Study on the Prediction of Aging Population in Gansu Based on Metabolic GM(1,1) Model

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Abstract. Since the 21st century, the number of people aged 65 and above in China has been increasing year by year. The aging population has grown faster and faster, and the aging of the population has become increasingly prominent. In order to explore the development trend of the elderly population aged 65 years and over in Gansu Province, this paper uses the gray system metabolism GM (1,1) model to predict the population aged 65 and above in Gansu Province from 2016 to 2022. The results show that the elderly population in Gansu Province will continue to rise in the next few years. In order to effectively alleviate this problem, this paper proposes three suggestions to improve the social pension security system in Gansu Province, establish an industrial base for the elderly, and promote the “two-child” policy.

Introduction

In recent years, the global population aging problem has become more and more prominent, and it has also received extensive attention from many domestic and foreign scholars. The research of foreign scholars focuses more on the impact of aging on the social economy. Mikiko Oliver (2015) explored the relationship between Japan's population structure and Japan's economic changes from 1975 to 2011. The results show that Japan’s aging population has a negative impact on real per capita GDP growth, mainly due to the decline in the working-age population[1]. James M. Poterba (2014) analyzes the retirement protection status of the aging population in the United States. He believes that the income sources of the elderly are very different. For low-income seniors, social security is an important support; for high-income seniors Words, personal pensions, assets, and earnings are even more important. Research by domestic scholars focuses on the relationship between the aging of the population and the industrial structure and the impact on the social economy[2]. Feng Jianfeng and Chen Weimin (2017) discussed the mechanism of the impact of aging on the economic growth in China. The results show that the aging of the population mainly affects the speed of economic growth through labor productivity[3]. Wang Guixin and Gan Yihui (2017) studied the impact of aging population in China on regional economic growth. The article shows that although the age of China’s population aging has not yet formed a negative impact on regional economic growth, the aging of the population in the future will become increasingly serious. And its negative impact on regional economic growth is inevitable[4].

In general, the current academic research on the area of population aging still has some deficiencies. Firstly, there is less research on the aging of the population in the western region. Secondly, there is less research on the development trend of population aging. Therefore, based on the relevant data in Gansu Statistical Yearbook, this paper uses the metabolic GM(1,1) model to predict the population aged 65 and above in Gansu Province from 2016 to 2022, and analyzes the forecast results. We hope to make a contribution to the study of population aging.
Research Methods and Data Processing

Research Methods

This paper uses the grey system GM(1,1) model prediction method to predict and analyze the population aged 65 and above in Gansu Province from 2016 to 2022.

Construction and Test of GM(1,1) Model. Build steps. The GM(1,1) model is the basis for the grey prediction. The two “1”s represent the first-order equation and one variable, respectively. The steps for building this model are as follows:

The first step is to set the original array with m observations:

\[
X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), \ldots, X^{(0)}(m)\}
\]  
(1)

The second step is to add new series \(X^{(1)}\):

\[
X^{(1)} = \{X^{(0)}(1), X^{(0)}(2), \ldots, X^{(0)}(m)\}
\]

(2)

The third step is to use \(X^{(0)}\) and \(X^{(1)}\) to establish matrices \(B\) and matrices \(y_n\):

\[
B = \begin{bmatrix}
\frac{1}{2}(X^{(0)}(1) + X^{(0)}(2)) & 1 \\
\frac{1}{2}(X^{(0)}(2) + X^{(0)}(3)) & 1 \\
\frac{1}{2}(X^{(0)}(3) + X^{(0)}(4)) & 1 \\
\frac{1}{2}(X^{(0)}(m-1) + X^{(0)}(m)) & 1 \\
\end{bmatrix}
\]

(3)

\[
y_n = \begin{bmatrix}
X^{(0)}(2) \\
X^{(0)}(3) \\
X^{(0)}(4) \\
\vdots \\
X^{(0)}(m) \\
\end{bmatrix}
\]

(4)

The fourth step, according to the matrix sum \(B\) and \(y_n\), uses the least-squares method to fit the parameters \(a\) and \(b\):

\[
\hat{\alpha} = \left( \begin{array}{c} a \\ b \end{array} \right) = (B^T B)^{-1} B^T y_n
\]

(5)

The fifth step is to substitute the parameters \(a\) and \(b\) into the time response equation:

\[
\hat{X}^{(0)}(n+1) = X^{(0)}(0) - \frac{b}{a} \frac{1}{e^{-\frac{b}{a}}} + \frac{b}{a}
\]

(6)

In the sixth step, the prediction equation is:

\[
\hat{X}^{(0)}(m+1) = \hat{X}^{(0)}(m+1) - X^{(0)}(m) = a \left[ X^{(0)}(t) - \frac{b}{a} \right] e^{-\frac{b}{a}}
\]

(7)

Accuracy test. In order to test the credibility of the prediction results, the model needs to be tested for accuracy. The test method is as follows:

(1) Residual test. The point-by-point test model predicts the residual value of the restored value and the actual value.

Absolute residual sequence:

\[
\Delta^{(0)}(m) = \left| X^{(0)}(m) - \hat{X}^{(0)}(m) \right|
\]

(8)

Average relative residual:
\[ \varphi = \frac{1}{n} \sum_{i=1}^{n} \varphi_i, \quad \text{and} \quad \varphi_i = \frac{\Delta^{(i)}(m)}{X^{(i)}(m)} \]  

(9)

Given \( \alpha \), when \( \bar{\sigma} < \alpha \) and \( \bar{\rho} < \alpha \) it is established, the model construction is qualified.

### Table 1. \( \alpha \) value budget accuracy checklist.

| Range of values | Budget accuracy level |
|-----------------|-----------------------|
| \( \alpha = 0.01 \) | Excellent             |
| \( \alpha = 0.05 \) | Qualified             |
| \( \alpha = 0.1 \) | Unqualified           |

(2) Correlation test. The degree of similarity between the model sequence curve and the original sequence curve is examined.

\[ R = \frac{1}{m} \sum_{i=1}^{m} \frac{\Delta_{\min} + \lambda \Delta_{\max}}{\Delta_{s}(m) + \lambda \Delta_{\max}} (\lambda = 0.5) \]  

(10)

### Table 2. \( R \)-Value budget accuracy checklist.

| Range of values | Budget accuracy level |
|-----------------|-----------------------|
| \( R > 0.9 \)   | Excellent             |
| \( R > 0.8 \)   | Qualified             |
| \( R > 0.7 \)   | Unqualified           |
| \( R > 0.6 \)   | Satisfaction          |

(3) Post-test difference test. Test the statistical properties of the residual distribution.

Firstly, calculating the standard deviations \( S_1 \) and \( S_2 \) according to \( X^{(i)}(m) \) and \( \Delta^{(i)}(m) \):

\[ S_1 = \sqrt{\frac{\sum [X^{(i)}(m) - \bar{X}^{(i)}]^2}{m-1}} \]  

\[ S_2 = \sqrt{\frac{\sum [\Delta^{(i)}(m) - \bar{\Delta}^{(i)}]^2}{m-1}} \]  

(11)

(12)

Secondly, calculating the ratio \( C \):

\[ C = \frac{S_2}{S_1} \]  

(13)

Thirdly, calculating the small error probability \( p \): \( p = P(|\Delta^{(i)}(m) - \bar{\Delta}^{(i)}| < 0.6745 S_1) \)

In general, when \( p > 0.95 \) and \( C < 0.35 \), the model is better; when \( p > 0.8 \) and \( C < 0.5 \), it indicates that the model is qualified; when \( p > 0.7 \) and \( C < 0.65 \), it indicates that the model is marginally qualified; when \( p \) When \( C < 0.7 \) and \( C < 0.65 \), it indicates that the model is unqualified. At this time, it is necessary to correct the model and know that the accuracy is reached.

### Table 3. Prediction accuracy level checklist.

| Budget accuracy level         | \( p \)  | \( C \)   |
|-------------------------------|---------|----------|
| Good (level 1)                | >0.95   | <0.35    |
| Qualified (secondary)         | >0.8    | <0.5     |
| Reluctant (third level)       | >0.7    | <0.65    |
| Failed (Level 4)              | <=0.7   | >=0.65   |

**The Principle of Metabolic GM(1,1) Model Prediction.** The metabolic GM(1,1) model is based on the conventional GM(1,1) model, adds the latest data \( X^{(i)}(m+1) \) which predicted by the
GM(1,1) model to the original sequence \(X^{(0)}\), removes \(X^{(0)}(i)\), constitutes a new data sequence, and uses the new series \(X^{(0)}(2), X^{(0)}(3), \ldots, X^{(0)}(m+1)\) builds a GM(1,1) model to predict \(X^{(0)}(m+2)\) and perform an accuracy test. After the accuracy test is passed, it will be \(X^{(0)}(m+2)\) added and removed \(X^{(0)}(2)\), and a new series will be formed again to continue the prediction and test of the GM(1,1) model. Repeat this step until you have completed your prediction goal.

**Data Processing**

The research object of this article is the aged population aged 65 and above. Through forecasting the population aged 65 and above in Gansu Province from 2016 to 2022, analyze the development trend and propose countermeasures. The data used are all from the population aged 65 and above in the Statistical Yearbook of Gansu Province.

**Empirical Analysis**

The changes in the aged population aged 65 and above in Gansu Province from 2007 to 2015 are shown in Figure 1. As can be seen from the figure, the population of old people aged 65 and above in Gansu Province is continuously expanding. The annual increase rate before 2014 is relatively small, and the increase rate is large in 2015.

![Population size of 65 years old and above in Gansu Province, 2007-2015](image)

In order to understand the growth trend of elderly people aged 65 years and over in Gansu Province in the coming years, the population of this part of the population from 2007 to 2015 was selected as the basic data, and the metabolic GM (1,1) model was applied to Gansu Province 2016-2022. The population aged 65 and above is forecast. The specific results are as follows:

Table 4 shows the actual values of elderly population aged 65 and above in Gansu Province from 2007 to 2015. These 9 values are used as the basic data and substituted into the GM(1,1) model to predict the population of this age group in 2016 and carry out Accuracy test and accuracy test are passed; the 2007 data is removed and the 2016 data is added. Therefore, the new basic data is composed of data from 2008 to 2016, and the population of that age group in 2017 is predicted and precision inspection, accuracy inspection qualified; then remove the 2008 data, the 2017 data will be added, continue to repeat this step until the 2022 forecast of the population aged 65 and above. The specific forecast results and precision test results are shown in Table 5 and Table 6.

| Year | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|------|------|------|------|------|------|------|------|------|------|
| Actual value | 199.21 | 196.03 | 201.09 | 210.48 | 213.34 | 216.77 | 219.56 | 221.51 | 255.54 |

Table 4. Population aged 65 and above in Gansu Province, 2007-2015 Unit: 10,000.
From Table 5, it can be seen that in the next six years, the population of people aged 65 and above in Gansu Province will continue to rise. After 2021, the population in this age group will exceed 3 million. The number of people aged 65 and above in Gansu Province in 2022 is expected to reach 3,076,300, an increase of 520,900 compared with 2015.

Figure 2 shows the scale of the population aged 65 and over in Gansu Province from 2007 to 2022. It can be seen from Figure 2 that the population of people aged 65 and above in Gansu Province has been rising from 2008 to 2022, and the rate of increase has been relatively flat from 2008 to 2014, and there has been a relatively large increase from 2014 to 2015, 2015. After that, there was a slight decline, and it will continue to rise steadily during 2016-2022, and the rate of increase after 2016 will be faster than that of 2008-2014.

| Year | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|------|------|------|------|------|------|------|------|
| Actual value | 248.17 | 256.52 | 265.26 | 275.79 | 286.73 | 297.69 | 307.63 |

Table 5. Predicted population aged 65 and above in Gansu Province 2016-2022 [Unit: 10,000].

According to the model accuracy test standard, a total of 6 metabolisms were performed. The average relative residual value of the basic model is 0.0211, which is less than 0.05, indicating that the basic model is qualified; the maximum value of the average relative residual in the 6 times of metabolism is 0.0209, which is less than 0.05, indicating that the 6 metabolic models are all qualified. From the perspective of relevance, the correlation R of the basic model is 0.6967, which is greater than 0.6, indicating that the basic model is relatively satisfactory; the minimum value of the correlation R in the 6 times of metabolism is 0.6955, indicating that the 6 metabolic models are all satisfactory. From the perspective of the small error probability and the posterior variance ratio, no matter the basic model or the six metabolites, the small error probability P is 1 and the posterior variance ratio C is less than 0.3, indicating that the model is well constructed and the precision is excellent. From this, it can be concluded that this forecast has credibility.

Table 6. Accuracy checklist.

| Times Name       | Accuracy | Average Relative Residual | Association Degree R | Small Error Probability | Posterior Variance Ratio |
|------------------|----------|---------------------------|----------------------|-------------------------|--------------------------|
| Basic model      |          | 0.0211                    | 0.6967               | 1                       | 0.2994                   |
| A metabolism     |          | 0.0209                    | 0.6955               | 1                       | 0.2677                   |
| Secondary metabolism |      | 0.0205                    | 0.7030               | 1                       | 0.2565                   |
| Three times metabolism |    | 0.0177                    | 0.7414               | 1                       | 0.2456                   |
| Four times metabolism |     | 0.0159                    | 0.7661               | 1                       | 0.2278                   |
| Five times metabolism |    | 0.0148                    | 0.7909               | 1                       | 0.2184                   |
| Six times metabolism |     | 0.0143                    | 0.7876               | 1                       | 0.2045                   |
Conclusion and Suggestion

This paper uses the grey system forecast method to predict the aged population aged 65 and above in Gansu Province from 2016 to 2022, and analyzes the forecast results. The number of elderly people aged 65 and above in Gansu Province will continue to rise in the next seven years, reflecting that the ageing degree is continuously deepening. In order to effectively solve this problem. Through the above analysis, the article put forward three suggestions: Firstly improve the social pension security system, for example, including endowment insurance, medical insurance and other systems. Expand the coverage of old-age security, so that the social pension security system benefits older people; Secondly, establishing an industrial base for the elderly, creating a diversified pension model, and train professionals serving the elderly; Finally, in order to alleviate the aging of the population in Gansu Province, it can vigorously promote the “two-child” policy, so that the family has the concept of the two children into their hearts, increase the birth rate in Gansu Province.

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