Measurement and Analysis of Regional Inclusive Finance Composite Index Based on Contribution Analysis

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Abstract. In recent years, with the development of economic globalization, regional inclusive finance has received increasing attention from the international community. The development concept of inclusive finance has been deeply rooted in the people's hearts, and its practice has been continuously improved. Based on the data of financial services in Dalian, Liaoning Province, this paper uses principal component analysis (PCA) and artificial neural network-radial basis function (ANN-RBF) algorithm to measure and analyze the contribution of the inclusive financial index (FII). Firstly, the index system of regional inclusive finance is confirmed, and based on PCA dimension reduction, the index of regional inclusive finance is constructed. By constructing the evaluation model based on principal component analysis and artificial neural network-radial basis function contribution analysis, the measurement and analysis conclusions of regional inclusive finance comprehensive index is obtained. The results show that: (1) In recent years, FII in Dalian has gradually fluctuated and increased. (2)Among the influencing factors, the number of insurance institutions, number of employees in monetary and financial service, the amount of RMB loans of financial institutions in Dalian, the premium income of property insurance in Dalian, the proportion of total loans of financial institutions in Dalian to GDP, Dalian property insurance depth have the greatest impact.

Keywords: Principal Component Analysi; Artificial Neural Network; Radial Basis Function; regional inclusive finance; contribution analysis; index measure.

1. Introduction

In 2005, the United Nations introduced the concept of 'Inclusive Finance' in the International Year of Microcredit, which focuses on small and micro businesses, residents in remote areas, rural residents, urban low-income groups, the poor, the disabled and the elderly. The following year, the United Nations drafted the 'Blue Book on Inclusive Financial Systems'. They elaborated on the concept of developing countries establishing a sustainable financial system through policies and systems that can provide people with appropriate products and services. Vigorously creating inclusive finance is conducive to promoting the sustainable and balanced development of the financial industry, boosting the transformation and upgrading of economic development mode, and improving social equity and social harmony. At present, there are few studies in this area. In the past research and analysis of regional inclusive finance, the current international inclusive finance evaluation criteria mainly include the inclusive finance index system of the Inclusive Finance Alliance (AFI) in 2009; 2012' G20 Inclusive Financial Indicators System' etc. The 'Promotion of Inclusive Financial Development Plan (2016-2020)' issued by the State Council in 2015 also clearly states that it is necessary to establish and improve China's inclusive financial index system. At the same time, Sarma constructed the world's first Inclusive Financial Index (IFI) using the geometric average method and proposed three dimensions of indicators: Geographical permeability, product contact and utility. Arora [1] is based on an indicator system covering four dimensions of service scope, utility, convenience, and transaction costs in 98 countries. Chakravarty and Pal [2] Based on the methodology of the United Nations Development and Design Agency, inclusive sensitivity parameters were introduced as analytical methods in 17 states of India. Wang Jing and Hu Guohui took the lead in using the variation coefficient method to construct and analyze an inclusive financial index system.[3]

There are still research loopholes in previous studies on the index system of inclusive finance. First of all, most of the previous studies are national and need to be refined; Secondly, the

aforementioned research methods are mainly geometric average, weighted average and coefficient of variation, which still need to be innovated and modernized. Therefore, this paper proposes a PCA-ANN-RBF method to measure and analyze the comprehensive index of regional inclusive finance. This paper innovates in research methods and research objects. Firstly, this paper narrows the research scope of inclusive finance, shifts from nationwide to regional research, and improves the accuracy and pertinence of the research. Secondly, this paper applies PCA and ANN-RBF to the study of regional inclusive finance composite index, breaking through the previous inherent analysis methods to improve the accuracy of research and analysis. This paper mainly analyzes the development of inclusive finance in Dalian. Firstly, it confirms the index system of regional inclusive finance. Secondly, through PCA dimension reduction, index cleaning, and screening; Finally, by constructing an artificial neural network-radial basis function to analyze the contribution of independent variables, the measurement and analysis conclusion of regional inclusive financial comprehensive index are obtained.

This paper innovates research methods, combines an artificial neural network with inclusive financial index measurement, observes and analyzes the relevant indicators of inclusive financial development in Dalian through empirical research, and obtains the importance ranking of the development trend of inclusive financial index and the influencing factors of inclusive finance in Dalian.

2. Selection and Construction of Index System

Inclusive finance has the characteristics of inclusiveness, convenience, inclusiveness and comprehensiveness, which benefits more than 90 % of small and medium-sized enterprises. Based on the current situation of inclusive finance and the existing literature, this paper refers to the IFI index proposed by Sarma and divides the comprehensive index evaluation system into three levels from top to bottom. The first-level indicators include financial services availability, financial services participation and financial services involvement, which are used to evaluate the convenience, participation and effectiveness of inclusive financial services. [4]

2.1. Accessibility of Financial Service

Financial services rely on financial institutions and practitioners. The number of employees in financial institutions and the financial industry is positively correlated with the availability of financial services, which can measure the convenience and availability of financial services. This paper is based on the data of the number of institutions and employees, capital market services, insurance and other financial industries. The more the number of residents, the more convenient access to financial services, and the stronger the availability of financial services. [5]

2.2. Financial Services Participation

Among the current business carried out by financial institutions, various bank deposit and loan business are the main business, followed by the insurance business. Based on the above situation, this paper takes the deposit and loan amount and insurance amount as the secondary indicators, and analyzes the following three indicators: the amount of RMB loan from financial institutions, the amount of RMB deposit of urban and rural residents, the amount of RMB deposit per capita of urban and rural residents, the insurance density, property insurance and life insurance to measure the participation of financial services.

2.3. Financial Services Involvement

Developing inclusive finance aims to provide high-quality and convenient financial services, thereby promoting the transformation and upgrading of industrial structure and socio-economic development [6]. The proportion of total deposits and loans of financial institutions in GDP and the depth of insurance (the ratio of premium income to GDP) can measure the specific situation of

residents' participation in inclusive economic activities in the region and reflect the effectiveness and involvement of inclusive finance. The specific indicators are shown in Table 1.

Table 1 Indicator system

Primary indicators	Secondary indicators	Tertiary indicators	Reference
Accessibility of Financial Service X1	Number of institutions Y1	Number of financial institutions Y11	Retrieved February 5, 2022, from http://data-cnki-net-s.vpn.dufe.edu.cn:8118/ValueSearch/Index?ky=%E9%87%91%E8%9E%8D%E6%9C%BA%E6%9E%84%E6%95%B0&datatype=year
		Number of monetary and financial service institutions Y12	
		The number of capital market service institutions Y13	
		Number of insurance institutions Y14	
		Number of other financial institutions Y15	
	Number of employees Y2	Financial industry practitioners Y21	
		Number of employees in monetary and financial services Y22	
		Capital market service industry practitioners Y23	
		Number of employees in the insurance industryY24	
		Other financial industry practitioners Y25	
Financial Services Participation X2	Deposit and loan amount Y3	RMB deposit amount of financial institutions in Dalian (CNY 100 million) Y31	Retrieved February 3, 2022, from http://data-cnki-net-s.vpn.dufe.edu.cn:8118/ValueSearch/Index?datatype=year&ky=%E5%AD%98%E8%B4%B7%E6%AC%BE%E4%BD%99%E9%A2%9D
		Dalian's financial institutions' RMB loan amount (CNY 100 million) Y32	
		RMB savings deposits of urban and rural residents in Dalian(CNY 100 million) Y33	
		Dalian urban and rural residents' per capita RMB savings deposits (yuan) Y34	
	Insured amount Y4	Dalian insurance density Y41	
		Dalian property insurance premium income (millions) Y42	
		Dalian life insurance income (millions) Y43	
		Dalian per capita property insurance (Yuan) Y44	
		Dalian per capita life insurance (Yuan) Y45	
Financial Services Involvement X3	Proportion of total deposits and loans of financial institutions to GDP Y5	Proportion of total loans of financial institutions in Dalian to GDP Y51	Retrieved February 13, 2022, from http://www-epsnet-com-cn-s.vpn.dufe.edu.cn:8118/index.html#/Index
		Proportion of total deposits of financial institutions in Dalian to GDP Y52	
	Insurance penetration Y6	Dalian life insurance depth(%)Y61	
		Dalian property insurance depth(%)Y62	

3. Principal component analysis

Principal component analysis (PCA) originated from a paper published by Hottling in " Educational Psychology " in 1933. Principal component analysis is a statistical method for data

simplification, which creates a set of new variables called principal components. Each principal component is a linear combination of the original variables, and all principal components are orthogonal to each other [7]. Since its birth, PCA has been applied to many fields, including biology, physics, engineering science, etc. PCA is a dimensionality reduction method for multivariate data sets. Without losing important information, it cleans data by identifying a small number of variables and summarizes and clarifies information in continuous multivariate data. In a sense, these variables summarize a large dataset. The steps of PCA dimension reduction are as follows:

Step1: Convert all variables to the same size after standardization of the range of continuous initial variables. $Z = \frac{value - mean}{stardard\ \ deviation}$ (1)

Step2: Calculation of covariance matrix to identify correlation covariance:

$$\begin{aligned} Cov(X,Y) &= E\left[(X - E[X])(Y - E[Y]) \right] \\ &= \mathrm{E}[XY] - 2E[Y]E[X] + E[X]E[Y] \\ &= \mathrm{E}[XY] - E[X]E[Y] \end{aligned} \quad (2)$$

The covariance matrix is:

$$\begin{bmatrix} Cov(x,x)\ \mathrm{Cov(x,y)}\ \mathrm{Cov(x,z)} \\ Cov(y,x)\ \mathrm{Cov(y,y)}\ \mathrm{Cov(y,z)} \\ Cov(z,x)\ \mathrm{Cov(z,y)}\ \mathrm{Cov(z,z)} \end{bmatrix} \quad (3)$$

Step3: Eigenvectors and eigenvalues of covariance matrix are calculated to identify principal components.

Step4: Create a feature vector to determine which main components are retained.

Step5: Principal component analysis recast data set. Enter the initial variable, select the principal component and form the feature vector to relocate the data from the original axis to the principal component representation axis. This step can be realized by multiplying the transpose of the original data set by the transpose of the feature vector.

4. Artificial Neural Network - Radial Basis Function

4.1. Artificial Neural Network

W.S.McCulloch and W.Pitts propose the earliest mathematical model of neural network, and its MCP model simulates the working mechanism of human neurons [8]. Artificial Neural Networks (ANN) simulates neuron activity by mathematical model, an information processing system based on imitating the structure and function of brain neural network. ANN is different from mapping a simple linear relationship, which realizes a mapping between different dimensions. Because of its parallel distributed processing, self-organizing, adaptive, self-learning characteristics, and robustness and fault tolerance have attracted wide attention in many disciplines.

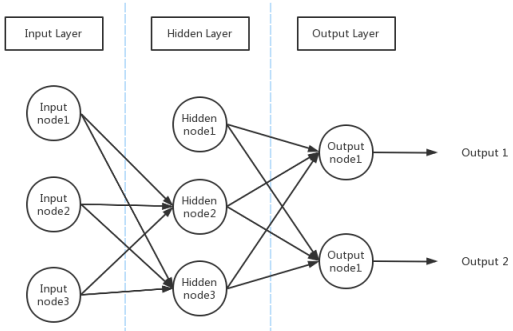


Figure 1 Artificial neural network model diagram

Artificial Neural Network (ANN) consists of three parts: Input Layer, Hidden Layer and Output Layer.

Step1: The input layer passes the formatted annotated data to the hidden layer after obtaining the true and complete initial data.

Step2: The hidden layer is named more than one layer because its neurons are not connected to the outside world. The hidden layer is responsible for calculating the data transmitted by the input layer and transmitting the data to the output layer.

Step3: The output layer mainly converts the data input by the hidden layer into a form for external cognition and completes the output of the results through calculation.

4.2. Radial Basis Function

The main ANN models include perceptron, multilayer mapping BP network, radial basis function (RBF) network, self-organizing feature mapping, (SOFM) network, and Hopfield network. RBF (Radial Basis Function) neural network, also known as radial basis function neural network, is a three-layer feedforward network with a single hidden layer proposed by Moody and Darke in the late 1980 s. It stimulates the neural network structure of local adjustment and mutual coverage in the human brain. It is a local approximation network [9]. It has the characteristics of simple structure, less calculation, fast convergence, and no local optimization. It is suitable for producing high-precision analysis results when the index system is small in scale. The basic principle of RBF is that for the input low-dimensional data, the high-dimensional hidden layer is formed through the nonlinear transformation of the radial basis function, and the hidden layer can realize the nonlinear mapping from input to output by linear transformation of output data

$$\phi(x,c)=\phi(\| x-c \|) \tag{4}$$

Where c is the center of the basis function, ‖ x-c ‖ is a distance measure, usually taken as Euclidean distance. The output of the network can be expressed as:

$$y_k^{(i)}=\sum_{i=1}^{m}\omega_{jk}\phi_j^{(i)}+\theta_k \tag{5}$$

ω_{jk} is the connection weight from hidden node j to output layer node k, Φj(i) is the output value of hidden node, θ_k is the threshold of output node k, and the matrix can be expressed as:

$$Y=\phi W,(\phi\in R^{P*(m+1)},W\in R^{S*(m+1)}) \tag{6}$$

$$Y=\begin{bmatrix} y_1^{(1)} & y_2^{(1)} & \cdots & y_s^{(1)} \\ y_1^{(2)} & y_2^{(2)} & \cdots & y_s^{(2)} \\ \vdots & \vdots & \ddots & \vdots \\ y_1^{(p)} & y_2^{(p)} & \cdots & y_s^{(p)} \end{bmatrix} \tag{7}$$

$$\phi=\begin{bmatrix} \phi_1^{(1)} & \phi_2^{(1)} & \cdots & \phi_m^{(1)} & 1 \\ \phi_1^{(2)} & \phi_2^{(2)} & \cdots & \phi_m^{(2)} & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \phi_1^{(p)} & \phi_2^{(p)} & \cdots & \phi_m^{(p)} & 1 \end{bmatrix} \tag{8}$$

$$W = \begin{bmatrix} \omega_{11} & \omega_{22} & \cdots & \omega_{ms} \\ \omega_{21} & \omega_{22} & \cdots & \omega_{ms} \\ \vdots & \vdots & \ddots & \vdots \\ \omega_{m1} & \omega_{m2} & \cdots & \omega_{ms} \\ \theta_1 & \theta_2 & \cdots & \theta_s \end{bmatrix} \tag{9}$$

5. Authentic Proof Analysis

5.1. Introduction of Research Objects and Data Collection

As a vice-provincial city in Liaoning Province, Dalian's gross regional product (GDP) has ranked first in the province for many years. Its contribution rate to the province's economic growth ranks first [9]. At the same time, inclusive financial development in its region is also valued by local governments. The higher level of development of inclusive finance in Liaoning Province is Shenyang and Dalian, and their inclusive financial index values are 0.72 and 0.64, respectively. The inclusive financial index of Dalian is lower than Shenyang, which is different from the regional GDP ranking. Therefore, this paper selects all kinds of financial service data in Dalian City, Liaoning Province, as an empirical case. The data comes from China' s economic and social big data research platform, Liaoning Province Statistical Yearbook, and China Insurance Regulatory Commission (EPS DATA) [11]. In order to improve the accuracy of the empirical results, this paper selects the data from 2009 to 2019 to verify the research accuracy and practical utility of the PCA-ANN-RBF model in measuring the comprehensive index of regional inclusive finance. SPSS is used for data dimension reduction and independent variable contribution analysis.

5.2. Data Dimension Reduction Based on PCA

Based on the data of various financial services in Dalian from 2009 to 2019, SPSS is used to reduce the dimension of PCA [12], and the FII index is obtained, as shown in Figure 2.

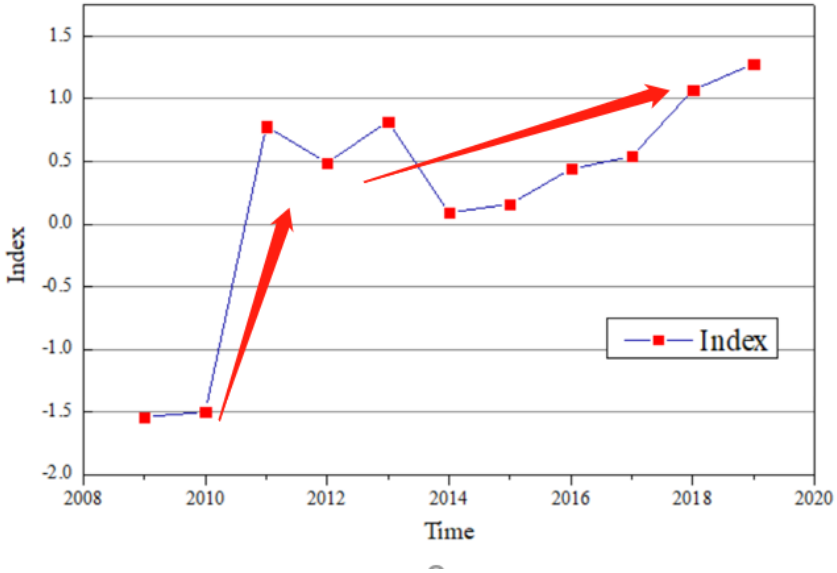


Figure 2 Index fluctuations

Figure 2 shows that after PCA dimension reduction, the index showed a fluctuating upward trend in 2009-2019. The index changed from negative to positive in 2010-2011, and there was a brief decline in 2012 and 2014, respectively. The peak values of the index appeared in 2009 and 2019, respectively. The lowest index was − 1.54, and the highest index was 1.28. The rise in the inclusive financial index reflects the gradual rise in inclusive financial development between 2009 and 2019. Among them, the 2008-2011 index rose much faster than after 2011, the line from steep to oblique gradually flat.

5.3. Contribution analysis based on RBF

The above dimension reduction data are used for contribution analysis by ANN [13], and the analysis of indicators reflecting the availability of financial services shows that among the number of institutions Y11 – Y15, the independent variable Y14 has the greatest impact on the availability of financial services (importance is 0.541), which belongs to the high importance index, the number of independent variables Y13, the importance of Y11, Y12 and Y15 in the capital market service industry are followed, and they are low importance indicators. Among the number of employees Y21 – Y25, the number of employees in the Y22 monetary and financial service industry is the most important (the importance is 0.322), followed by Y21 and Y25, and the three indicators all belong to the category of high importance. The two indexes are low importance indexes, and Y24 is higher than Y23.

Analysis of indicators reflecting financial service participation shows that Y32 is the only high importance indicator (0.465) among the four indicators of deposit and loan amount Y31-Y34, and its contribution ranks first., The importance of two to four are Y33, Y34, Y31. Three indicators are low importance indicators. Among the five indicators of insurance amount Y41 – Y45, the importance of Y42 is the highest among the important high indicators (the importance is 0.462), followed by Y44, and the importance of its low importance indicator is similar, which is in the order of Y41, Y43 and Y45.

The analysis of indicators reflecting financial service involvement shows that Y51 is a high-importance indicator (importance is 0.827) in the proportion of total deposits and loans of financial institutions in GDP, and its importance is stronger than that of low-importance indicator Y52. There are two dependent variables in the insurance depth index. Among them, Y62 is more important, which is a high importance index (importance is 0.757), and Y61 is a low importance index.

Based on SPSS, six ANN pieces of training are completed. The hidden layer function is sigmoid function, and the input layer is 4, 4, 3, 5, 2, and 2, respectively. The output layer is 1. The hidden layer is 13, and the output function is standardized. Among them, the test set mean square error of ANN training is 0.23, and the training set mean square error is 0.34. The specific contribution results are shown in Figure 3.

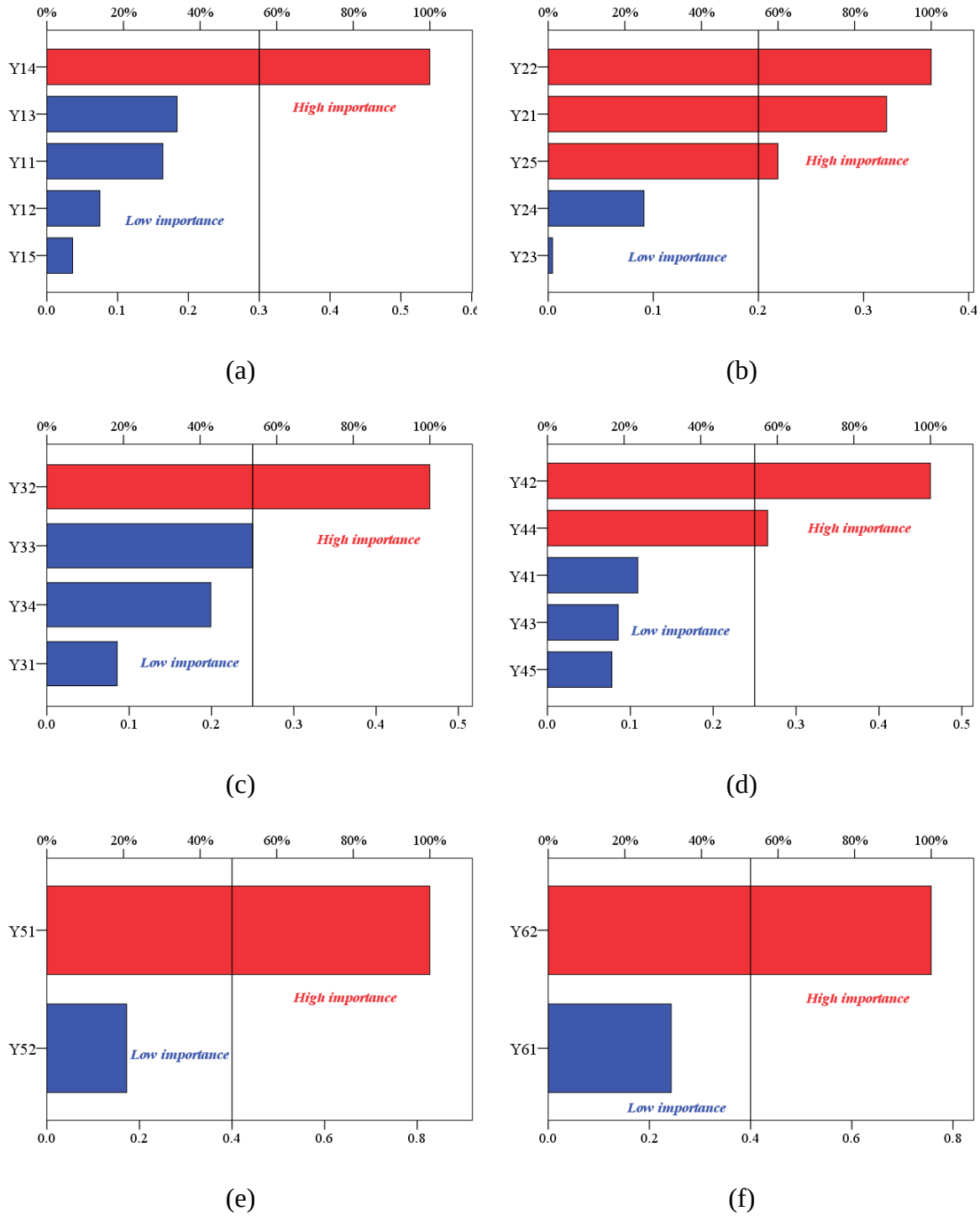


Figure 3. Importance of independent variables

5.4. Policy Proposal

Based on the above ANN training and analysis results, the number of insurance institutions in Y14, the number of employees in Y22 monetary and financial service industry, the number of RMB loans of financial institutions in Dalian City in Y32, the proportion of total loans of financial institutions in Dalian City in GDP in Y42, the premium income of property insurance in Dalian City in Y51, and the depth of property insurance in Dalian City in Y62 are the independent variables with the highest importance in their corresponding secondary indicators. Taking the above indicators as the foothold to improve the related policies may improve the effectiveness of inclusive financial development in Dalian City to a certain extent.

The specific policy recommendations are as follows :

We should vigorously promote inclusive finance, reserve talents for inclusive financial development, and increase the number of monetary and financial services employees. In order to improve the service ability of the monetary and financial services industry, it is necessary to make the masses and talents in the industry feel the importance of inclusive financial development. Starting from promoting inclusive financial knowledge, it will be gradually popularized in communities, schools and other units to attract high-quality financial talents.

Innovate the development model of inclusive finance, and enhance the proportion of total loans of financial institutions in Dalian to GDP. Focus on solving the contradiction that too large customer groups make the bank service ability is insufficient, and the bank is still the main channel of market credit. Expanding the online channels of financial outlets, using Internet technology online approval, intelligent monitoring, accurate description of small and micro enterprises and other inclusive subjects, accurate lending.

Improve the degree of national participation in insurance, focusing on improving insurance depth. The depth of insurance is positively correlated with individual disposable income, and negatively correlated with the Engel coefficient. The country vigorously develops the economy, improves the disposable income of residents, reduces the Engel coefficient, and helps residents increase insurance coverage and improve the insurance coefficient. At the same time, it strengthens the propaganda of personal and property insurance investment, maintains the stable demand for property insurance business, stabilizes the strength of personal insurance investment, and improves the depth of insurance.

6. Conclusion

(1) The index showed a fluctuating upward trend from 2009 to 2019, with high and low peaks in 2009 and 2019. Except for the two declines in 2012 and 2014, it was upward, reflecting the good development trend of inclusive finance.

(2) Among the dependent variable indicators, Y51 Dalian financial institutions loans accounted for the proportion of GDP, Y62 Dalian property insurance depth and the number of Y14 insurance institutions is the most important. To a certain extent, the above indicators can be used as the starting point and foothold of government agencies to formulate policies to help the development of inclusive finance in Dalian.

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