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GDP Forecast of Shanghai Based on Grey Model

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Abstract: *2021 is the first year of the "14th Five-Year Plan", and the formulation of economic policies in line with the realistic background is of great significance to the completion of the "14th Five-Year Plan" and the 2035 long-term plan. As the nation's economic and financial center city, Shanghai has always been a benchmark for leading the Chinese economy. Therefore, this paper selects Shanghai's GDP data from 2010 to 2019 as a sample to establish a Shanghai GDP prediction model based on the gray model GM (1, 1), and predicts Shanghai's GDP total and growth data from 2020 to 2026. The empirical results show that the total GDP of Shanghai will continue to grow in the future, but the GDP growth rate will gradually slow down. Finally, this article puts forward corresponding countermeasures and suggestions based on the status quo of Shanghai's economic development.*

Keywords: *Shanghai, GDP, Grey prediction model*

1. Introduction

Looking at the domestic and international environment, the "14th Five-Year Plan" period is the initial period of China's comprehensive construction of a socialist modern power in the new era, and the deepening period of major changes unseen in the world in a century. This period is also a critical period for Shanghai to continue to deepen the construction of the "five centers" and accelerate its construction into a socialist modern city with international influence. Based on the 14th five year plan, Shanghai has the courage to innovate and overcome difficulties. With the main goal of improving the "four functions" and promoting the digital transformation of the city, and with the fundamental driving force of deepening the supply side structural reform and improving the quality and efficiency of opening to the outside world, Shanghai has accelerated the construction of an important focus for economic development and built a new development platform for Shanghai's future economy, It shows the new atmosphere and strong will of China to build a powerful socialist modern country.

As the nation's economic and financial center city, Shanghai has always been a landmark for leading the Chinese economy. In the first half of 2021, Shanghai's total economic volume increased by 12.7% year-on-year, while the total output value of Shanghai's strategic emerging industries increased by 19.6% year-on-year. These two data show the vigorous momentum of Shanghai's economic development at the beginning of the "14th Five-Year Plan" period. This paper uses the grey prediction model to predict and analyze the total GDP and growth rate of Shanghai in the next 7 years, analyzes the reasons according to its change trend, and finally gives some suggestions to promote the further development of Shanghai's economy.

2. Literature Review

In recent years, many domestic scholars have conducted various analyses and researches on my country's economic development. Manyi Lu [1] uses the grey relational analysis method to analyze the quality of economic development in the western region. The conclusion shows that the relationship between innovation and coordination in the western region is the closest, but the level of coordinated development in most cities is relatively low. Jing An [2] uses the grey relational analysis method to analyze the influencing factors of Foshan's financial development level. The conclusion shows that the biggest correlation with the efficiency of Foshan's financial service industry is the total per capita wages of employees, and Foshan municipal government should further expand Foshan's financial demand and improve the GDP growth rate. Dehuai Gui [3] uses the grey prediction model to predict and analyze the container throughput of Shanghai port from 2020 to 2025. The conclusion shows that the container throughput of Shanghai port has been showing a gradual growth trend, which is conducive to the further development of Shanghai port, but also poses a great challenge to Shanghai port. Yuntao Zhu [4] uses the

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grey prediction model to predict and analyze Shanghai's industrial energy consumption from 2015 to 2020. The conclusion shows that Shanghai's industrial energy consumption will continue to increase after 2015. Xueyan Xu [5] uses the grey prediction model to predict and analyze Shanghai's marine GDP from 2018 to 2022. The conclusion shows that Shanghai's marine economy will continue to grow, and the total marine output value will exceed 1 trillion yuan by 2021. Dandan Bai [6] uses the grey prediction model to fit and predict the relationship between economic structure and economic growth in Gansu Province. The conclusion shows that the total output value of Gansu Province will continue to increase from 2018 to 2020, and the ownership structure and social structure are the main forces driving the economic growth of Gansu Province. Hanzhi Li [7] uses the grey prediction model to predict and analyze the total GDP of Hebei Province from 2014 to 2019. The conclusion shows that the economic prospect of Hebei Province will be still considerable in the next five years. Ye Yan [8] uses the grey correlation analysis method to analyze the correlation between agricultural modernization and rural economic development in Jiangsu Province. The conclusion shows that the correlation between the total power of agricultural machinery and rural economic development is the strongest, followed by rural power consumption, effective irrigation area, etc.

To sum up, most of the current domestic researches apply grey relational analysis to analyze regional economic development and its influencing factors, or apply grey forecasting models to predict Shanghai Port's container throughput, Shanghai's industrial energy consumption, and Shanghai's marine economic development. There are few forecasts and analyses on the total GDP and GDP growth rate of Shanghai's economic development level.Therefore, this paper selects Shanghai as the research object, uses GM (1,1) grey prediction model to predict the GDP growth of Shanghai in the next few years, and finally puts forward relevant suggestions for the future economic development of Shanghai. This paper uses the change of Shanghai GDP to reflect the change trend of national GDP, and provides theoretical support for the country to further improve relevant economic policies and formulate development plans.

3. Data Selection

This paper selects the total GDP and growth data of Shanghai from 2010 to 2019, and establishes the GDP prediction model of Shanghai based on Grey Model GM (1,1). The data is taken from the 2020 Shanghai Statistical Yearbook.

Table 1: Total GDP and growth rate of Shanghai from 2010 to 2019

Year	Total GDP (RMB100mn)	GDP growth (%)
2010	17915.41	10.2
2011	20009.68	8.3
2012	21305.59	7.5
2013	23204.12	7.9
2014	25269.75	7.1
2015	26887.02	7.0
2016	29887.02	6.9
2017	32925.01	7.0
2018	36011.82	6.8
2019	38155.32	6.0

4. Theoretical Basis of Grey Prediction Model

4.1 Basic Principle of Grey Prediction Model

Grey prediction refers to the use of GM model to estimate and predict the development and change law of system behavior characteristics. At the same time, it can also estimate and calculate the time when the abnormal situation of behavior characteristics occurs. In essence, these works regard "random process" as "grey process" and "random variable" as "grey variable", and mainly take GM (1,1) in grey system theory Model.

4.2 Establishment Steps of Grey Prediction Model

4.2.1 Inspection and Processing of Data

Firstly, this paper forecasts the total GDP data of Shanghai. In order to ensure the feasibility of the

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modeling method, it is necessary to check the known data columns.We set reference data as $\mathcal{X}^{(0)}$ = ($\mathcal{X}^{(0)}(1)$, $\mathcal{X}^{(0)}(2)$,...,$\mathcal{X}^{(0)}(10)$)={17915.41, 20009.68, 21305.59, 23204.12, 25269.75, 26887.02, 29887.02, 32925.01, 36011.82, 38155.32}

Calculate the rank ratio of a sequence of numbers:

$$\lambda(k)=\frac{\mathcal{X}^{(0)}(k-1)}{\mathcal{X}^{(0)}(k)}, k=2, 3, \ldots, n \quad (1)$$

That is, $\lambda = \{0.895, 0.939, 0.918, 0.918, 0.940, 0.900, 0.908, 0.914, 0.944\}$, because the test values of grade ratio are within the standard range [0.834, 1.199], it means that this data is suitable for the construction of GM (1,1) model.

4.2.2 Establishment of GM (1,1) Model

Firstly, We accumulate the reference sequence $\mathcal{X}^{(0)}$ once to generate the sequence:

$$\mathcal{X}^{(1)}=(\mathcal{X}^{(1)}(1), \mathcal{X}^{(1)}(2), L, \mathcal{X}^{(1)}(n)) \quad (2)$$

Among them, $\mathcal{X}^{(1)}(k)=\sum_{i=1}^{k}\mathcal{X}^{(0)}(i)$ (k=1, 2, …, n)

That is, $\mathcal{X}^{(1)}$ ={17915.41, 37925.09, 59230.68, 82434.8, 107704.55, 134591.57, 164478.59, 197403.6, 233415.42, 271570.74}

Secondly,we find the mean sequence:

$$\mathcal{Z}^{(1)}=(\mathcal{Z}^{(1)}(2), \mathcal{Z}^{(1)}(3), \ldots, \mathcal{Z}^{(1)}(n)) \quad (3)$$

Among them, $\mathcal{Z}^{(1)}(k)=0.5\mathcal{X}^{(1)}(k)+0.5\mathcal{X}^{(1)}(k-1)$, (k=2, 3, …, n)

That is, $\mathcal{Z}^{(1)}$={27920.25, 48577.885, 70832.74, 95069.675, 121148.06, 149535.08, 180941.095, 215409.51, 252493.08}

So the grey differential equation is established as:

$$\mathcal{X}^{(0)}(k)+a\mathcal{Z}^{(1)}(k)=b, k=2, 3, \ldots, n \quad (4)$$

The whitening differential equation is:

$$\frac{dx^{(1)}}{dt}+ax^{(1)}(t)=b, k=2, 3, \ldots, n \quad (5)$$

Thirdly, We let $u=(a,b)^T, Y=(\mathcal{X}^{(0)}(2), \mathcal{X}^{(0)}(3), \ldots, \mathcal{X}^{(0)}(n))^T, B=\begin{bmatrix}-\mathcal{Z}^{(1)}(2) & 1\\ -\mathcal{Z}^{(1)}(3) & 1\\ \vdots & \vdots\\ -\mathcal{Z}^{(1)}(n) & 1\end{bmatrix}$, then, by the least square method, the $\hat{u}=(a,b)^T=(B^TB)^{-1}B^TY$ that makes $J(\hat{u})=(Y-B\hat{u})^T(Y-B\hat{u})$ reach the minimum value is obtained:

$$a=-0.0842, b=17313.8352 \quad (6)$$

Fourthly, by solving equation (5), we get:

$$\hat{x}^{(1)}(k+1)=(\mathcal{X}^{(0)}(1)-\frac{a}{b})e^{-ak}+\frac{a}{b}, k=0, 1, \ldots, n-1, \ldots \quad (7)$$

That is, $\hat{x}^{(1)}(k+1)=223542.9e^{0.08k}+205627.5$

Finally, the predicted value of the original sequence is obtained through progressive subtraction calculation:

$$\hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k), k=1, 2, \ldots, n-1, \ldots \quad (8)$$

That is, $\hat{x}^{(0)}$={17915.410, 19637.363, 21362.372, 23238.911, 25280.291, 27500.992, 29916.767, 32544.751, 35403.586, 38513.550}

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4.2.3 Test of GM (1,1) Model

In this paper, the relative error test method is used, and we let the relative error be $\mathcal{E}(k)$:

$$\xi(k)=\frac{\mathcal{X}^{(0)}(k)-\hat{x}^{(0)}(k)}{\mathcal{X}^{(0)}(k)}, k=1, 2, \ldots, n$$
$$\hat{x}^{(0)}(1)=\mathcal{X}^{(0)}(1) \quad (9)$$

If $\xi(k)<0.2$, it can be considered to meet the general requirements; if $\xi(k)<0.2$, it is considered to meet the higher requirements.

The model inspection is shown in Table 2 below:

Table 2: Test results of GDP total forecast model

Serial number	Original value	Predicted value	Residual error	Relative error
1	17915.410	17915.410	0.000	0.000%
2	20009.680	19637.363	372.317	1.861%
3	21305.590	21362.372	-56.782	0.267%
4	23204.120	23238.911	-34.791	0.150%
5	25269.750	25280.291	-10.541	0.042%
6	26887.020	27500.992	-613.972	2.284%
7	29887.020	29916.767	-29.747	0.100%
8	32925.010	32544.751	380.259	1.155%
9	36011.820	35403.586	608.234	1.689%
10	38155.320	38513.550	-358.230	0.939%

The maximum relative error of the model is 0.023 < 0.1, which means that the prediction accuracy of the model meets high requirements.

Similarly, we establish a grey prediction model of GDP growth in Shanghai. Firstly, rank ratio test is conducted on the GDP growth data of Shanghai from 2010 to 2019. The results show that the original data dose not pass the rank ratio test, and translation conversion is required, that is, the translation conversion value of 1.00 is added to the original value. At this time, the original data becomes (1.102, 1.083, 1.075, 1.079, 1.071, 1.070, 1.069, 1.070, 1.068, 1.060). As a result, the rank ratio test values for the translation transformed data are all within the standard range interval [0.834, 1.199], which means that the present data is suitable for GM (1,1) model building. Secondly, It is calculated that $a = 0.0021$ and $b = 1.0840$, then the prediction model for the growth rate of GDP in Shanghai is $\hat{x}^{(1)}(k+1)=-515.1e^{0.0021k}+516.2$, and after the subtraction calculation, the original sequence prediction value can be obtained. Finally, the relative error test is applied to test the accuracy of the model, and the maximum value of relative error of the model is 0.047 < 0.1, which indicates that the model prediction accuracy reaches a high requirement.

5. GDP Forecast and Analysis of Shanghai

According to the grey prediction model of Shanghai's GDP (7), the grey prediction values of Shanghai's total GDP and GDP growth in the next 7 years can be calculated, as shown in Table 3.

Table 3: GDP Forecast of Shanghai from 2020 to 2026

Year	2020	2021	2022	2023	2024	2025	2026
Total GDP (RMB100mn)	41897	45577	49581	53936	58674	63828	69435
GDP growth(%)	0.061	0.058	0.056	0.054	0.052	0.050	0.048

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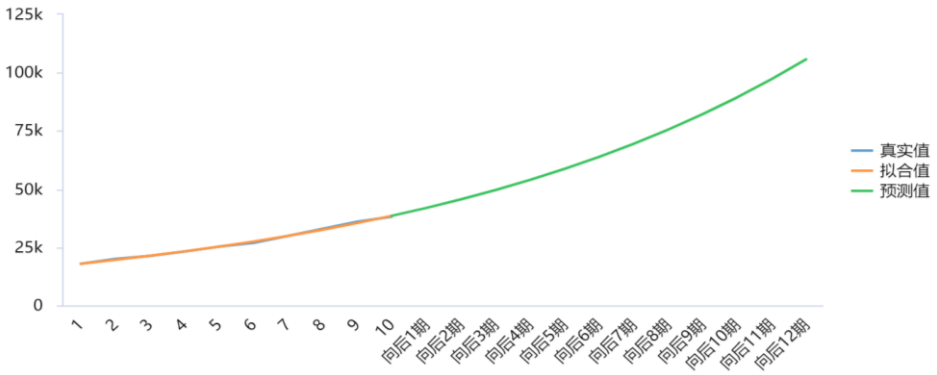

Figure 1: Changes in total GDP during 2010-2026 in Shanghai

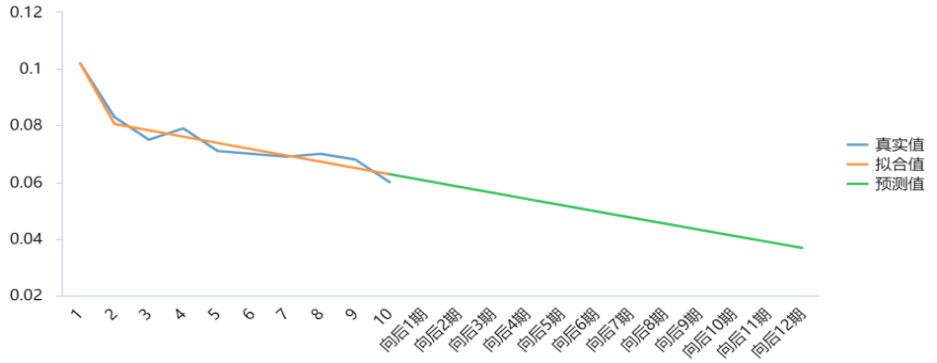

Figure 2: Changes in GDP growth rate during 2010-2026 in Shanghai

Through the above analysis, this paper can conclude that from 2010 to 2026, the total GDP of Shanghai will always show a gradual growth trend, but the GDP growth rate will generally show a downward trend year by year. In 2020, Shanghai's GDP will increase by 55.83% over 2015 and 6.1% in 2020. By 2026, Shanghai's GDP will increase by 65.73% over 2020 and 4.8% in 2026. Overall, the total GDP of Shanghai will continue to grow, which shows the vigorous development situation and strength of Shanghai now and in the future to a great extent, but at the same time, the slowdown of growth rate also poses a great challenge to Shanghai.

6. Thoughts on the Construction and Development of Shanghai

Shanghai city has seen a continuous increase in total GDP at a rate higher than 5% each year over the past decade, but the problem of imbalances in its economic structure has also become more prominent. The Shanghai municipal government has made gross and local adjustments to the industrial structure in recent years, and the tertiary industry output value has increased year by year in the proportion of the total output value of Shanghai, and the rationality of the overall economic structure has been continuously enhanced, at the same time, the adjustment of the industrial structure has also caused a gradual slowing of GDP growth. The Shanghai municipal government should achieve a slowing of GDP growth on the basis of a continuous increase in the total volume over the next five years, but it will still have great difficulties in achieving this goal because of the continuing weakening of traditional dividend such as the demographic dividend and dividend of the land of the Shanghai Municipality.

At present, the increasing transaction cost of Shanghai has resulted in a large amount of investment outflows, and the problem of industry hollowing has become increasingly severe, and the economic growth model pulled by investment and elements has largely lost its role. Faced with the dilemma of declining GDP growth, the Shanghai municipal government must shift its focus on development to be innovation driven, from quantity to quality, and replace the thinking mode of increasing the total amount of labor element input with the thinking mode of increasing labor productivity.

The development of strategic new industries in Shanghai, as well as the Internet industry, has squeezed out the space for the development of the traditional heavy industry, the property industry, and the processing labor-intensive industry, and new technologies, new industries, and new models constitute a new strategic direction for the development of Shanghai. But these new industrial forms are still in the

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nurturing stage, and their lead-in role is limited, so that the huge capacity lagging industries cannot be eliminated in a short time, and it is difficult to realize the resurgence of GDP growth. Based on this, over the next five years, the Shanghai municipal government should continue to advance open-ended and hub based urban infrastructure construction to accelerate coordinated development with the Yangtze River Delta, the Yangtze River economic belt, and use "" go "" and "" introduce ""Constitute a macro cycle of resource flows and draw on empirical means of industrial structure adjustment along river as well as inland cities to reflect deeply on the inadequacy of the optimization and upgrade of Shanghai's internal industry structure, to help the Internet + and strategic new industries quickly preempt Shanghai's market share, and to attenuate the magnitude and speed of GDP growth decline.

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