

The prediction of GDP growth in Shandong Province with gray model

Zhonghao Dong¹, Xinyu Gao²

¹*School of Information Science and Engineering, East China University of Science and Technology, Shanghai, 201424, China*

²*School of Economics and Management, Huaibei Normal University, Huaibei, Anhui, 235000, China*

Abstract: 2021 is the first years of the new journey to build a socialist modern country in an all-round way after China has built a well-off society. Shandong Province, which is in an important position of China's economic development, ranks third in the country's GDP and plays a crucial role in the economic construction of China's second one-hundred-year goal. In this paper, the gray forecast model is used to forecast the GDP of Shandong Province in the next five years. Due to the vigorous promotion of the resumption of work and production in Shandong Province, and the huge potential of the consumer market for the large population of Shandong Province and continuous growth of residents' income, it is showed in the report that Shandong Province's GDP growth rate will rebound rapidly, and maintain a steady growth trend in the next five years, which is based on the solid foundation and long-term positive trend of the economic development in Shandong Province. Finally, this paper puts forward some policy suggestions for the economic development of Shandong Province in view of the above research results.

Keywords: Shandong Province, GDP, Gray Forecast Model, Policy Recommendations

1. Introduction

2021 is the beginning of China's 14th Five-Year Plan, the contradiction between the people's growing need for a better life and the uneven and inadequate development has become the main contradiction in our society at this stage, and the second one-hundred-year goal also put forward a higher goal for economic growth and national well-being. To realize the overall layout of the 14th Five-Year Plan, it is surely inseparable with the regional driving and leading role of the major economic province. Shandong Province, as one of the most developed provinces in China, occupies a pivotal position in the economic development situation of the country, the total economic volume ranks third in the country, and has maintained a relatively fast economic growth rate; and the total population of Shandong Province ranks second in the country, the total population size in 2020 is more than 100 million, which has a quite significant impact on the construction of the well-off society and the development of the national economy. In addition, in today's era of China's economic rise and cultural revival, there is more mutual influence between economic construction and cultural development, and Shandong Province, as the home of Confucius and Mencius, for thousands of years has bred a profound and far-reaching Qilu culture and Confucian culture, is one of the main birthplaces of Chinese civilization, and therefore an indispensable part of the national economic and cultural construction. Unique geographical location also brings unique conditions for Shandong's economic development, Shandong Province is located in the North China Plain, and also belongs to China's eastern coastal economic development zone, is surrounded by the Bohai sea and the Yellow Sea, and boasts numerous port cities. It is also close to developed economies such as the South Korea and Japan. It can be seen that the future economic growth of Shandong province is of great significance to the national economic development.

2. Literature Review

In recent years, numerous domestic scholars have predicted the future development status with grey model. Based on the GM(1,1) model in the grey model prediction theory, Zhu Yuntao made a gray prediction on the tonnage of standard coal used in Shanghai's industrial energy consumption and predicted the corresponding data from 2015 to 2020. The conclusion shows that Shanghai's industrial energy consumption will continue to increase, but the growth rate will slow down. Based on the GM(1,1) prediction model and the relevant statistical data from 2010 to 2017, Yan Yujun predicted the total

number of population aged 65 and above and the ratio of aging coefficient in Shanghai from 2018 to 2037. Results indicate that over the next 20 years, Shanghai 65 and older population and aging coefficient increases year by year, and shows a trend of rapid growth. To sum up, the current research on the gray forecast model on social and economic problems has an agreeable practical application and effect test, but lack of the forecast analysis for economic growth in the future "14th Five-Year Plan" period, so this paper makes a reasonable forecast of the GDP growth of Shandong Province in the next few years, providing reference data and theoretical planning for the government to introduce the relevant economic development policies and formulate relevant target programs during the 14th Five-year Plan.

3. Data Selection

According to the Statistical Yearbook of Shandong Province 2020 and the Statistical Bulletin of National Economic and Social Development of Shandong Province, the GDP of Shandong Province in recent ten years is shown in the table below, and the broken line chart is drawn:

Table 1: The gross domestic product of Shandong Province in the last ten years

Year	2011	2012	2013	2014	2015
GDP (hundred million ¥)	39064.9	42957.3	47344.3	50774.8	55288.8
Year	2016	2017	2018	2019	2020
GDP (hundred million ¥)	58762.5	63012.1	66648.9	70540.5	73129.0

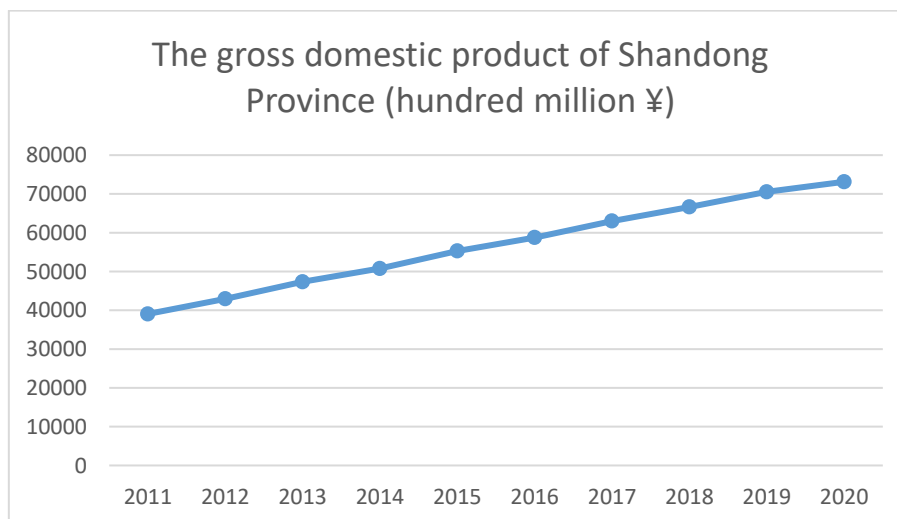


Figure 1: The gross domestic product of Shandong Province in the last ten years

As can be seen from Figure 1, in the past decade, the total GDP of Shandong Province has shown a steady growth trend, with annual GDP increasing year by year and relatively stable growth rate. Only in 2020, the growth rate slowed down due to the impact of COVID-19, but the total GDP still maintained a rising trend. In addition, GDP growth is influenced by socio-economic, policy implementation, scientific and technological progress, population change, natural conditions and other aspects, the influencing factors are related to each other and there is greater uncertainty, it is nearly impossible to fully clarify the mechanism of the role. Therefore, this paper adopts the gray forecast model to make the corresponding forecast and analysis of GDP growth in the next five years during the 14th Five-Year Plan period in Shandong Province.

4. Methodology

Gray forecast is a prediction for systems that contain both known and uncertain information, by identifying development trend of dissimilarity degree between the system factors, and by generating and processing raw data to find out the law of system changes. Grey system seeks its change rule through the collation of raw data, that is, the generation of grey sequence. The generation of grey sequence can weaken the randomness of original data and show its regularity.

Set $x^{(0)} = [x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)]$, as the original sequence, the accumulate plus generation

number listed as $x^{(1)} = [x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(n)]$, where $x^{(1)}(k) = \sum_{i=1}^k x^{(0)}(i), k = 1, 2, \dots, n$

Then definite the grey differential equation model of GM(1,1) for $x^{(0)}(k) + ax^{(1)}(k) = b$, in this type, a is called development coefficients, b is called grey influencing coefficients.

Set $k = 2, 3, \dots, n$, GM(1, 1) can be expressed as $Y=Bu$

$$\text{In this equation: } u = \begin{bmatrix} a \\ b \end{bmatrix}, Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix}, B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix}$$

By using monadic regression analysis, the estimate of a, b is $\hat{u} = \begin{bmatrix} \hat{a} \\ \hat{b} \end{bmatrix} = (B^T B)^{-1} B^T Y$

Thus, the white differential equation model is $\frac{dx^{(1)}(t)}{dt} + ax^{(1)}(t) = b$

The solution is $x^{(1)}(t) = (x^{(0)}(1) - \frac{b}{a})e^{-a(t-1)} + \frac{b}{a}$

Then get the accumulation of predicted value

$$\hat{x}^{(1)}(k+1) = (x^{(0)}(1) - \frac{b}{a})e^{-ak} + \frac{b}{a}, k = 1, 2, \dots, n-1$$

Then the corresponding predicted value is obtained through accumulate subtract generation:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), k = 1, 2, \dots, n-1$$

After the predicted value is obtained, test the GM(1,1) model by the methods below:

The mean square error of original sequence $x^{(0)}(k)$: $S_0 = \sqrt{\frac{\sum_{k=1}^n [x^{(0)}(k) - \bar{x}^{(0)}]^2}{n-1}}$, where

$$\bar{x}^{(0)} = \frac{\sum_{k=1}^n x^{(0)}(k)}{n}$$

The mean square error of residual error sequence $\varepsilon^{(0)}(k)$: $S_1 = \sqrt{\frac{\sum_{k=1}^n [\varepsilon^{(0)}(k) - \bar{\varepsilon}^{(0)}]^2}{n-1}}$, where

$$\bar{\varepsilon}^{(0)} = \frac{\sum_{k=1}^n \varepsilon^{(0)}(k)}{n}$$

Calculate the mean square error ratio $C = \frac{S_1}{S_0}$,

And calculate the probability of small error $P = \left\{ \left| \varepsilon^{(0)}(k) - \bar{\varepsilon}^{(0)} \right| < 0.6745 S_0 \right\}$

The accuracy test indexes of grey forecast model refer to the following table:

Table 2: Model accuracy index reference

Mean relative residual Q	Probability of small error P	Mean square error ratio C	Model accuracy
<0.01	>0.95	<0.35	Optimal
<0.05	>0.80	<0.50	Qualified
<0.10	>0.70	<0.65	Barely qualified
>0.10	<0.70	>0.65	Unqualified

5. Result

Based on the grey forecast model mentioned above and the GDP of Shandong Province from 2011 to 2020, the grey forecast of GDP of Shandong Province from 2021 to 2025 is carried out.

Get the GM(1,1) forecast model: $x^{(1)}(k+1) = 671001.7e^{0.0645458k} - 631936.8$

And through accumulate subtract generation:

$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), k = 1, 2, \dots, n-1$, The GDP of Shandong Province in the next five years are predicted, as shown in the following table:

Table 3: GDP forecast value of Shandong Province in the next five years

Year	2021	2022	2023	2024	2025
GDP(hundred million ¥)	79978.0	85310.5	90998.5	97065.8	103537.6

After model accuracy test, the results are obtained: C=0.0086, P=1, the prediction accuracy is optimal, the model is very accurate and the prediction result is good.

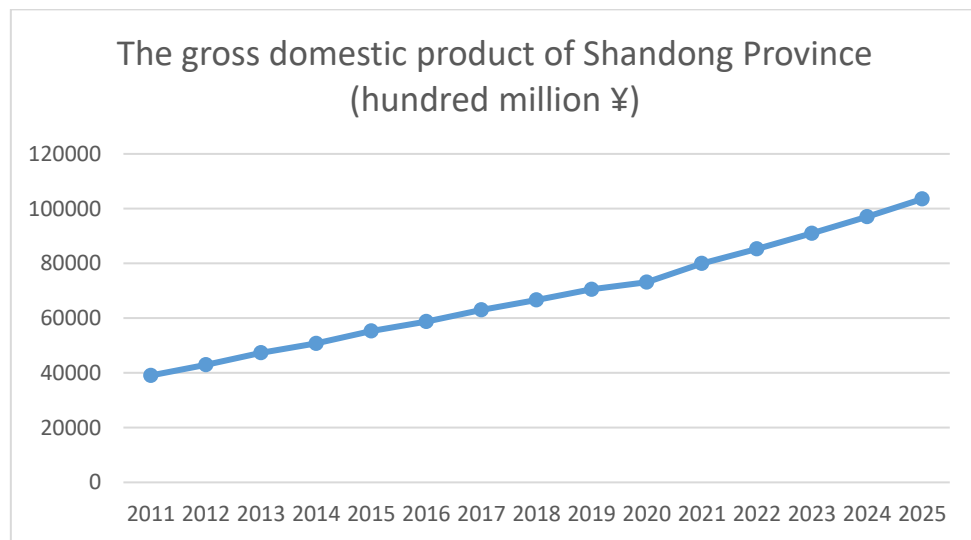


Figure 2: GDP Growth Trend of Shandong Province from 2011 to 2025 (including forecast)

Visualize the predicted results by drawing a line chart, from Figure 2, after the GDP growth rate of Shandong province slowed down in 2020 due to the impact of the epidemic, the GDP growth rate rebounded rapidly in 2021 and remained stable in the following years, showing a trend of steady GDP growth.

6. Conclusion

1) Do a timely job of economic recovery in the post-epidemic era

In 2020, economic growth rate of Shandong Province slowed significantly due to the COVID-19 epidemic, and with the increasingly improving situation of the epidemic, numerous provinces of China gradually begin to introduce economic recovery policies. In the process of socialist modernization, Shandong Province has shown good economic growth momentum and considerable potential for economic development, and needs to speed up the process of economic recovery, make the trend of

economic growth return to the pre-epidemic level as soon as possible.

2) Introduce prudent policies for economic development

From the GDP of Shandong Province over the past decade and forecast for the next five years, it can be found that the GDP growth rate in Shandong Province is relatively stable except for the outbreak of the COVID-19 in 2020. Therefore, according to the actual situation of economic development in Shandong Province, the government should promote the steady economic growth of Shandong Province and conduce to the stable progress of local social economy and people's living standards.

References

- [1] Zhu Yuntao, Mao Junpeng, Ren Yipo, Li Weifen. *Analysis of industrial energy consumption forecast in Shanghai based on gray model [J]. Shanghai saves energy, 2016(09): 498-502.*
- [2] Gui Dehuai, Zhang Xianhui. *Analysis of container throughput forecasting in Shanghai harbour based on gray forecasting model [J]. Journal of Zhangzhou Vocational and Technical College, 2020, 19(03): 33-36+40.*
- [3] Zhang Li, Jin Jian, Tang Zhiqiang. *The mathematical model of Shanghai's GDP growth and its analysis and forecast [J]. Journal of Changshu Polytechnic Institute, 2011, 25(08): 35-38.*
- [4] Yan Yuxuan, Yan Yunlou. *The trend of population aging in Shanghai and its influencing factors - based on GM (1,1) and main component analysis [J]. Chinese Journal of Gerontology, 2021, 41(14): 3093-3098.*
- [5] Deng Julong. *Gray control system [J]. Journal of the Chinese Academy of Technology, 1982(03): 9-18.*