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Application of Grey Model in GNP Prediction and Analysis of Sichuan Province

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Abstract: *This paper establishes the 30-dimensional long sequence of Sichuan Province's Gross Domestic Product (GDP) from 2010-2019 and corrects the normal gray model of 6-dimensional short sequence by improving the initial value solution condition method of differential equation. After testing the paper model, the results show that the 6-dimensional short sequence gray prediction model modified by improving the initial value solution condition method of differential equation predicts good Sichuan GNP from 2020-2021.*

Keywords: *GNP product; Gray theory; GM (1,1) model; Residue correction*

1. Introduction

The prediction of gross national product is an important part of economic accounting, which can help the government to judge whether the economy is shrinking or expanding. It can provide an important basis for China's macroeconomic management departments to understand the operation status of the economy, formulate economic development strategies, medium-term and long-term plans and various macroeconomic policies.

Since the reform and opening up, Sichuan province has made rapid economic development by leaps and bounds. By 2019, the province's GDP has reached 4,661.582 billion yuan. In order to maintain the long-term and rapid development of the national economy, it is necessary to study the development status of the national economy, find out the objective laws of the economic development, make scientific predictions on the economic development and make the corresponding decisions in time.

In recent years, many studies have used various models to predict GNP and adopted a series of methods to improve the prediction accuracy. Yang Zhikai et al [1] The ARIMA model was used to predict and improve the GDP in Guilin, with a relative error of 2.5%; Chen Xianxiong [2] GM (1,1) model was used to predict the total health cost in Guangdong Province, and the relative error reached 3% [3] Empirical prediction and analysis using optimized gray model to Xinjiang GDP, and the relative error reached 5.27%.

Gray prediction is a very effective method in economic prediction. Its main feature is that the original data needed to establish the prediction model is small, easy to collect, simple method and high accuracy [4]. This paper establishes a grey model for the GDP of Sichuan from 2010-2019 (see Table 1) and further improves the model for the GDP of 2021 from 2020-2021.

2. Gray prediction model

2.1. Overview of the grey theory [5, 6]

Grey system theory is a strong penetration, wide application of emerging transverse discipline, it is "unknown" "small sample" partial information "," poor information "uncertainty system as the research object, mainly through the" part " known information generation, development, extract valuable information, realize the correct understanding of the system operation rules and effective control.

ISSN 2616-5902 Vol. 4, Issue 5: 29-34, DOI: 10.25236/AJBM.2022.040507

Table 1: Gross national product of Sichuan Province from 2010-2019

a particular year	gross national products	primary industry	secondary industry	tertiary industry	industry	construction business
2010	17224.78	2384.89	8283.21	6556.68	7032.89	1317.42
2011	21050.87	2854.62	10014.39	8181.86	8457.36	1642.71
2012	23922.41	3142.55	11231.06	9548.80	9408.52	1919.92
2013	26518.02	3257.42	12418.94	10841.66	10308.99	2217.67
2014	28891.33	3524.74	13082.69	12283.90	10703.84	2494.79
2015	30342.01	3660.96	13192.45	13488.60	10735.01	2555.50
2016	33138.48	3900.60	13450.13	15787.75	10790.93	2757.77
2017	37905.14	4262.51	14569.17	19073.46	11437.80	3235.85
2018	42902.10	4427.43	16056.94	22417.73	12360.07	3809.77
2019	46615.82	4807.24	17365.33	24443.25	13365.66	4123.48

Note: Data are from Sichuan Statistical Yearbook in 2020

Trend chart of Sichuan Province GNP data from 2010-2019 and fit it, as shown in the Figure 1:

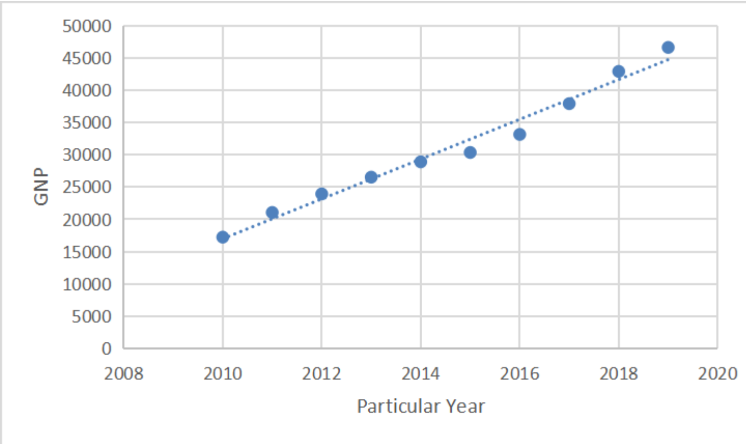

Figure 1: The GDP Trend and Index Fit Map of Sichuan Province in 2010-2019

As can be seen from Figure 1, the GDP trend map of 2010-2019 in Sichuan Province was fitted with a linear function. The fitting effect is intuitively good, and R can be obtained by using the added trend of the figures in MATLAB The value is as high as 0.9786, with a very good fitting effect, that is, the GDP of Sichuan Province increased almost linearly in 2010-2019. Considering the gray nature of the GDP system, the GM (1,1) series gray model can be selected to explore and understand the original time series, and then predict and analyze the GDP of Sichuan Province.

2.2. GM (1,1) model

The GM (1,1) model can weaken the randomness and volatility of the original sequence X (0), provide more effective information for the gray model, and the original sequence is exponential [5]. Let the original data sequence is: $X^{(0)}=[x^{(0)}(1),x^{(0)}(2),......,x^{(0)}(n)]$, in order to weaken the randomness and volatility of the original sequence, to provide more effective information for the gray model, before establishing the gray prediction model, the original data, preprocessing method mainly has: data logarithm, data open n times, data smoothing and using sequence operators to weaken or strengthen the original data column [9]. According to the requirements of GM (1,1) modeling, most of the new sequence data level ratio (i. e., the previous data divided by the next data) must fall between intervals so that the next step can be taken.After preprocessing of the raw data, the required new data column X1 will be met $(e^{-\frac{2}{n+1}},e^{\frac{2}{n+1}})$ $^{(0)}$ One cumulative generation process, namely 1-AGO (Accumulating Generation Operator), to strengthen its regularity and remember the generation sequence as:

$$x^{(1)}(k)=\sum_{i=1}^{k}x1^{(0)}(i)=x^{(1)}(k-1)+x1^{(0)}(k) \qquad (k=1,2,3,\ldots,n) \qquad (1)$$

The GM (1,1) model is a dynamic model consisting of a first-order differential equation containing

ISSN 2616-5902 Vol. 4, Issue 5: 29-34, DOI: 10.25236/AJBM.2022.040507

univariates:

$$x1^{(0)}(k)+az^{(1)}(k)=b \qquad （k=1,2,3,...,n） \tag{2}$$

$z^{(1)}k$ $x^{(1)}k$ Among these are the immediately adjacent to the mean generating sequence, i. e $z^{(1)}(k)=0.5[x^{(1)}(k)-x^{(1)}(k-1)]$

The whitening equation (also called the shadow equation) of equation (2) is:

$$\frac{dx^{(1)}}{dt}+ax^{(1)}=b \tag{3}$$

Where a is called the developmental gray number, b is called the endogenous control gray number, and the effective interval of a is (-2,2). Apply least squares to find the solutions available:

$$\hat{a}=(a,b)^T=(B^TB)^{-1}\cdot B^T\cdot Y_n \tag{4}$$

Among

$$B=\begin{pmatrix} -1/2(x^{(1)}(1)+x^{(1)}(2)),1 \\ -1/2(x^{(1)}(2)+x^{(1)}(3)),1 \\ \cdots \qquad \cdots \\ -1/2(x^{(1)}(n-1)+x^{(1)}(n)),1 \end{pmatrix} \tag{5}$$

$$Y_n=[x1^{(0)}(2),x1^{(0)}(3),...,x1^{(0)}(n)]^T \tag{6}$$

The solution of the equation, the time response function is:

$$\begin{cases} \hat{x}^{(1)}(k+1)=(x1^{(0)}(1)-\frac{b}{a})\cdot e^{-ak}+\frac{b}{a} \\ \hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k) \end{cases} \tag{7}$$

To ensure that the built gray model has high prediction accuracy and credibility, the residual test and posterior difference test are required.

a. Residual test

$x^{(0)}(k)$ $\hat{x}^{(0)}(k)$ $e^{(0)}(k)$ The residual sequence, relative error sequence and average relative error are found, respectively: Δ_k $\overline{\Delta}$

$$\overline{\Delta}=\frac{1}{n}\sum_{k=1}^{n}\left|\frac{x^{(0)}(k)-\hat{x}^{(0)}(k)}{x^{(0)}(k)}\right|\times 100\% \tag{8}$$

b. Posterior difference test

The raw data mean values and the residual mean values are obtained: $\bar{x}$ $\bar{e}$

$$\bar{e}=\frac{1}{n-1}\sum_{k=2}^{n}e^{(0)}k \tag{9}$$

s_1^2 s_2^2 The ratio C of the raw data variance, the residual variance and the mean variance of the variance and the small error probability P are obtained:

ISSN 2616-5902 Vol. 4, Issue 5: 29-34, DOI: 10.25236/AJBM.2022.040507

$$C=\{\frac{1}{n-1}\sum_{k=2}^{n}[e^{(0)}(k)-\bar{e}]^2\}^{1/2}/\{\frac{1}{n}\sum[x^{(0)}(k)-\bar{x}]^2\}^{1/2}$$
$$P=p(\left|e^{(0)}(k)-\bar{e}\right|<0.6745s_1) \quad (10)$$

$e^{(0)}k$、Δ_k、C According to the grey system theory, the smaller the usual value, the larger the P-value, the better the model accuracy. When the development coefficient occurs, the built GM (1,1) model can be used for medium-and long-term prediction $a\in[-0.3,2)$ [7, 8].

3. Prediction and analysis of the GDP in Sichuan Province

3.1. A 10-dimensional gray GM (1,1) model for the data sequence from 2010-2019

According to the GNP data sequence of Sichuan Province from 2010-2019 shown in Table 1, all levels of the raw data sequence can be calculated for the raw data sequence, as shown in Table 2: $X^{(0)}=[x^{(0)}(1),x^{(0)}(2),......,x^{(0)}(n)]$

Table 2: 10 level ratios of the data

k	1	2	3	4	5	6	7	8	9	10
λ	0.819172	0.850803	0.885909	0.933041	0.952035	0.928954	0.914917	0.908675	0.885979	0.835856

$(e^{-\frac{2}{n+1}},e^{\frac{2}{n+1}})=(0.9375,1.0666)$ It is seen from the above table that almost all level ratios are not within the interval, so this data sequence cannot be directly used to model. In order to ensure the feasibility of modeling, the original data sequence must be preprocessed. In this paper, the original data sequence is opened four times to obtain the new data sequence. The vast majority of the processed new data sequence falls in the above interval, so it can be used to establish a gray prediction model. $X1^{(0)}$

$X1^{(0)}$ The gray GM (1,1) model is based from the grey prediction model principle in 2.2:

$$\hat{x}^{(1)}(k+1)=1417.049e^{-0.0287k}-232.439 \quad (11)$$

$$\hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k) \quad (12)$$

$\hat{X}^{(0)}(k+1)$ $(\hat{X}(k+1))$^4 Here is the predicted value, because the original data sequence was preprocessed 4 times, so, is the actual predicted value. According to the above gray GM (1,1) model, the gross national product of Sichuan Province in 2020 will be 1,054.442 billion yuan. See Table 3 for details.

Table 3: Comparison between actual and predicted value of Sichuan GDP from 2010 to 2019 (RMB 100 million yuan)

a particular year	actual value	predicted value	residual	fractional error%
2010	17224.78	13144.82615	4079.953845	23.68653675
2011	21050.87	14743.62169	6307.248306	29.96193652
2012	23922.41	16536.87756	7385.532441	30.87286122
2013	26518.02	18548.24582	7969.774183	30.05418272
2014	28891.33	20804.25532	8087.074684	27.99135479
2015	30342.01	23334.66159	7007.348408	23.09454254
2016	33138.48	26172.83932	6965.640677	21.01979535
2017	37905.14	29356.22252	8548.917476	22.55345179
2018	42902.1	32926.79828	9975.301717	23.25131338
2019	46615.82	36931.66055	9684.15945	20.77440545
2020	48598.76	39589.65655	9009.10345	18.53772287
2021	53850.79	41564.65471	12286.1353	22.81514401

It can be seen from Table 3 that the maximum relative error of the predicted value from the actual value is 30.87%, minimum error of 18.53% and average error of 24.55%.According to the standard of gray prediction model residual test, if the average relative error of the model is 1% or less, the accuracy level of the model is level 1, if it is more than 1% and less than 5%, and if it is greater than 5% and less

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than 20%[9]It can be seen that the accuracy of the model does not reach level 4, and its prediction effect is not good, so the model must be corrected.

3.2. Correction to the 6-dimensional normal GM (1,1) model

The traditional gray GM (1,1) model is established as the original data column with Sichuan Province data from 2014-2019, whose prediction accuracy is still level 3 and does not reach the expected prediction accuracy, so it is also necessary to be corrected. This paper adopts the initial value condition method of solving the differential equation to correct the 6-dimensional short gray 1 GM (1,1) model [11].

Consider consider the initial value of the GM gray (1,1) model, let the correction formula is

$$x'1^{(0)}(1) = x1^{(0)}(1) + \sigma \tag{13}$$

σ The correction item is included in the formula. The value of the correction term is determined by the error between the original sequence and the new prediction value in the least squares sense, and the resulting value is-1.56897, so the corrected prediction model isσσ

$$\hat{\hat{x}}^{(0)}(k+1) = 321.54e^{0.0197k} \tag{14}$$

$\hat{\hat{x}}^{(0)}(k+1)$^4 For the actual predicted value. The model predicts the GNP of Sichuan Province in 2020

4992.532.1 billion yuan, 5163.5569.87 billion yuan in 2021, and 5587.465 billion yuan in 2022.See Table 4 for details

Table 4: Comparison between Actual and Prediction tive of Sichuan GDP from 2010 to 2019 [Improvement]

a particular year	actual value	predicted value	residual	fractional error%
2010	17224.78	17331.25557	106.4756	0.618153
2011	21050.87	20854.56479	196.3052	0.932528
2012	23922.41	24568.56215	646.1521	2.701033
2013	26518.02	26324.23565	193.7844	0.730765
2014	28891.33	29851.25649	959.9265	3.322542
2015	30342.01	31512.25618	1170.246	3.856851
2016	33138.48	32221.56997	916.91	2.766904
2017	37905.14	38875.23698	970.097	2.559276
2018	42902.1	41235.25699	1666.843	3.885225
2019	46615.82	45987.68256	628.1374	1.347477
2020	48598.76	49925.32156	1326.562	2.72962
2021	53850.79	51635.56987	2215.22	4.113626

We can see from Table 4 that the relative error of the corrected model is smaller than that of the original model, and the average error is

2.4636% is much smaller than the average relative error of the original model, and the prediction accuracy basically achieved satisfactory results.

4. Model evaluation

When preprocessing the original data sequence, different preprocessing methods are adopted, and the accuracy of the established prediction model is different. In this paper, we only use the four-time method to preprocessing the original data sequence, and the results are single, lacking comparability in this respect. Although only one method is used to preprocess the original data, the established prediction model has high accuracy, and the predicted GDP of Sichuan Province is relatively in line with the actual growth trend. The prediction model has certain practical value, objectively predicts the GDP of Sichuan Province from 2019-2022, and provides a more reliable basis for government departments to formulate corresponding economic policies.

ISSN 2616-5902 Vol. 4, Issue 5: 29-34, DOI: 10.25236/AJBM.2022.040507

5. Conclusion and Discussion

(1) In the GNP prediction, the GNP of Sichuan Province has incomplete and uncertain nature, consistent with the characteristics of gray variables, and the gray prediction method has the advantages of less original data, simple calculation process and stable prediction results. Therefore, this paper puts forward the gray GNP prediction model.

(2) From the modeling prediction results of this paper, it can be seen that the error of the uncorrected ordinary 30-dimensional long sequence gray GM (1,1) model is greater than the error of the corrected normal 6-dimensional short sequence gray GM (1,1) model

(3) In the established prediction model, the modified 6-dimensional GM (1,1) prediction model of the improved differential equation is the most similar to the actual value, and the ratio of mean variance $C = 0.01745 < 0.35$, small probability error $p = 1$, and development coefficient $a = 0.23549584$ (0.3,2). The model accuracy is good, which can be used to predict the GDP of Sichuan Province from 2010 to 2021.

(4) The GDP of Sichuan Province is in the growth stage. Through the gray model of Sichuan Province GDP forecast, it is learned that the GDP of Sichuan Province will continue to grow in the future, and the government departments should adopt loose policies to it to stimulate its development.

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