145311	1.176995
_cons	-788.1948	239.001	-3.30	0.002	-1270.518	-305.8713

Table 1: Regression analysis of average wage and GDP per capita.

Table 1 shows the results and reliability of the linear relation between the average wage and GDP per capita in Shaanxi.

Model	Value	95% Confidence interval
	0.0018	[0.0015,0.0021]
	0.1262	[0.1219,0.1306]
		~

R-squares = 0.9953

Table 2: Logistic model.

Table 2 shows the results and reliability of the Logistic model.

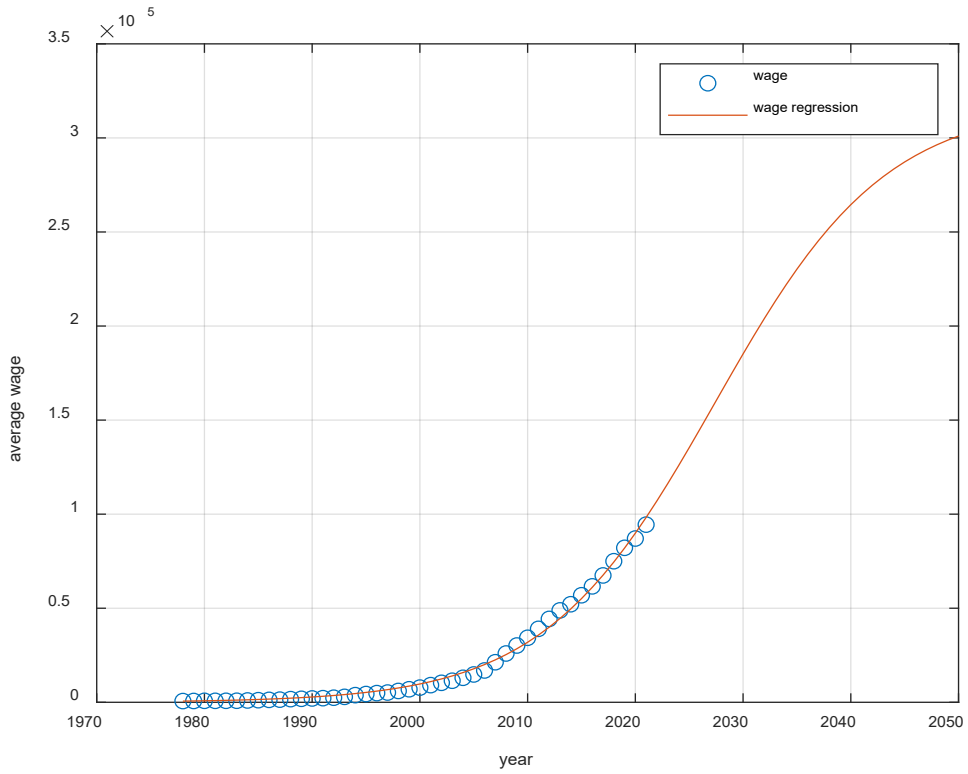
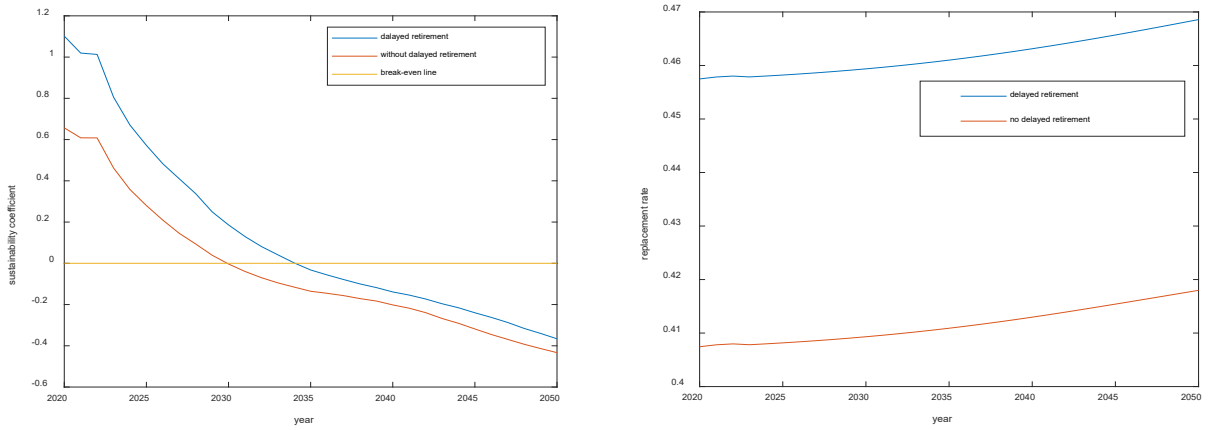


Figure 3: Logistic model fitting curve.

Figure 3 shows the prediction of the average wage and the known average wage in Shaanxi.

3.2 The prediction of replacement rate and sustainability



(a) (b)

Figure 4: The sustainability coefficient and replacement rate prediction.

The sustainability coefficient and replacement rate is shown in Figure 4 (a) and Figure 4 (b) respectively.

3.3 Questionnaire

The researcher collected the reproductive intentions of the target group and their attitude toward the pension. Some quantitative and qualitative methods are used to analyse them.

	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf.	Interval]
acceptable_ratio	.16	.0035598	44.95	0.000	.1530229	.1669771

Table 3: Bootstrap confidence interval of highest acceptable personal contribution ratio

Table 3 shows the bootstrap estimation of the mean value of the highest acceptable personal contribution ratio.

4. Discussion and conclusion

As is shown in Figure 2, according to the Leslie population model, the elderly population proportion will increase in the next 30 years. However, the working population proportion will keep decreasing. That means the pension will be tenser and tenser.

In addition, the average wage is predicted by the Logistic regression. It will raise as is shown in Figure 3.

According to the population prediction and the average wage prediction, the researcher predicted the pension replacement rate and the sustainability as is in Figure 4. Considering the delayed retirement policy, the break-even year will be postponed from 2030 to 2035, in the meantime the replacement rate will also be raised by about 5%. In conclusion, the delayed retirement policy does benefit the pension temporarily.

However, the delayed retirement policy cannot reverse the long-term declining trend of the pension. The researcher improves the pension coefficient (personal contribution ratio and the enterprise contribution ratio) according to the data got from a questionnaire which is shown in Table 3. The impact of individual contribution rate increases does rise the sustainability and replacement rate. The corporate contribution rate couldn't affect the replacement because it doesn't change the pension issuance. However, both of the effects will be fading with time.

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