Prediction and Analysis of Regional Economy Based on Grey Prediction Model GM (1,1)

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Abstract. In recent years, China's economy has developed rapidly and made many achievements. However, the economic development of China's various regions is uneven, and the gap in per capita GDP is large. Therefore, each region needs to formulate different development plans according to its own economic development needs. In order to better understand and predict the economic development of different regions in China, this paper collects the Gross Domestic Product (GDP) data of Beijing, Chongqing and Heilongjiang Province from 2002 to 2021, and uses the gray prediction model GM (1,1) to predict it. The relative error of Chongqing, Heilongjiang and Peking is 9.714%, 8.399% and 3.412% respectively, it fits well with result.

Keywords: Economy, GDP, GM (1,1), Economy Balance, Prediction.

1 Introduction

Nowadays, China is in a state of rapid development, and the economy of many cities is also in the process of rapid development. People's lives are getting better day by day. However, there are still problems such as unbalanced development in some regions. And some regions are in a state of economic decline. In order to further study the difference in the development speed of different regions, we selected three different provinces and regions in China, namely Beijing, Chongqing and Heilongjiang. In addition, we chose the grey prediction method to analyze and forecast the regional GDP of these three regions in the past 20 years. This method was proposed by Professor Julong Deng from China in 1982 [8]. This method requires a small sample size, is convenient for calculation, and the established model has a high accuracy, which can better reflect the status of the data, and the prediction results are accurate. It is more consistent with the data volume we selected. So we choose GM (1,1) method to apply in our experiment. The research purpose of this paper is to analyze and forecast the economic development problems in several regions of the country, so as to deal with and analyze the problems caused by the unbalanced development.

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2 Related Works

Before we conduct experiments, we first need to determine which method is most suitable for us. We find that the grey prediction model GM (1,1) is ideal for this study. This method was proposed by Professor Julong Deng in 1982 [8]. We found the gross regional development value of three regions in the past 20 years from China National Data Network. However, the amount of data is still small, and there are large residuals and average relative errors when selecting least squares fitting LS and other methods. But when using the grey prediction model GM (1,1), we can find that the average relative error of this method is smaller than the least squares fitting LS, and the accuracy is higher, and the prediction result is more accurate. At present, the model has been widely used in the prediction and evaluation of various data, such as rainfall analysis [7], traffic condition analysis and prediction [5-6], electricity price prediction [2], population prediction [1], Human Health Data [15], etc.

So we chose this way to evaluate and predict the development of Beijing, Heilongjiang, Chongqing and the regions they represent. For example, the impact of brain drain on the local economy in Heilongjiang Province [12] and the development differences between different regions. For the reason why we choose these three region to study, as the capital of China, Peking has the fastest and most representative economic development. Heilongjiang, as the representative of Northeast China, is also an important window for opening the China Mongolia Russia Economic Corridor, the Middle East Railway, the Kazakhstan Europe Train and the northward development. However, in recent years, the population loss, economic decline and other problems are serious, which also has certain analytical value [14]. Chongqing, as an important pillar of economic development and opening up in the southwest, has a great reference.

The grey prediction model GM (1,1) was proposed by Professor Julong Deng from China in 1982 [8]. This method has the advantages of small sample size, convenient calculation, high accuracy of the model, good reflection of data conditions, accurate prediction results, etc. In recent years, grey prediction model GM (1,1) has been widely used in regional economic prediction or price prediction. Kai Li and others selected the annual GDP data of Guangdong Province, made a quantitative analysis using GM (1,1), and made a short-term forecast [4]. Zhao Yue et al. used the grey prediction model GM (1,1) to predict the oil and gas price cost [3].

3 Method

Establish time series matrix T.

$$T^{(0)} = （T^{(0)}(1), T^{(0)}(2), \dots, T^{(0)}(n)）\tag{1}$$

Next, calculate the level ratio $L(k)$.

$$L(k) = \frac{T^{(0)}(k-1)}{T^{(0)}(k)}, (k = 1,2, \dots, n)\tag{2}$$

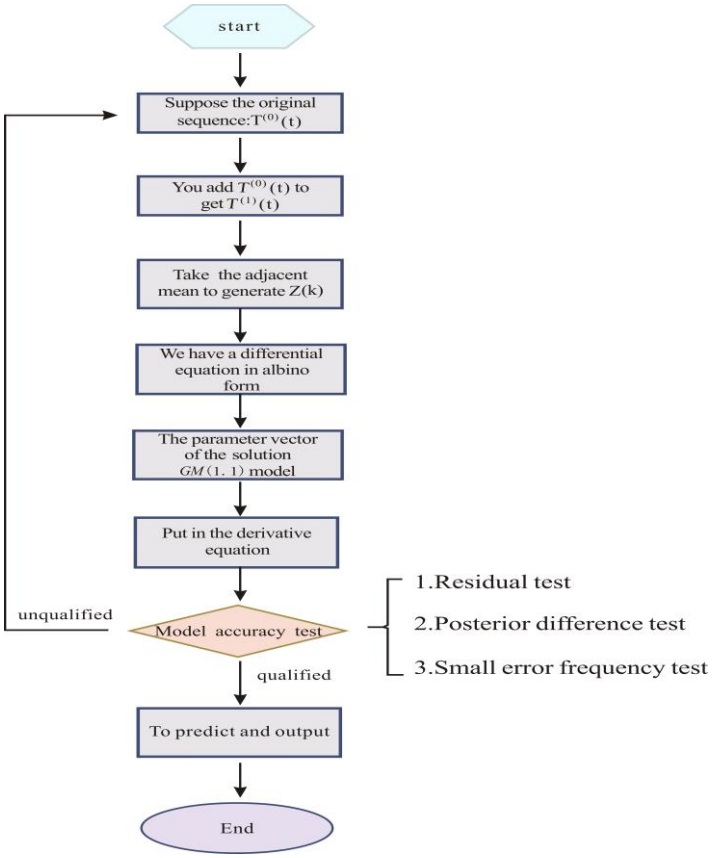

Fig. 1. GM (1,1) Flow Chart

(The Figure 1 is drawn by the author with CorelDRAW)

Then calculate the interval $\left(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}}\right)$, if all level ratios are in the range $\left(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}}\right)$, it means that the data is suitable for model construction. If the level ratio test is not passed, the sequence shall be " translation transform" so that the translated sequence can meet the step ratio test.

In the process of construct the model, the data is accumulated to form a generating column.

$$T^{(1)}(k) = \sum_{p=1}^{k} T^{(0)}(p), (k = 1,2, \dots, n) \tag{3}$$

Let the newly generated adjacent mean sequence be $Z(k)$, then:

$$Z(k) = (T'(k) + T'(k+1))/2\,, (k = 1,2, \dots, n) \tag{4}$$

After we get the$T^{(1)}(p)$, Construct data matrix B and data vector Y.

$$B = \begin{pmatrix} -\frac{T^{(1)}(1)-T^{(1)}(2)}{2} & 1 \\ -\frac{T^{(1)}(2)-T^{(1)}(3)}{2} & 1 \\ -\frac{T^{(1)}(3)-T^{(1)}(4)}{2} & 1 \\ -\frac{T^{(1)}(4)-T^{(1)}(5)}{2} & 1 \\ \vdots & \vdots \\ -\frac{T^{(1)}(n-1)-T^{(1)}(n)}{2} & 1 \end{pmatrix} \tag{5}$$

$$Y = \begin{pmatrix} T^{(0)}(2) \\ T^{(0)}(3) \\ T^{(0)}(4) \\ T^{(0)}(5) \\ \vdots \\ T^{(0)}(n) \end{pmatrix} \tag{6}$$

Next, we need to calculate the development coefficient a and grey consumption b.

$$\begin{bmatrix} a \\ b \end{bmatrix} = (BB^T)^{-1}B^TY \tag{7}$$

Construct the whitening equation of the model $T^{(1)}(k) + aZ(k) = b$.

$$\frac{dT^{(1)}}{dt} + aT^{(1)} = b \tag{8}$$

Use a and b, we can establish a response function.

$$T^{(1)}(k+1) = \left(T^{(0)}(1) - \frac{a}{b}\right)e^{-ak} + \frac{a}{b}, (k = 1,2,\dots,n) \tag{9}$$

After constructing the model, we need to conduct an accuracy test, and use a and b to calculate the posterior error ratio N, if $N < 0.35$, indicates that the model has high accuracy. If $0.35 < N < 0.65$, this indicates that the model is accurate. If $N > 0.65$, it indicates that the accuracy of the model is not high.

Then calculate the residual error and relative error of the model to confirm the accuracy of the model fitting.

4 Experimental Analysis and Results

The regional GDP of Beijing, Chongqing and Heilongjiang for 20 years from 2002 to 2021 was obtained through China National Data Network. The data of three regions is shown as Table 1. (The Table 1 is made by author with Word 2021)

Table 1. Regional GDP(Billion)

YEAR	PEKING	CHONGQING	HEILONGJIANG
2002	452.57	227.98	324.27
2003	526.72	261.56	360.97
2004	625.25	305.95	413.47
2005	714.98	344.84	475.64

2006	838.7	390.03	532.98
2007	1042.55	477.07	612.63
2008	1181.31	589.95	713.42
2009	1290.09	665.12	721.89
2010	1496.4	806.53	830.83
2011	1718.88	1016.12	993.5
2012	1902.47	1159.54	1101.58
2013	2113.46	1302.76	1184.91
2014	2292.6	1462.38	1217.08
2015	2477.91	1604.05	1169
2016	2704.12	1802.3	1189.5
2017	2988.3	2006.63	1231.3
2018	3310.6	2158.88	1284.65
2019	3544.51	2360.58	1354.44
2020	3594.32	2504.14	1363.34
2021	4026.96	2789.4	1487.92

The data of these three regions are searched by the author from China Data Network.

When calculating the level ratio $L(k)$, we found that the stage ratios were not all in the interval $(0.909, 1.1)$, so we carried out translation transformation to make the sequence after translation transformation meet the stage ratio test.

After translation and transformation of three groups of data, we found that the grade ratios after translation and transformation are all in the interval $(0.909, 1.1)$, indicating that the series after translation transformation is suitable for building a gray prediction model.

After calculation, a and b, and the posterior error ratio N are obtained in Table 2, Table 3 and Table 4. (The Table2, Table 3 and Table 4 are made by the author with Excel 2021)

Table 2. These Value of Chongqing

Development Coefficient $\boldsymbol{a}$	Grey Consumption $\boldsymbol{b}$	Posterior Error Ratio N
-0.036	2707.425	0.007

Table 3. These Value of Heilongjiang

Development Coefficient a	Grey Consumption b	Posterior Error Ratio N
-0.025	1867.286	0.055

Table 4. These Value of Peking

Development Coefficient a	Grey Consumption b	Posterior Error Ratio N
-0.033	4216.836	0.003

It can be seen from the above table that the posterior error ratio $N < 0.35$, and the model accuracy is high. The Model Fitting Prediction Diagrams of these there region are as followed, and the unit of the Y-axis is hundred million China Yuan. The original data and prediction results shown as figure 2.

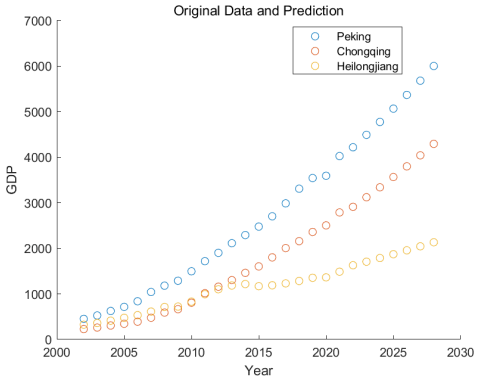

Fig. 2. The Original Data and Prediction Results

(The Figure 2 is drawn by the author with MATLAB)

The relative error of Chongqing, Heilongjiang and Peking is 9.714%, 8.399% and 3.412% respectively, it fits well with result. (The Table 5 is made by the author with Excel 2021)

Table 5. Forecast value of regional GDP in the next seven years

Years	Chongqing	Heilongjiang	Peking
2022	2912.965	1628.854	4219.949
2023	3123.044	1707.888	4493.632
2024	3340.861	1788.927	4776.397
2025	3566.701	1872.021	5068.547
2026	3800.861	1957.221	5370.391
2027	4043.647	2044.582	5682.253
2028	4295.376	2134.158	6004.464

According to the experimental results of the three region, they all show an upward trend.

5 Conclusion

Through our experimental results, we can find that in the three regions, the relative error of Beijing is the smallest, and the prediction effect is the best, and the regional GDP of Beijing in the next seven years will also develop much faster than the other two regions. The prediction effect of the relative error in Heilongjiang is also the worst. By analyzing the data, we could know clearly about the level of economic development of different region. In the next seven years, the GDP of Heilongjiang is also slower than that of the other two regions. The reason may be that the brain drain problem in North-east China is serious and the economy is sluggish.

In the future work, we can increase the scale of data sets. In North China, we can combine the data of Beijing, Tianjin and Hebei, in Northeast China, we can increase the data of Jilin and Liaoning, and in Southwest China, we can combine the data of Yunnan, Guizhou and Chongqing.

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