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Research on Regional Economic Development Difference Forecast Based on BP Neural Network

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Abstract:

The problem of unbalanced economic development in the east and west of China and the big difference in regional economic development is becoming more and more prominent. As a classical algorithm in artificial intelligence, BP neural network has great advantages in mining the intrinsic relation of sequence data and trend prediction. This article is based on the GDP and GDP per capita statistical data of 31 national provinces from 2000 to 2017 , utilizing the variation coefficient method as the measure index of the regional development difference, and then using the BP neural network model, to establish the forecast model of regional economic development differences, analyze and forecast differences in regional economic development in China in the future, the change rule of the forecast results show that: the regional economic development difference of China's GDP and per capita GDP will increase slightly in the next five years , and the differences changing rate of GDP is larger than per capita GDP , but both gradually stabilized.

Keywords*: BP neural network, Regional economy, Developmental differential prediction.*

I. INTRODUCTION

Since the reform and opening up, our regional economic policy has shifted from emphasis on fairness to emphasis on efficiency. Considering the good foundation and high investment returns in eastern coastal areas, a regional economic policy tilted towards the east is implemented, which accelerates the all-round upsurge of the national economy and formation of new economic growth sources. However, accompanying regional difference is increasingly prominent, which is mainly manifested in the unbalanced economic development in the east, central and western regions. The regional imbalanced economic development has become a significant issue that hinders the sustained, rapid and healthy development of domestic economy.

Regional economic difference has always been one core issue in regional economics research. The research on China's regional economic differences by domestic and foreign scholars mainly focuses on the measurement and evaluation of regional economic differences, the convergence and divergence tests of

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regional economic changes, and the mechanism of regional economic growth differences [1-4]. With the deepening of domestic economic reform and the continuous changes in economic development, there is increasingly urgent need for short-term forecast of regional economic development differences. In response to this problem, some scholars use time series models for modeling and forecast analysis. Using the autoregressive (AR) model, Zheng Fei [5] proceeded from the comprehensive regional economic differences, studied forecast method for regional economic differences, and forecasted the comprehensive regional economic differences in China. Through the statistical measurement and rationality test of the current regional economic differences in 14 provincial cities in Liaoning Province during 1997-2008, Chen Xiaoting [6] put forward a specific method to narrow the economic difference. Based on seven hypothetical schemes, Zhang Shengfu [7] forecasted, analyzed and discussed the change trend in domestic regional economic differences and its policy implications. Wan Daoxia [8] used a variety of measurement methods to display the economic differences among various regions in China and their change characteristics, and forecasted the future trends of domestic regional economic differences through the R/S fractal theory.

The above research progress reveals that the research methods of regional economic differences are mostly based on linear forecast models. However, the uncertainty and high noise characteristics of regional economic development make accurate forecast difficult, and the differences in economic development involve a multi-level, multi-factor complex system, so the traditional linear forecast model has certain limitations [9, 10], making it difficult to effectively forecast the regional economic development. In recent years, nonlinear models, especially artificial intelligence algorithms, have gradually replaced the traditional time series models in financial forecast, and their ability to tap into the nonlinear relationships between variables can effectively improve the accuracy in economic development forecasts. At present, nonlinear forecast models mainly include artificial neural network, support vector regression model, etc. As the most widely used artificial neural network, BP neural network can quickly establish a nonlinear mapping relationship between independent variables and dependent variables of economic development differences to meet the error accuracy requirements, thus effectively forecasting the change trend in economic development differences.

To this end, based on the statistical data of GDP and per capita GDP in each province during 2000-2017, this paper uses the coefficient of variation as a measure of regional economic development differences, adopts the BP neural network model, evaluates and forecasts the degree of economic development differences using the good nonlinear learning ability of artificial neural networks to quantitatively analyze the future change trends of economic development differences in various regions of China, thus providing a certain data basis for the optimization of domestic regional economic development policies.

II. MEASUREMENT OF REGIONAL ECONOMIC DEVELOPMENT DIFFERENCES

In the analysis of regional economic development differences, determination of measurement indexes is the basis for evaluating regional economic development differences [11-13]. In this paper, the regional

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GDP and per capita GDP are used as the data basis, and the coefficient of variation (CV) is used as the quantitative evaluation index to measure the regional economic development difference. The coefficient of variation reflects the degree of difference or dispersion between each unit of the overall economic development, which is a commonly used index in economic statistics to measure the data difference. The specific expression is as follows:

$$CV(k) = \frac{\sqrt{\sum_{i=1}^{n} \left(x_i(k) - \mu(k)\right)^2 / N}}{\mu(k)} \tag{1}$$

Where: $CV(k)$ is the degree of regional economic development difference in the kth year; $x_i(k)$ is the GDP or per capita GDP of the province numbered i in the kth year; $\mu(k)$ is the national average regional GDP or average regional per capita GDP in the kth year; N is the total number of research subjects.

Before using formula (1) to calculate the degree of regional economic difference, in order to standardize the coefficient of variation, it is normalized to the interval $[0,1]$, so that we can analyze the change trend in degree of economic development difference more intuitively. The standardized coefficient of variation of regional economic development is expressed as follows:

$$\beta(k) = \frac{CV(k) - CV_{\min}}{CV_{\max} - CV_{\min}} \tag{2}$$

Where: $\beta(k)$ is the standardized coefficient of variation of the regional economy in the kth year; $CV_{\max}$ and $CV_{\min}$ are the maximum and minimum values of the coefficient of variation, respectively.

According to Equation (2), the criterion for judging the change trend of national regional economic differences is as follows:

① $\beta(k) = 0$

It suggests that the degree of national regional economic development difference in the kth year is the smallest for the research samples, reflecting that the regional economic development is well balanced in that year.

② $0 < \beta(k) < 1$

When $\beta(m) > \beta(n)$, it suggests that regional economic development has greater difference in the mth year than in the nth year, with balance of regional economic development reduced. When $\beta(m) < \beta(n)$, it indicates that the regional economic development has smaller difference in the mth year than in the nth

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year, with regional economic development more balanced.

③ $\beta(k)=1$

It suggests that the degree of national regional economic development difference in the kth year is the biggest for the research samples, reflecting the poor balance of regional economic development in that year.

III. FORECAST OF REGIONAL ECONOMIC DEVELOPMENT DIFFERENCE BASED ON BP NEURAL NETWORK MODEL

BP neural network is a method for forecasting regional economic development differences by computer. It does not require the establishment of a deterministic model for the analysis of regional economic development differences. The system output depends on the connection weights between the system input and output, and the threshold of these connection weights is determined through the learning of training samples. Due to the complex factors influencing regional economic development differences, many analytical models under ideal conditions are difficult to apply to the change trend forecast of economic development differences. In this case, BP neural network algorithm based on actual data is undoubtedly an effective analysis method for simulating the changes of regional economic differences.

BP neural network algorithm consists of an input layer, a hidden layer, and an output layer, with layers connected by different weights. After training, such neural network can learn the input -output mapping relationship from the training sample. The structure of the BP neural network algorithm is shown in Fig. 1. The analysis principle of regional economic development difference based on BP neural network is as follows: the time set $(x_1, x_2, \cdots x_n)$ of the analysis data is used as the input of the neuron, $w=(w_1, w_2, \mathrm{L}\ w_n)$ is the connection weight between the neuron and the previous neuron. The processing of the input signal by the neuron involves two processes. The first step is to calculate the weighted sum of the input signal, and then subtract the threshold variable to obtain the net input value net of the neuron, namely:

$$net=\sum_{i=1}^{n} w_i x_i-\theta \tag{3}$$

The second step is to perform a functional operation on the net input value net to obtain the output y of the neuron, namely:

$$y=f(net) \tag{4}$$

f is called transformation function (or characteristic function), and its common forms mainly include: linear function, step function, Sigmoid function. Sigmoid function is the most commonly used transformation function, and its functional form is expressed as follows:

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$$f(x)=\frac{1}{1+e^{-\lambda x}} \tag{5}$$

Suppose there are n groups of input and output data in the network layer, $(x^{(1)},x^{(2)},\mathrm{L}\ x^{(n)})$ and $(y^{(1)},y^{(2)},\mathrm{L}\ y^{(n)})$. For the Nth group of input and output data, firstly, according to the current internal expression of the neural network, forward propagate the sample input model $x^{(N)}$, calculate the actual network output. The training error can be calculated by comparing the standardized coefficient of variation output result d_i of output layer with the actual calculated value y_i of standardized coefficient of variation. The training error of the output layer and the hidden layer is calculated as follows:

$$E(w,\theta)=\frac{1}{2}\sum_{i=0}^{n-1}(d_i-y_i)^2 \tag{6}$$

According to the calculation error $E(w,\theta)$ of the training sample, the error is back-propagated, that is, reverse calculation is performed according to the principle of minimizing the square of the difference E between the network output value and the expected value. Then, the connection weight of each adjacent node in the network is adjusted. After a sufficient time of learning and training, the network weight vector converges to an optimal value, and E change also tends to stabilize at this time. After the network training, the degree of regional economic development difference in different years can be calculated through the input of the time set, that is, the output value of the standardized coefficient of variation.

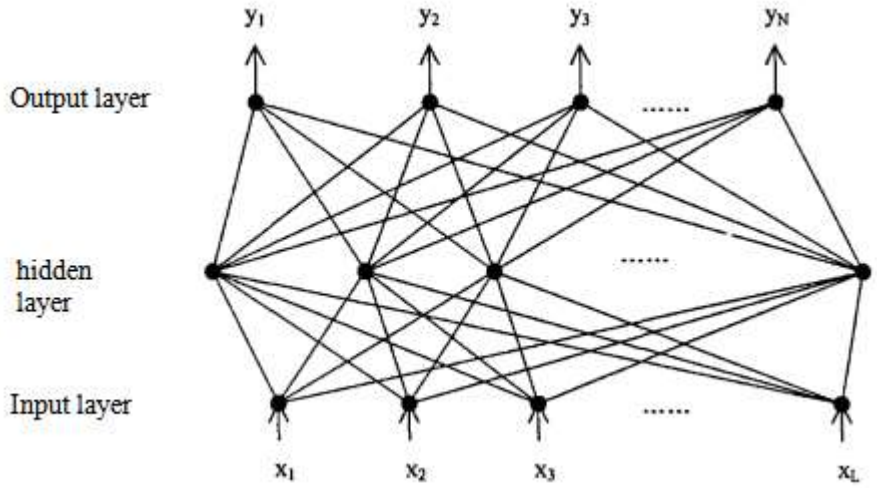

Fig 1: BP neural network model

When using the BP neural network model to forecast the change trend of regional economic development differences, the factor set affecting the standardized coefficient of variation should be used as the input sample for model training. Due to the complex factors influencing regional economic development differences, this paper analyzes changes in regional economic development differences with

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focus on studying the change law of economic development differences over time, so the standardized coefficient of variation is assumed to be a function of time t, namely:

$$\beta = f(t) \tag{7}$$

Hence, when using the BP neural network model to analyze the trend of regional economic differences, we should first calculate the standardized coefficient of variation of the national regional economic differences over the years based on the sample data (regional GDP or per capita GDP) and formula (2). Then, using the corresponding time set as the input sample and the standardized coefficient of variation of the past years as the output sample, based on the input time set sample and the output variation coefficient sample, the sample data can be trained by BP to obtain the optimal neural network structure, which meets the criterion of minimizing the error between the output value of the standardized coefficient of variation of the BP neural network and the actual calculated value of the standardized coefficient of variation. Using the trained neural network, it is then possible to effectively forecast the change trend of regional economic development differences.

IV. EMPIRICAL ANALYSIS

Since the reform and opening up, the widening regional economic development difference appears in China after relatively great economic development in various regions. For a long period of time in the future, China's regional economic growth will still display an unbalanced growth pattern. Due to the widening imbalance, problems in political, economic and social aspects may arise. Therefore, it is a very meaningful work to forecast and control the degree of regional economic development differences in China in the future period of time. This section adopts the regional economic difference measurement analysis method based on the coefficient of variation to analyze the degree of difference in GDP and per capita GDP between 31 provinces across the country during 2000-2017. In view of the future change trend of regional economic differences, the regional economic development difference forecast proposed in this chapter can be used to forecast the degree of regional economic development difference in China in the next five years.

4.1 Analysis on Regional Economic Development Differences in China

According to the historical GDP and per capita GDP data of 31 provinces published by the National Bureau of Statistics, and based on the measurement formula of regional economic development differences, the change trend of regional economic differences in China during 2000 -2017 are calculated, and changes in regional economic development differences in China are studied based on economic development differences of various provinces in China.

4.1.1 GDP development differences among provinces across the country

Based on the GDP statistics of 31 provinces across the country, combining formula (2), the change

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process curve regarding the degree of regional economic difference in China during 2000-2017 is plotted as shown in Fig. 2. Fig. 2 suggests that the GDP difference of various provinces in China presents cyclical fluctuations. In the sample data of 2000-2017, the GDP difference among the provinces in China gradually widens in 2000-2006 and gradually reaches a peak. 2006 has the greatest degree of economic difference among various provinces. Afterwards, national economic development difference gradually narrows in 2007-2013. 2013 has the smallest economic difference among the research samples. In 2014-2017, the degree of economic development difference among provinces across the country exhibits an increasing trend, with an increase rate exceeding that in 2000-2006. Therefore, it is necessary to pay close attention to the change trend of unbalanced economic development to avoid further rapid expansion of unbalanced economic development.

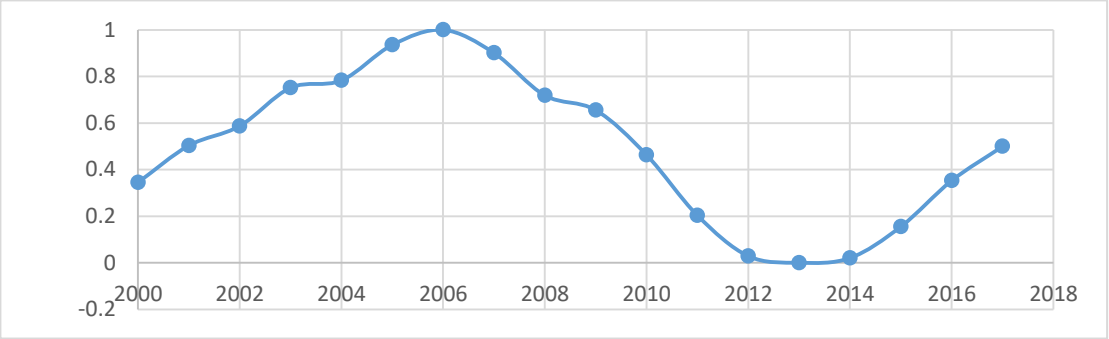

Fig 2: The variation process line of GDP of all provinces

4.1.2 Differences in the development of per capita GDP among provinces across the country

Based on the statistical data of per capita GDP in 31 provinces across the country, combining formula (2), the change process curve regarding the degree of per capita GDP difference in China in 2000-2017 is plotted as shown in Fig. 3. Fig. 3 shows that the change process curve of per capita GDP difference in China is significantly different from that of GDP difference among various provinces. In 2000-2004, the per capita GDP difference among various provinces remains basically unchanged, with small difference in overall. In 2005-2017, the per capita GDP difference among various provinces in China tends to gradually decrease. Where, 2014 has the smallest economic differences among the provinces. Afterwards, the national economic development differences fluctuate steadily in 2015-2017. The primary reason for the obvious differences between the change process of GDP and per capita GDP is that, since the reform and opening up, with the economic development, large population of the economically underdeveloped areas flows to the economically developed areas. The floating population increases their own income and also promotes the economic development of the inflowing areas. Since the per capita GDP is defined as the ratio between the GDP and the permanent population, the rapid expansion of the population in developed provinces has reduced the unbalanced per capita GDP among various provinces.

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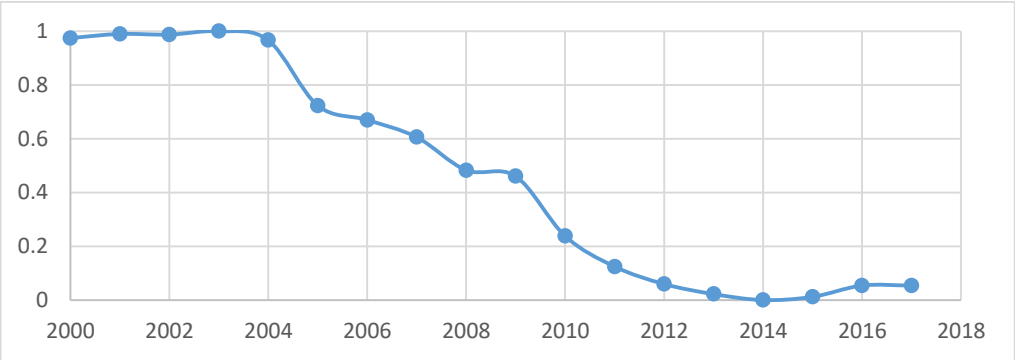

Fig 3: The variation process line of capita GDP of all provinces

4.2 Forecast of the Trend in National Regional Economic Development Difference

There are many factors influencing regional economic development differences, involving complex influence mechanisms and forming a highly uncertain nonlinear system. This section uses the BP neural network model to forecast the change trend of national regional economic development differences. First, formula (2) is used to calculate the degree of GDP and per capita GDP difference among various provinces in China during 2000-2017 and use it as the data basis, and then the BP neural network model is used to learn and train the sample data. Finally, the change trend in the national economic development differences in the next five years is forecasted.

4.2.1 Forecast of GDP development differences among provinces across the country

According to formula (2), the degree of GDP difference among various provinces in the country in 2000-2017 is calculated as shown in Tab. 1. The calculation results of GDP difference among various provinces in 2000-2017 are used as the learning samples of the BP neural network model. Through error back propagation of multilayer feedforward network, the optimal fitting network structure is obtained. According to estimated change trend of regional economic development differences, the complex correlation coefficient for the fitting result of the BP neural network model is 0.992, and the mean square error is 0.00436. The fitting results of training sample and all samples are shown in Fig. 4 and Fig. 5. In order to verify the validity of the BP neural network forecast model, based on the BP neural network model and the commonly used AR time series model, the GDP difference coefficient $\beta(i)$ of each province in 2000-2014 is used as a training sample to forecast the GDP difference coefficient $\beta(i)$ of each province in 2015-2017. The forecast results and actual calculated values of the two models are shown in Tab. 2. It can be seen from Tab. 2 that the forecast results based on the BP neural network model are closer to the actual values, and the model has good forecast effect. The trained neural network model is used to forecast the degree of national GDP difference in the next five years (2019-2023). The forecast results are shown in Tab. 3. It can be seen from the table that the degree of national GDP difference will first increase in the short term and stabilize after 2020.

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TABLE I. Results of the difference degree of GDP between different provinces in China from 2000 to 2017

Time	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
$\beta(i)$	0.345	0.503	0.587	0.751	0.783	0.935	1.000	0.901	0.719
Time	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
$\beta(i)$	0.656	0.463	0.203	0.029	0.000	0.020	0.155	0.352	0.499

TABLE II. The actual calculated values and the statistical tables of BP neural network model and AR model predicted values

Year	**actual calculated value**	**BP neural network model forecast value**	**AR model forecast value**
2015	0.155	0.155	0.163
2016	0.352	0.354	0.382
2017	0.499	0.499	0.543

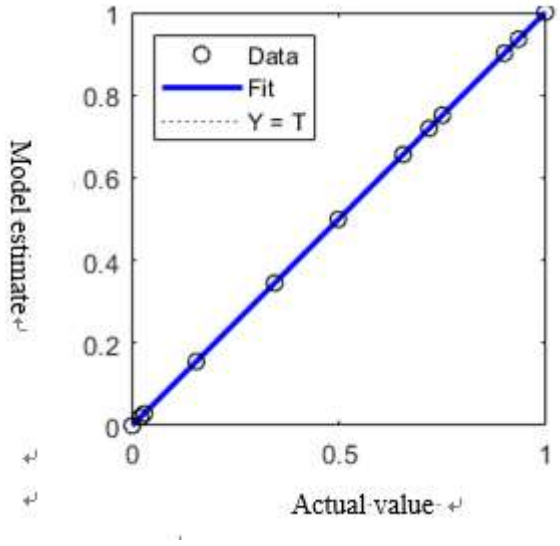

Fig 4: The fitting results of training sample

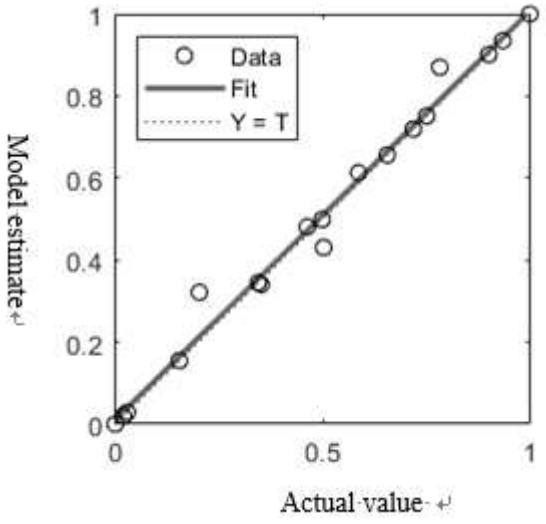

Fig 5: The fitting results of all sample

TABLE III. The forecast result of GDP difference among all provinces in the next five years

Year	**2019**	**2020**	**2021**	**2022**	**2023**
Forecast value	0.772	0.794	0.806	0.809	0.810

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4.2.2 Forecast of the difference in per capita GDP development of various provinces across the country

According to formula (2), the degree of per capita GDP difference among various provinces in the country in 2000-2017 is calculated as shown in Tab. 4. The calculation results of per capita GDP difference of each province in 2000-2017 are used as the learning sample of the BP neural network model to estimate the change trend of regional economic development difference. The complex correlation coefficient for the fitting result of the BP neural network model is 0.993, and the mean square error is 0.00774. The fitting results of the training samples and all samples are shown in Fig. 6 and Fig. 7. In order to verify the validity of the BP neural network forecast model, based on the BP neural network model and the commonly used AR time series model, the difference coefficient $\beta(i)$ of per capita GDP of each province in 2000-2014 is used as a training sample to forecast the difference coefficient $\beta(i)$ of per capita GDP of each province in 2015-2017. The forecast results and actual calculated values of the two models are shown in Tab. 5. It can be seen from Tab. 5 that the forecast results based on the BP neural network model are closer to the actual values, demonstrating good model forecast effect. The trained neural network model is used to forecast the degree of national per capita GDP difference in the next five years (2019-2023). The forecast results are shown in Tab. 6. It can be seen from the table that per capita GDP difference and GDP in China will share the same change trend in the short term, increasing first and then stabilizing after 2022.

TABLE IV. Results of the difference degree of capita GDP between different provinces in China from 2000 to 2017

Time	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
$\beta(i)$	0.974	0.989	0.987	1.000	0.966	0.723	0.670	0.606	0.483
Time	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
$\beta(i)$	0.461	0.238	0.125	0.060	0.022	0.000	0.012	0.054	0.054

TABLE V. The actual calculated values and the statistical tables of BP neural network model and AR model predicted values

Year	**actual calculated value**	**BP neural network model forecast value**	**AR model forecast value**
2015	0.012	0.013	0.021
2016	0.054	0.028	0.099
2017	0.054	0.054	0.065

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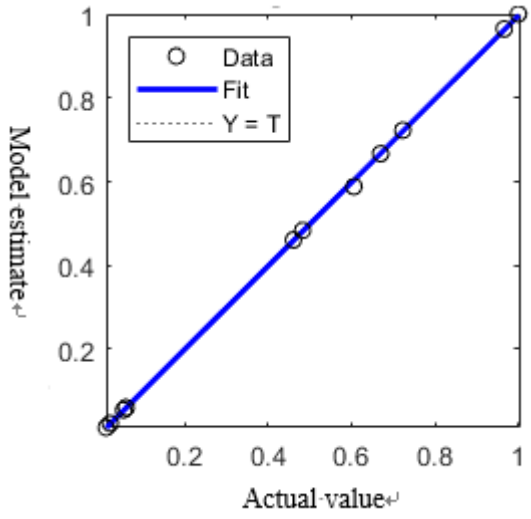

Fig 6: The fitting results of training sample

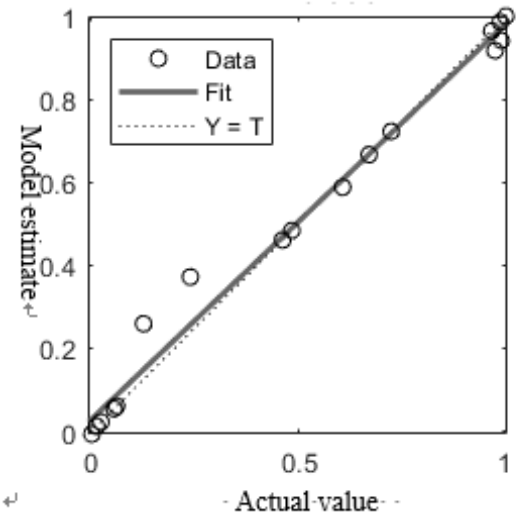

Fig 7: The fitting results of all sample

TABLE VI. The forecast result of GDP difference among all provinces in the next five years

Year	**2019**	**2020**	**2021**	**2022**	**2023**
Forecast value	0.137	0.140	0.141	0.142	0.142

V. CONCLUSION

To forecast national regional economic development difference, this paper starts from two perspectives of GDP difference and per capita GDP difference in 31 provinces in China, quantitatively analyzes economic development difference of each province based on the coefficient of variation measurement method, and applies the BP neural network model to the forecast analysis of economic difference. Validity of the method is verified by comparing it with the actual calculated value and the AR model forecast value. The forecast results show that, in the next 5 years, the difference in GDP and per capita GDP among various provinces in China will widen, and the growth rate of GDP difference exceeds that of per capita GDP, but both will gradually stabilize.

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REFERENCES

[1] Yang Kaizhong (1994). Research on the Change of Regional Economic Differences in China. Economic Research Journal, 1994(12):28-33.

[2] Döring T, Blume L (2015). Differences in Regional Economic Prosperity: Do State Policies Matter? An Empirical Investigation of Data from the German States. Social Science Electronic Publishing, 2015, 11(1):29-49.

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[3]Yu L (2008). The Ratio of Education Investment and Differences in Regional Economic Growth. Economic Research Journal, 2008.

[4] Xu Jianhua, Lu Feng, Su Fanglin, Lu Yan (2005). The spatiotemporal scale analysis of China's regional economic differences. Geographical Research, 2005(01):57-68.

[5] Zheng Fei, Tang Bingyong (2000). Research on the forecasting method for first-class regional economic difference. Journal of Natural Science of Heilongjiang University, 2000(02):39-42.

[6] Chen Xiaoting (2010), Tian Chengshi. Statistical evaluation and trend forecast of regional economic differences in Liaoning. Foreign Economic Relations & Trade, 2010(08): 101-103.

[7] Zhang Shengfu (2016). Forecast of change trend in China's regional economic differences and policy implications. China International Business, 2016(19): 66-68.

[8] Wan Daoxia, Yang Dongmei (2014). Measurement and forecast of regional economic differences in China Journal of Guangxi University of Finance and Economics, 2014, 27(01): 23-27.

[9] Lin Yifu, Liu Mingxing (2003). China's economic growth convergence and income distribution The Journal of World Economy, 2003(08):3-14+80.

[10] Lin Yifu, Cai Fang, Li Zhou (1998). Analysis of regional disparities in China's economic transformation period. Economic Research Journal, 1998(06): 5-12.

[11] Yuan Xiaoling, Zhong Yunyun, Guo Yiqun. (2010) Measurement and evolution analysis of China's regional economic development differences: an empirical study based on TOPSIS method. Inquiry into Economic Issues, 2010(02):33-39.

[12] Deng Yuyuan (2018). Measurement of regional economic development differences——taking Sichuan Province as an example. Economic & Trade, 2018(15):35-37.

[13] Liu Xuanzi (2012). Measurement of Economic Development Level in Western Regions and Analysis of Inter-provincial Differences. Northwest A&F University, 2012.