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Measurement and Analysis of Regional Financial Development Index Based on ANN-RBF Contribution Analysis

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Abstract

At present, focusing on the development of the financial industry and contributing to high-quality economic development is a hot topic of current research. In this paper, a comprehensive index system consisting of a macro-financial environment index, financial scale index, financial efficiency index, and financial risk and security measurement index is constructed. Based on the ANN-RBF contribution analysis algorithm, this paper collects and calculates relevant financial data of six regions in China using three statistical methods: EWM, CVM, and CRITIC. The results show that North China has the best comprehensive financial development, while Northwest China has the worst comprehensive financial development. In addition, this paper finds that the importance of the market value of stock circulation/regional GDP is 22% and the importance of normalization is 100%; the importance of financial market trading volume/regional GDP is 15.7% and the importance of normalization is 71.2%. By focusing on the key indicators, we focus on the development of regional finance and promote the quality development of the national economy.

Keywords: *ANN-RBF; regional finance; development index; EWM-CVM-CRITIC*

1. Introduction

As China's reform progresses, the relationship between regional economic development and the level of finance has received more attention. How to promote the high-quality development of regional finance and promote the transformation and upgrading of regional economy is a key issue to achieve the goal of modernization. Through the analysis of regional financial development indicators, the shortcomings of regional financial development can be grasped and targeted measures can be carried out. At present, there are few studies in this area.

In recent years, the focus of research on measuring regional financial development has gradually shifted to the relationship between financial development and economic growth. In terms of the macro-financial environment, many scholars believe that the quantity of investment as well as the efficiency of investment are key factors in promoting rapid economic growth, while the savings-investment conversion rate is a key indicator of the impact of financial development on economic growth. Regarding the scale of regional financial development, many scholars internationally have experienced the development process from individual indicators to comprehensive indicators. With the gradual maturity of financial markets, the measurement of stock market capitalization and insurance depth has also been gradually incorporated into the evaluation system. Regarding the research on the evaluation system of financial efficiency, the current mainstream view is to evaluate finance as a resource from both macro and micro perspectives. On the whole, China lacks a unified evaluation system of risk prevention indicators. Other scholars point out that the monitoring of real estate crises should also be included in the risk early warning system. Although some other nonlinear early warning models are currently useful in solving China's financial early warning problems, they are not mature enough in the application, so the setting of the model indicator system has not been studied in depth.

Previous research results tend to specialize in a certain perspective of financial development, and less often use quantitative analysis to measure the level of regional financial development, which makes it difficult to evaluate the level of regional financial development accurately and comprehensively. In this paper, 11 indicators are selected from four aspects: macro-financial environment, financial scale, financial efficiency, and financial risk. The EWM-CVM-CRITIC model is used to generate the regional development index, and on this basis, the ANN-RBF contribution analysis model is used for contribution analysis.

2.Indicator system

As reflected in the innovative capacity of financial instruments and the ability of financial institutions to adapt to the uncertainties of the development of the macroeconomic environment. Drawing on previous research results and combining the current situation of China's financial market development, this paper constructs a four-dimensional financial development index evaluation system including macro-financial environment indicators, financial scale indicators, financial efficiency indicators, and financial security and risk measurement indicators to measure and analyze the financial development level of different regions in China.

2.1 Macro-financial environment indicators

Macro financial environment refers to the collection of factors that affect various activities of financial subjects under a specific financial system. On the one hand, macro-financial environment indicators can reflect the foundation and space of regional financial development; on the other hand, whether the macro-financial environment can remain stable is also directly related to the degree of risk fluctuation of regional financial development. The macro-financial environment indicators selected in this paper are GDP growth rate (X_1), national wealth (X_2), and the proportion of tertiary industry (X_3).GDP growth rate (X_1)： China's gross domestic product (GDP) growth rate is an important indicator of a region's economic dynamism. The data used in this paper to use this indicator are from annual data of each region in China.National wealth (X_2)：National wealth = average capital-output ratio of GNP. This paper assumes that the industrial structure and technology level are relatively stable in the short run and that the marginal capital-output ratio is approximately equal to the average capital-output ratio. Proportion of tertiary industry (X_3)： By analyzing and comparing the industrial structures of the three regions, we can analyze the basis of regional financial development and the space for future development. At present, China is in the middle level among developing countries, and the internal economic structure of each region has its peculiarities.

2.2 Financial scale indicators

Since China's regional financial policies are relatively consistent, the actual level of financial market development is uneven. Therefore, we assume that the financial ecology is consistent and simply measure the scale and level of financial development in the region. This paper measures the scale of regional financial development from two dimensions of financial depth (X_4) and financial width (X_5).Financial depth (X_4)： Financial depth reflects the degree of financialization of the regional economy. When measuring the depth of regional finance, the selected evaluation index is the percentage of regional financial market transactions in regional GDP.Financial width (X_5)： It is generally believed that the larger the proportion of financial industry employees to the total employment in the region, the stronger the innovation capacity of the financial industry and the more dynamic its development. In this paper, we use the regional financial industry employment rate to measure the regional financial breadth.

2.3 Financial efficiency indicators

The current mainstream view holds that financial efficiency refers to the relationship between input and output of the financial sector, namely the efficiency of the use of financial resources. This paper selects the savings rate (X_6), savings-investment conversion rate (X_7) two indicators to monitor the turnover efficiency of financial resources in the region.

Savings rate (X_6)： Savings rate = total resident savings/GDP. on the one hand, individual savings can be converted into investment resources. On the other hand, an excessively high savings rate can lead to a lack of consumption power and hinder economic development. Therefore, an equilibrium value should be found between different savings rates and the effective conversion of savings into investment.

Savings-investment conversion efficiency (X_7) ： Savings-investment conversion ratio = deposits/loans. This ratio is one of the priorities for increasing domestic demand and promoting rapid capital financing, and reflects the degree of sophistication and openness of the regional financial system.

2.4 Financial security and risk measurement indicators

With the continuous international financial turmoil since the 21st century and the impact of the new coronavirus in the past two years, the safety and stability of China's regional financial market is particularly important. This paper constructs four indicators, from the bank market (X_8), capital market (X_9), insurance market (X_{10}), and government debt (X_{11}) four aspects to comprehensively evaluate the regional financial security and risk.Bank market index (X_8)： Banks are one of the basic ways for residents to participate in financial activities in most parts of China. In this paper, the non-performing loan ratio is chosen as an indicator of bank market risk.Capital market index (X_9)： Due to a large amount of capital, long maturity, and high risk, it is important and relevant to measure the risk of the capital market. In this paper, we choose the market value of listed company stocks outstanding as a proportion of GDP as an indicator of capital market risk.Insurance market index (X_{10})： The index to measure the risk of the insurance market is the insurance depth. Insurance depth = regional premium income / GDP, reflecting regional insurance coverage and insurance industry development level.Government debt index (X_{11})： Government debt is the debt issued by the government in overseas financial markets or borrowed from foreign governments and banks. This paper will use the ratio of government bond issuance income to total fiscal income to measure government debt indicators.

Table 1 Indicator system

Index classification	Name of indicator
Macro-financial environment indicators	GDP growth rate X_1
	National wealth X_2
	The proportion of tertiary industry X_3
Financial scale indicators	Financial depth X_4
	Financial width X_5
Finance efficiency indicators	Savings rate X_6
	Savings-investment conversion efficiency X_7
Financial Security and Risk Measurement	Bank market index X_8
	Capital market index X_9
	Insurance market index X_{10}
	Government debt index X_{11}

3.Regional Financial Development Index Measurement based on EWM-CRITIC-CVM

3.1 EWM model

EWM (Entropy Weighting Method) uses the degree of variation in the value of each indicator to calculate the weight of each indicator. Entropy is a measure of the degree of disorder in a system. Therefore, information entropy can be used as a tool to calculate the weight of each indicator to provide a basis for the comprehensive evaluation of multiple indicators. The specific steps are as follows.

STEP1:Assume that there are n objects to be evaluated and m evaluation indicators (which have been normalized) form a normalization matrix as follows.

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{pmatrix} \quad (1)$$

The data are normalized and the normalized matrix is denoted Z . For each element in Z .

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^{2}}} \quad (2)$$

By processing X_{ij} to get Z,Z is the normalized matrix of X.Determine if there are negative numbers in the Z matrix, if so another normalization method needs to be used for X . The matrix X is then normalized once, with the following normalization formula.

$$\tilde{z}_{ij} = \frac{x_{ij} - \min\{x_{1j}.x_{2j}....x_{nj}\}}{\max\{x_{1j}.x_{2j}...x_{nj}\} - \min\{x_{1j}.x_{2j}....x_{nj}\}} \quad (3)$$

STEP2:Calculate the weight of the ith sample under the jth indicator and consider it as the probability used in the relative entropy calculation. Calculate the probability matrix P . Each element in P is as follows.

$$p_{ij} = \frac{\tilde{z}_{ij}}{\sum_{i=1}^{n} \tilde{z}_{ij}} \quad (4)$$

STEP3:Calculate the information entropy of each indicator and calculate the information utility value and normalize it to obtain the entropy weight of each indicator. For the j th indicator, the e_j The larger it is, the greater the information entropy of the j th indicator, and the smaller its corresponding information entropy is, the formula for calculating its information entropy is

$$e_j = -\frac{1}{lnn} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \quad (5)$$

Define the information utility value $d_j = 1 - e_j$ and normalize the information utility values to obtain an entropy weight for each indicator.

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \quad (6)$$

3.2 The CRITIC model

The CRITIC (Criteria Importance Through Inter-Criteria Correlation) method is an objective evaluation method that determines the weight of each indicator based on the conflict and contrast intensity between the evaluation indicators. The lower the conflict, the stronger the positive correlation; the higher the standard deviation of an indicator, the stronger the contrast strength. Suppose there are n samples to be evaluated and p evaluation indicators, where X_{ij} represents the value of the j th evaluation indicator of the i th sample. The original indicator data matrix is formed as

$$X=\begin{pmatrix} x_{11} & \cdots & x_{1p} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{np} \end{pmatrix} \tag{7}$$

STEP1:Dimensionless processing

The CRITIC weighting method generally uses forward or inverse processing, but normalization is not recommended. If a larger value of the indicator is used (positive indicator), the expression is as follows (8), and if a smaller value of the indicator is used (inverse indicator), the expression is as follows (9).

$$x_{ij}^{/}=\frac{x_j-x_{\min}}{x_{\max}-x_{\min}} \tag{8}$$

$$x_{ij}^{/}=\frac{x_{\max}-x_j}{x_{\max}-x_{\min}} \tag{9}$$

Step 2: Indicator variability. In the CRITIC method,the standard deviation is used to indicate the variance fluctuation of the values taken within each indicator. The larger the standard deviation, the greater the variance of the indicator values, the more information can be filtered, and more weight should be given to the indicator. Expressed in terms of standard deviation, the S_j denotes the standard deviation of the j th indicator.

$$\bar{x}_j=\frac{1}{n}\sum_{i=1}^{n}x_{ij}$$
$$S_j=\sqrt{\frac{\sum_{i=1}^{n}\left(x_{ij}-\bar{x}_j\right)^2}{n-1}} \tag{10}$$

STEP3:Indicator Conflict. The stronger the correlation with other indicators, the less conflicting the indicator is with other indicators, and the more the same information is reflected, the more repetitive the evaluation content is, which to a certain extent also weakens the evaluation strength of the indicator, and the weight assigned to the indicator should be reduced. r_{ij} The correlation coefficient between evaluation indicators i and j

$$R_j=\sum_{i=1}^{p}\left(1-r_{ij}\right) \tag{11}$$

STEP4:Amount of information

$$C_j=S_j\sum_{i=1}^{p}\left(1-r_{ij}\right)=S_j\times R_j \tag{12}$$

STEP5:Objective weights. So the objective weight of the jth indicator W_j is.

$$W_j=\frac{C_j}{\sum_{j=1}^{p}C_j} \tag{13}$$

3.3 Coefficient of variation method algorithm

CVM (Coefficient of Variation Method) directly uses the information contained in each indicator to obtain the weight of the indicator by calculation. The basic idea is that if it is more difficult to reach the average level when the evaluated object performs, a larger weight should be given to the indicator; conversely, a smaller weight should be given. The steps are as follows.

STEP1:Collection and collation of raw data

STEP2:Calculate the mean of each indicator $\bar{x}_i$ and standard deviation σ_i , and G_i denotes the observed value of indicator I at period j .

$$\bar{x}_i=\frac{1}{n}\sum_{i=1}^{n}G_{ij} \tag{14}$$

$$\sigma_i=\sqrt{\frac{\sum_{i=1}^{n}\left(G_{ij}-\bar{x}_i\right)^2}{n}} \tag{15}$$

STEP3:Calculate the coefficient of variation

Due to the different scales of the indicators in the indicator system, it is not appropriate to directly compare the degree of difference between them. To eliminate the influence of the different scales of each indicator, the coefficient of variation is needed to measure the degree of difference in the values taken for each indicator. v_i is the coefficient of variation of the ith indicator, also known as the standard deviation coefficient. σ_i is the standard deviation of the ith indicator. $\bar{x}_i$ is the mean of the ith indicator. Let $i=1,2,\ldots n$, the coefficient of variation is calculated by the formula

$$v_i=\frac{\sigma_i}{\bar{x}_i} \tag{16}$$

STEP4:The coefficients of variation were normalized, and thus the weights of each indicator were obtained, such that $i=1,2,\dots,49$, its calculation formula is

$$w_j = \frac{v_i}{\sum_{i=1}^{n} v_i} \quad (17)$$

STEP5: then the calculated final indicator weights

$$W=\{w_1, w_2, \dots w_n\} \quad (18)$$

4. ANN-RBF algorithm

4.1 Introduction to ANN

ANN(Artificial Neural Network) is a mathematical model of neuronal activity, a complex network structure formed by interconnecting a large number of processing units.

ANNs have self-learning capabilities, especially in image recognition and processing and future prediction; associative storage capabilities, and high-speed solution-seeking capabilities to find the best solution to complex problems. Artificial neural networks use feedback-based networks combined with problem-solving algorithms to find the best solution to a complex problem.

4.2 Introduction to RBF

In 1985, Powell proposed the radial basis function (RBF) method for multivariate interpolation. The RBF neural network is a three-layer neural network consisting of an input layer, a hidden layer, and an output layer.

RBF networks are capable of approximating arbitrary nonlinear functions and can handle intractable regularity problems in the system.

STEP1: Input layer, which consists of signal source nodes. The number of input nodes, I, is the dimensionality of the input samples. It is assumed that there are N input samples and each input sample is an I-dimensional column vector, i.e. $X=(x_1, x_2, \dots, x_I)^T$, each element of the sample column vector is used as a node in the input layer. This layer is mainly used to pass the input samples to the hidden layer. Before that, the input samples need to be normalized so that the input values of each node have the same magnitude to avoid the effect of magnitude.

STEP2:hidden layer, the number of neurons in th J e hidden layer varies with the application to be solved, and the activation function of each hidden node uses a radial basis function. Suppose the number of nodes in the hidden layer is J. Then the hidden layer maps the I-dimensional input vector into the J-dimensional space by mapping $f \cdot R^I \to R^J$ The I-dimensional input vector is mapped into the J-dimensional space. c_j and σ_j are the centre and width of the jth implicit layer neuron, respectively. c_j which has the same dimension as the number of input nodes and is also an I-dimensional variable, $j=1,2,\dots J$ · $\|\cdot\|$ is the Euclidean distance. $\varphi(\cdot)$ is the radial basis function. The output of the jth neuron in the hidden layer is:

$$h_j(X) = \varphi\left(-\frac{\| X - c_j \|}{\sigma_j}\right) \quad (19)$$

STEP3:output layer, which response to the output of the implicit layer. Assuming that the number of nodes in the output layer is , this layer is a mapping of the implied layer space to the output layer, mapped as f · $R^I \to R^J$. The mapping function is a linear function that linearly combines the outputs of the layers of the implicit layer by connecting the weights. w_{jk} is the connection weight of the jth implied node to the kth output node, $k=1,2,\dots K$ · The expressions are as follows.

$$y_k = \sum_{j=1}^{J} w_{jk} h_j(X) \quad (20)$$

5. Empirical Analysis

5.1 Object Selection and Data Collection

This paper collects the relevant data of each region from China Financial Yearbook, China Statistical Yearbook, Ministry of Finance of the People's Republic of China, and Shanghai Stock Exchange, etc. Since the very individual data involved are not made public or missing and lost on various public platforms, this paper adopts the time series difference method to supplement them[7]. The series data are mainly from the China Statistical Yearbook (2015~2020), and all the mean values are taken, with long statistical years and consistent sources, so the data are highly credible.

5.2 Indicator weighting calculation

Considering the advantages and disadvantages of different statistical methods for weight measurement, this paper will choose three statistical methods to calculate the weights separately, namely EWM, CVM, and CRITIC, and finally, the arithmetic mean will be used as the final weight calculation result. The indicators are standardized according to the positive index that contributes to the regional financial development index and the negative index that contributes to the negative index. The results of the indicator measurement are shown in Table 2.

Table 2 Calculation results of the weights of regional financial development index evaluation indicators

Indicators	EWM	CVM	CRITIC	Average
X_1	0.056	0.064	0.091	0.070
X_2	0.084	0.084	0.104	0.091
X_3	0.100	0.106	0.070	0.092
X_4	0.131	0.121	0.090	0.114
X_5	0.094	0.082	0.112	0.096
X_6	0.068	0.069	0.103	0.080
X_7	0.074	0.079	0.088	0.080
X_8	0.083	0.090	0.075	0.083
X_9	0.190	0.172	0.062	0.141
X_{10}	0.048	0.060	0.094	0.067
X_{11}	0.073	0.075	0.111	0.086

It can be seen from the above data that indicator X_9 has the largest value of 0.141, so it is given the highest weight, while indicator X_{10} has the smallest value of 0.067 and is given the lowest weight accordingly. In addition, the equal-weighting approach selected in this paper integrates the advantages and disadvantages of each weighting method and is more realistic. After standardizing the indicators for each province and city, according to the formula $\sum X_i Y_i$, the sizes of the six regional financial development indices in China can be measured, as shown in Table 3.

Table 3 Results of the Six Regional Economic and Financial Development Indices in China

	North China	Northeast Region	East China	South Central Region	Southwest Region	Northwest China
X_1	-0.683	-1.501	0.172	-0.046	1.439	0.068
X_2	-0.360	-0.471	0.696	0.724	-0.292	-0.807
X_3	0.885	-0.198	-0.019	-0.132	-0.152	-0.421
X_4	2.032	-0.218	-0.441	-0.394	-0.461	-0.377
X_5	1.408	1.025	-0.412	-0.479	-0.767	-0.215
X_6	-0.828	-1.508	0.672	0.430	0.788	-0.352
X_7	-0.094	0.129	0.299	-0.005	-0.039	-0.346
X_8	-0.147	0.573	-0.546	0.396	-0.212	0.243
X_9	0.744	-0.479	0.100	-0.243	0.129	-0.403
X_{10}	0.835	1.413	-0.552	-0.383	-0.877	0.282
X_{11}	-0.347	-0.271	-0.777	-0.179	0.995	0.776
Development index Y	0.413	-0.152	-0.074	-0.050	0.022	-0.178

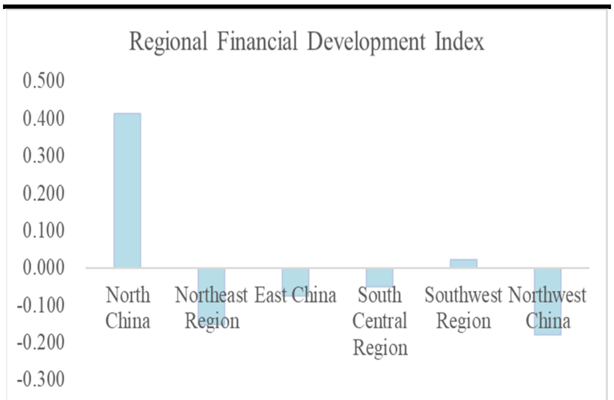

Figure 1 Financial Development Index of Six Regions in China

As shown in Figure 1, the six regional financial development indices calculated for North China (0.413), Northeast China (-0.152), East China (-0.074), South Central China (-0.050), Southwest China (0.022) and Northwest China (-0.178) reflect the different effects of each indicator on the financial development of different regions. The overall financial development index levels are lower in regions with poorer economic development levels, with North China having a significantly higher development index than other regions, while Northwest China and Northeast China have lower development indices, which also reflects the weaker economic base and less well-developed financial markets in some regions of China.

5.3 ANN-RBF based contribution analysis

Using the data analysis function of SPSS software,all 11 indicators were used as input layers of the neural network and were treated as covariates and "normalized" in the "variable selection section", while "index" was used as the dependent variable. The output results were tested several times. To fully reflect the accuracy of the results, we finally chose a "two-layer" hidden layer with hyperbolic tangent function, a constant equation function for the activation function in the output layer.

In the case processing summary, 27 regions were assigned to the training sample, accounting for 73%, and the remaining regions were assigned to the test sample, accounting for 27%; the error calculation in the model summary was based on the test sample, and the sum-of-squares error in the training set error was 1.695, with a relative error of 0.13; the sum-of-squares error in the test error was 0.198, with a relative error of 0.154. The prediction results are shown in Figure 3. It can be seen from the above data that the trained ANN network has a strong generalization and is suitable for use in the later independent variable importance analysis.

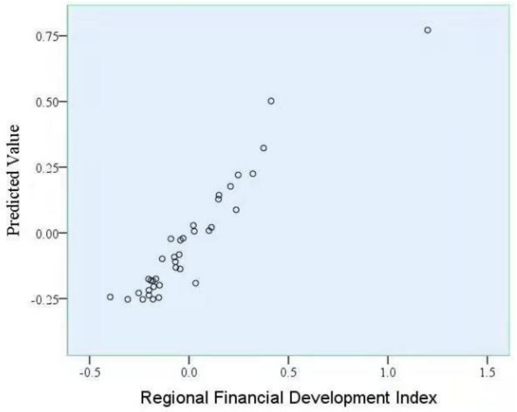

Figure 2 Predicted real-world graphs under ANN-RBF

In order to more intuitively reflect the contribution of each indicator to the regional financial development index, this paper will combine the analysis of the importance of independent variables with the analysis chart. As shown in Figure 4, indicator X_9 has 22% importance and 100% normalized importance, which is significantly higher than other indicators, while indicators X_5 and X_6 have 2.3% and 2.9% importance respectively, and 10.2% and 13.1% normalized importance respectively, which are significantly lower than other indicators.

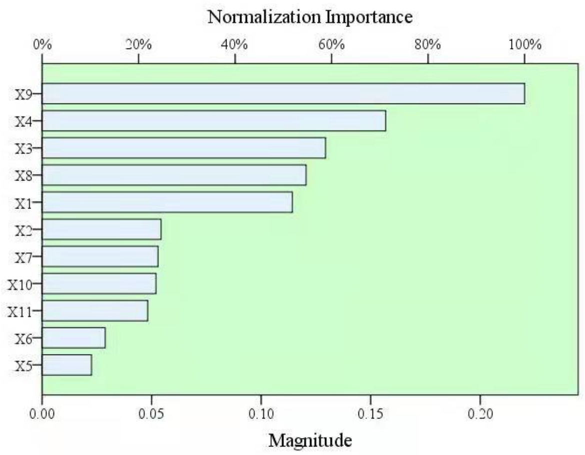

Figure 3 Significance analysis of independent variables

As seen from the figure, stock market circulation and GDP not only promote the upgrading of China's industrial structure but also have a more obvious impact on regional financial development, while showing regionalized differences. And in recent years, the new crown pneumonia epidemic has had a large impact on the whole financial market, and despite China has adopted an extraordinarily loose monetary policy, the financial development of each region still suffers a large impact.

(1) Regions should fully call on financial resources to serve the prevention and control of the epidemic and the resumption of work and production, strive to balance economic development and risk prevention and promote regional financial development.

(2) The government should formulate and implement effective policies to enhance the liquidity of the stock market, and at the same time should strengthen the skills training for investors to equip them with relevant professional knowledge and investment skills.

(3) To promote GDP growth, regions should strengthen inter-regional cooperation to form a situation of mutual promotion, coordinated development, and a win-win situation.

6. Conclusion

(1) The trained network is highly accurate and provides scientific data support, and it is believed that with the in-depth research and application, ANN-RBF, as an advanced artificial intelligence algorithm, can be better applied in the analysis of regional financial development differentiation.

(2) In the regional financial development index chart, the northwest region has the lowest development index and is in an unbalanced state, so how to achieve rapid economic development in the northwest region is the key breakthrough direction for China's economic development; in the analysis of the importance of independent variables, the value of the market value of stock circulation/regional GDP is the largest, which should be used as a key concern for the later study of financial development in each region.

(3) Overall, the financial development index of each region in China shows obvious differentiation, which requires that the government should differentiate the relevant policies according to the development situation of each region when formulating them, to promote the high-quality development of regional finance to the greatest extent.

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