

A Study on the Impact of China's Digital Inclusive Finance on Green Finance in Guangdong Province Based on ANN-MLP Algorithm

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Abstract. Green financial markets and products play an essential role in financial support for high-quality development and the construction of ecological civilization as practical subjects for realizing a green economy. This paper selects Guangdong Province as the research object, and based on a total of 120 data on various indicators of green finance and digital inclusive finance in Guangdong Province from 2011 to 2020, it firstly establishes green finance and digital inclusive finance indicator system, and combines the neural network technology based on multi-layer perceptron (MLP) to build a prediction model of the impact of digital inclusive finance on green finance in Guangdong Province. After the model training and measurement, eight important diagrams of independent variables were finally obtained to illustrate the impact of digital inclusive finance on green finance respectively. This provides a theoretical reference for the government to introduce relevant policies to support the development of digital inclusive finance and green finance.

Keywords: ANN-MLP algorithm; Guangdong Province; Green finance; Digital inclusive finance.

1. Introduction

The progress of digital technology drives the development of inclusive finance, and the inclusive finance achieved by relying on digital technology is called digital inclusive finance. At present, China's digital inclusive financial system is forming an all-around development pattern with banking financial institutions as the core, Internet enterprises as the support, non-bank financial institutions as the supplement, and financial technology enterprises as the empowerment. The infrastructure is constantly improving, and the system guarantee is sound. However, the attitude of traditional financial institutions toward the development of inclusive finance is hot on the outside but cold on the inside. Mainly because of geographical constraints, traditional institutions have to bear high costs when providing financial services to inclusive groups, which contradicts the profit-seeking nature of financial institutions. Therefore, a green and low-carbon model that balances environmental, social and economic benefits has become the central theme in the stage of high-quality economic development. In recent years, inclusive finance has been used to expand the coverage group of financial services, reduce enterprises' financing constraints, and optimize the efficiency of total factor resource allocation through a series of information technology tools. This inclusive, digital and technology-based approach to financial services has solved the problem of green finance being unable to achieve effective coverage when faced with traditional financial services, and promoted the efficient development of green finance, which has important theoretical and practical significance for the integration and development of both.

As the most dynamic area in the development of China's financial system, the inclusive nature of digital inclusive finance helps to alleviate the financing discrimination of the traditional financial system and improves the efficiency and fairness of financial services. At the same time, it has played an important role in boosting investment and promoting consumption. Regarding regional differences, the economic disincentive effect of digital inclusive finance is more pronounced in areas with low-

value economic bases, low-value industrial structure bases and high-value innovation capacity areas. From the perspective of the transmission mechanism, the development of digital inclusive finance has promoted the transformation and upgrading of industrial structure in the central region and advanced industrial structure development, thus alleviating the inhibiting effect of digital inclusive finance on economic growth.

In the past few years, China's digital finance has made great development and has had a great impact globally [1]. However, there has been a lack of an indicator system to measure its overall development level. The issue of measuring and influencing factors of inclusive finance has been a hot topic of research, among which the most representative ones are Sarma and Pais [2]. They first adopt the method of calculating HDI by the United Nations Development Programme measured the inclusive finance development index of 45 countries, but did not study the influencing factors. Jing Wang and Guohui Hu [3] selected three dimensions of penetration, accessibility, and actual usage to construct an inter-provincial financial inclusion index system in China. They analyzed the factors affecting financial inclusion using OLS regression, showing that financial accessibility, macroeconomics, and income disparity significantly affect financial inclusion. Zhang Guojun et al. [4] measured the difference in financial inclusion between the East and West regions of China under the new normal. Factors such as income level, urbanization factor and geographical environment can improve the level of financial inclusion and reduce financial exclusion. A more representative one is the Peking University Digital Financial Inclusion Index (2011~2015), released by the Center for Internet Finance Research of Peking University in 2016, which is based on the data support of Ant Financial Services. After collecting data on digital financial inclusion in China, the researchers constructed 24 indicators in three dimensions of Internet financial services: breadth of coverage, depth of use, and digital support services. The indicator system provides research ideas and authoritative data support for the research in this field. Song [5] directly used this indicator system to study the positive effect of digital inclusive finance in narrowing the urban-rural income gap.

However, the large body of literature looks at the one-way impact of each factor on financial inclusion. It ignores the cumulative effect of financial development, i.e., the current form of the financial economy tends to be influenced by prior financial development. There are two main problems. First, the quantitative study of digital inclusive finance index is insufficient, the methods of determining the weights of each indicator remain divergent, and the results may not reflect the real situation. Second, when constructing the regression indicator system, the impact of financial lag on digital inclusive finance is ignored, so the lag index is not considered in the model.

In this paper, we use the powerful nonlinear mapping ability and generalization ability of ANN algorithm, train it with samples to realize the mapping from input space to output space, conduct a detailed analysis of various factors affecting digital inclusive finance on green finance, so as to achieve the purpose of time series prediction, and further explore the impact of digital inclusive finance on green finance. This paper provides a theoretical reference for the government to make the right economic decisions. It is conducive to the government's formulation of corresponding policies for developing inclusive finance and green finance, which will enhance the quality and efficiency of economic development and promote the high-quality development of a green and low-carbon economy.

2. Dependent variable indicator system-Green finance

There are two broad definitions of green finance, narrowly defined as the desire to determine what percentage of a given financial asset is green. Some measures are procedural, such as "environmental, social and governance" management. In contrast, others are industry standards for priority green industries, such as renewable energy, recycling, waste management and environmental protection. The focus is on assessing the state of the environment and identifying priority industries and technologies for green finance support.

A broad definition is the desire to define the overall objectives of the financial system in terms of sustainability and propose methods to measure its effectiveness. The focus is on the financial system as a whole and macroeconomic stability [6] by setting financing criteria according to the objectives of the financial system and by allocating capital effectively and efficiently to environmental risks.

Currently, there are important differences in the definition of "green finance" between developed and developing countries. The former is more concerned with climate and considers future climate change and the corresponding technological adjustments as the main risk factors for financial institutions. In developing countries such as China, investments are considered "green finance" as long as they can save fossil energy use and reduce energy consumption per unit.

In view of the fact that most of the existing studies are qualitative cases and there is a lack of systematic research on the development of green financial markets at home and abroad[7], we refer to the existing methods of constructing green financial product indices at home and abroad as well as their advantages and disadvantages, and derive the elements covered by the green financial indices[8]. The details are shown in Table 1.

Table 1 Green Finance Indicator System

Tier 1 Indicators	Secondary indicators	Indicator code	Data source	Calculation method
Social Development Indicators	Green Investment	X1	Mark Data Network	Investment in environmental pollution control as a percentage of GDP
	Government Support	X2	Mark Data Network	Financial environmental protection expenditure/general government budget expenditure
Market Development Indicators	Green Credit	X3	Mark Data Network	Bank of China credit balance
	Green Bonds	X4	WIND	Number of bonds issued
	Green Insurance	X5	Mark Data Network	Agricultural insurance income / total agricultural output
	Green Fund	X6	WIND	Number of funds issued
	Carbon Finance	X7	Carbon trading	Carbon market trading volume (amount)

3. Independent Variable Indicator System-Digital Inclusive Finance

3.1. Definition of Digital Inclusive Finance

The GPMI white paper, "Global Standard Setting Bodies and Inclusive Finance - The Evolving Landscape," developed at the 2016 G20 Hangzhou Summit, is a more representative definition of digital inclusive finance. Digital Inclusive Finance is a general reference to all actions that promote financial inclusion through digital technology. Its essence is still finance, a product of the intensive development of modern digital technologies such as big data, cloud computing, and inclusive finance. As a powerful complement to the traditional financial system, digital inclusive finance has the advantages of "low cost, high speed, and wide coverage". It can promote green TFP by optimizing capital allocation and reducing or even limiting the flow of resources to high-polluting industries and enterprises [8].

3.2. Overview of the impact of digital inclusive finance on green finance

(a) Digital inclusive finance serves the development of green economy by promoting technological innovation Science and technology innovation promote the development of green economy mainly through the following aspects: First, technological innovation can promote a large number of pollution prevention, energy-saving and ecological protection technologies to be widely used in the

process of production and environmental management, thus promoting the development of green economy. Second, technological innovation has promoted the rapid development of a large number of green, energy-saving, and environmentally-friendly equipment manufacturing enterprises, which has increased China's new economic growth points and thus promoted green economic development through rapid industrial structure optimization and upgrading. Third, technological innovation makes a large number of energy-saving and environmentally friendly green products into life, profoundly promoting people's clothing, food, housing and transportation to green, low-carbon direction, thus promoting the development of green economy.

(b) Digital inclusive finance serves green economic development by allocating funds to green enterprises. Green enterprises need to green their traditional production methods to achieve energy saving, emission reduction and efficient production methods, which requires a large amount of capital investment, while the return risk of green transformation is relatively high. Digital inclusive finance uses big data technology to reduce the information asymmetry between green enterprises and financial institutions. The elimination of information asymmetry reduces the risk of financial institutions, which are willing to allocate more funds to green enterprises, effectively solving the problem of difficult and expensive financing for green enterprises, so that green enterprises can obtain financial funds at a lower cost and successfully realize the transformation of green production methods.

(c) Digital inclusive finance serves the development of green economy by promoting consumption level improvement and green consumption guidance. Digital inclusive finance enhances the ability of financial institutions to evaluate and manage customer risks, enabling low-income groups and small, medium and micro enterprises in remote areas to access digital inclusive finance services, effectively stimulating the enthusiasm of local innovation and entrepreneurship, and promoting the improvement of residents' income, which in turn enhances their consumption ability. In addition, the development of digital inclusive finance has greatly eased the liquidity constraints of a large number of consumers, enabling them to more easily convert their investments and savings into consumption, lowering the cost of consumption and thus stimulating consumption. The process of improving consumption ability is often accompanied by upgrading consumption structure, coupled with the guidance of government and public opinion on green consumption. More consumption will be concentrated on green products, thus promoting the development of green enterprises from the demand level, thus promoting the development of green economy. Specific indicators are shown in Table 2.

Table 2 Digital Inclusive Finance Indicator System

Data Metrics for Digital Inclusion	Indicator code	Data source	Calculation method
Total Index	Y1	Digital Finance Research Center, Peking University	Developed by Digital Finance Research Center, Peking University
Breadth of coverage	Y2		
Depth of use	Y3		
Degree of digitization	Y4		

4. ANN-MLP Model

4.1. Construction of Artificial Neural Network Model

Artificial Neural Network (ANN) is a brain-type intelligent information processing system that is widely interconnected by many neurons and aims to imitate the structure and function of the human brain. Based on the knowledge of network topology, it is the abstraction, simplification and simulation of human brain nervous system.

As the basic unit of artificial neural networks, neurons are multi-input and single-output nonlinear components. Neurons are used to process the information transmitted in the neural network, and are connected by weights. A neuron receives the information of all the outputs connected to it as its input,

uses the activation function to calculate the corresponding output, and then transmits the output to other neurons[9].

Artificial neural network has the advantages of large-scale parallel, distributed storage and processing ability, fast computing speed, strong fault tolerance, and high self-learning ability. In a complex environment with vague information, incomplete information and contradictions, neural networks can complete all kinds of problems well by virtue of its self-learning ability, and establish a comprehensive evaluation model closer to the combination of qualitative and quantitative human thinking modes.

This paper uses ANN's powerful nonlinear mapping ability and generalization ability to train samples to realize the mapping from input space to output space to achieve the purpose of time series prediction and explore the impact of inclusive finance on green finance.

4.2. Construction of Multi-layer Perceptron model

Multi-layer Perceptron (MLP) is an artificial neural network with a forward structure that contains at least one hidden layer consisting of a fully connected layer. The outputs of each hidden layer are transformed by activation functions, mapping a set of input vectors to a set of output vectors.

By adding a hidden Layer and activation function, multi-layer perceptrons can approach the wanton function, express the nonlinear problem as a linear problem with higher dimensions, and overcome the weakness that perceptrons cannot identify inseparable linear data. It consists of three parts: The bottom layer is the input layer; The middle is the hidden layer, which can have multiple; Finally, the output layer. It can be regarded as a directed graph consisting of multiple node layers, each fully connected to the next layer. Each node is a neuron with a nonlinear activation function but not the input node.

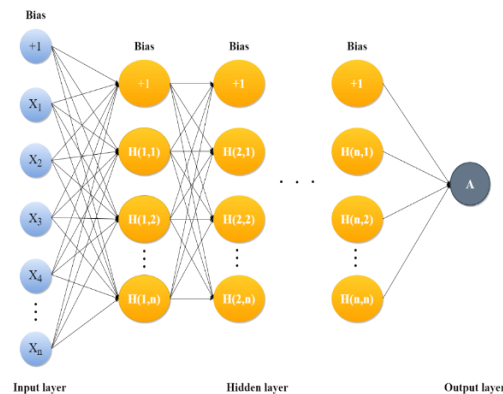


Fig 1. MLP diagram

Both MLP and RBF are feed forward artificial neural networks, which can well solve the problem of pattern classification and generalize the imprecise input data. Compared with RBF, which has advantages in prediction ability and operation speed, MLP has the disadvantages of difficulty in selecting the number of hidden nodes, slow learning speed, easy falling into local minimum and insufficient learning[10]. However, the characteristics and advantages of MLP are also obvious. RBF only responds to the limited part of the input space. Although the training speed is fast and simple, it usually requires a lot of hidden nodes and is sensitive to the dimension[11]. MLP is a more distributed method that requires fewer training samples and can directly establish a prediction model by learning the actual data without understanding the complex mechanism.

The supervised learning method of the Back Propagation algorithm is used to train the multi-layer perceptron, and the steps are as follows[12]: first, forward propagation. Firstly, the output function is used to calculate the final error of the model according to the given data. Second, reverse propagation. The error is passed back forward layer by layer to obtain the error of each neuron. Finally, the error of each neuron in each layer is derived from the weight and bias, and the weight of each neuron is adjusted. The optimal solution of weight and bias is obtained iteratively, and the specific function

mapping relationship is established to construct the optimal neural network model with the minimum loss function.

The predicted output function y is

$$y = f\left(\sum_{i=1}^n w_i x_i + b\right) \quad (1)$$

Among them, the weight ; for the input vector ; for bias.

The error function δ is

$$d_k = (t_k - y_k)f(y_{ink}) \quad (2)$$

Where $f(\bullet)$ is the nonlinear activation function; t_k is the k th given target value; y_k is the k th forecast output value.

5. Empirical Analysis

5.1. Study subjects and data collection

Due to the relatively late start of China's carbon finance market, pilot projects in two provinces and five cities, including Beijing, Shanghai, and Guangdong, began in 2011. Therefore, considering the availability of carbon finance index data in green finance indicators, this paper selects Guangdong Province as the research object. After collecting and using multiple imputation methods to fill in a small number of missing values, and using the average value of green finance subdivision indicators to measure the overall green finance index, the article finally obtained a total of 120 pieces of data on various indicators of green finance and inclusive finance in Guangdong Province from 2011 to 2020. Make a standardized heat map, as shown in Figures 2 and 3.

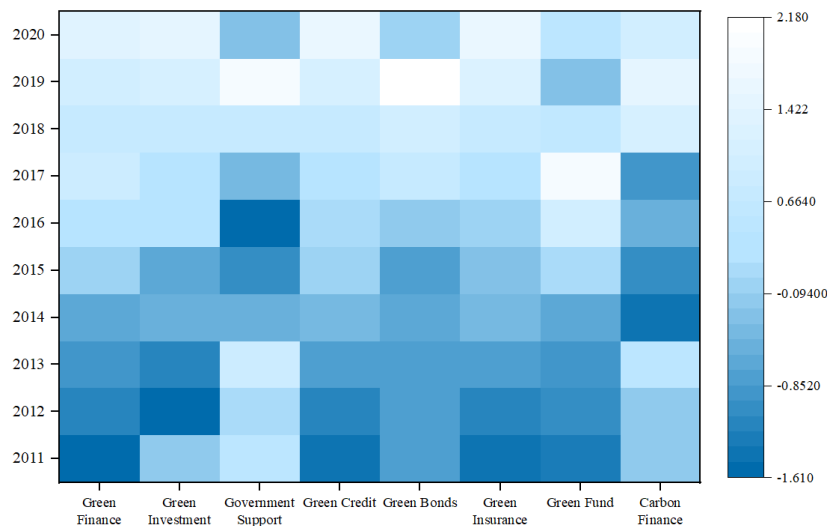


Figure 2 Green finance data

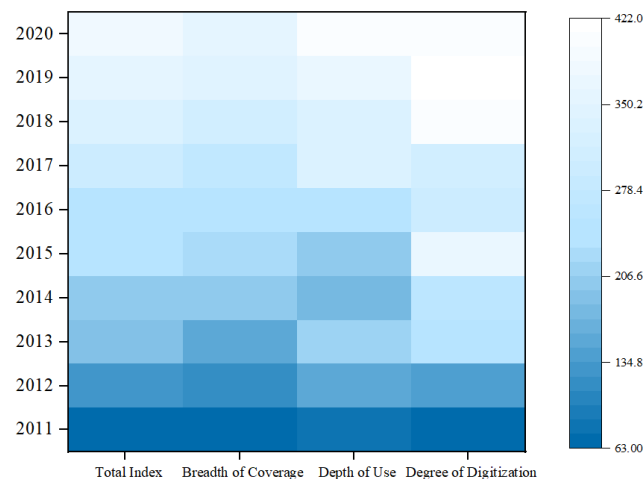


Figure 3 Inclusive finance data

As can be seen from Figure 2, the overall green finance index (X1-X7) is increasing year by year, among which green investment (X1), green credit (X3), green bonds (X4), green insurance (X5) and green funds (X6). The overall change trend of the five indicators converges with the overall index. The values of government support (X2) and carbon finance (X7) indicators first decreased and then increased. Considering that carbon finance is not yet market-oriented, it is more dependent on government policy guidance and promotion, so the convergence between the two is reasonable. In addition, there is a process of digestion and run-in in the market for the introduction of carbon trading, so there will be a trend of the first decrease and then an increase.

As can be seen from Figure 3, the changes in the overall financial inclusion index (Y1) and the coverage (Y2), the depth of use (Y3), and the degree of informatization (Y4) have increased year by year.

5.2. ANN calculation

This paper establishes a three-layer neural network model including input, hidden, and output layers for training. The input layer of the model is set to 4 nodes, corresponding to the four indicators of digital financial inclusion. In order to ensure the best performance of the network system, the hidden layer is set to 7 nodes, the output layer is the total index of green finance and seven subdivision indicators, and a 4-7-1 three-layer feedforward-reverse optimal neural network model is constructed. And use Relative Error to measure the error size of training and prediction. The collected data set is divided into the training set and testing set according to the year, of which the samples from 2011 to 2016 are the training set, and the samples from 2017 to 2020 are the testing set. The model base learning rate is set to 0.1, and the number of training iterations is 500.

The model prediction results are biased, as shown in Table 3, and the Relative Errors are all within an acceptable and reasonable range.

Table 3 Relative Error of ANN model

Output	Training set Relative Error	Testing set Relative Error
X1	9.1%	1.4%
X2	6.3%	10.6%
X3	2.1%	0.4%
X4	13.7%	8.1%
X5	15%	1.1%
X6	6.4%	6.5%
X7	4.3%	3.2%
X1-X7	17.1%	13.2%

5.3. Analysis and Conclusion

After model training and calculation, the eight independent variable importance maps shown in (a)-(h) in Figure 4 are finally obtained:

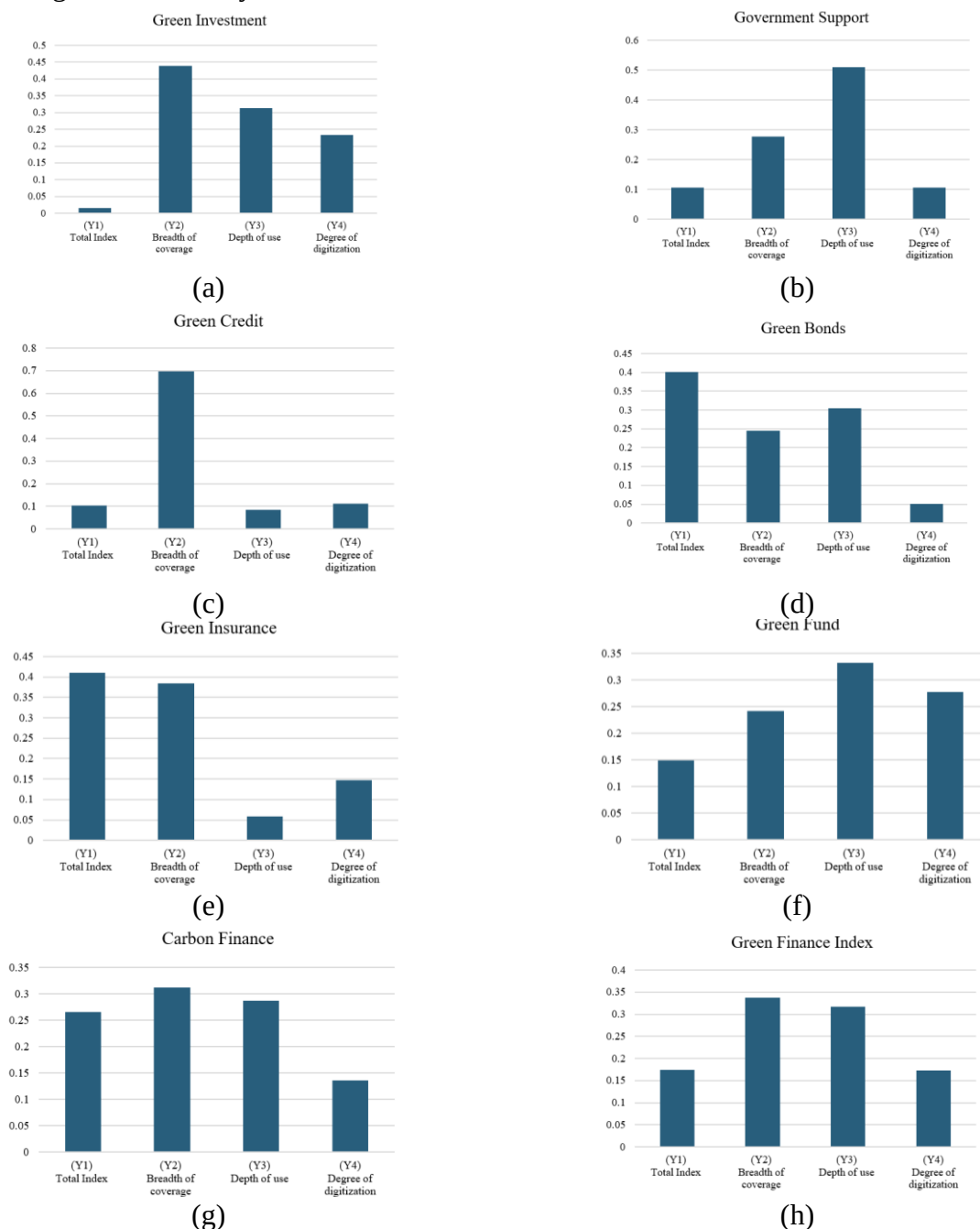


Figure 4 Illustration of the importance of independent variables

The graph (a) shows that the breadth of coverage has the greatest impact on the green investment indicator (0.438). Environmental pollution investment is usually directed to multiple areas to be treated, and the concentration is small. Therefore, when the coverage of inclusive finance is high, it is conducive to the effective flow of funds to all areas. Figure (b) shows that the depth of use has the greatest impact on government support (0.510). This result aligns with the digital government proposal put forward in the Outline of Vision 2035. It is necessary to deepen the digital applications in the financial field, and use emerging technologies such as big data and blockchain to promote scientific decision-making, so as to realize the transformation from virtual to real. Figure (c) shows that green credit is mainly affected by the breadth of use (0.698), and the effect is much higher than the other three indicators. Green credit is a vital financing channel for small and micro enterprises to

carry out green transformation and contribute to the "dual carbon" goal. The extension of digital finance will help commercial banks to further expand capital investment, and use information technology to scientifically measure corporate leverage and financing capabilities to achieve green Credit "should be fully loaned", enabling the capital market to effectively stimulate the vitality of the green transformation of the real economy. Figure (d) shows that, for green bonds, the development of the digital financial inclusion aggregate index has the greatest impact (0.401). In recent years, the rapid development of China's green bond market has become an important way for enterprises to demonstrate their social responsibility and raise funds. The overall development of inclusive finance is conducive to private enterprises, small and micro enterprises, and other vulnerable groups in the market to expand green bonds and other emerging financing methods with lower interest rates.

Figure (e) shows that green insurance is greatly affected by the overall index (0.410) and coverage breadth (0.384). Green insurance is currently in the ascendant stage, and it is a management method for enterprises to deal with environmental risks. Green insurance has a huge unexploited market space, and may become an important risk control investment for companies with hidden environmental risks. The expansion of the coverage of digital inclusive finance will help enterprises in need to contact and choose green insurance products that suit them, and evaluate their own risks by digital means. Figure (f) shows that the depth of use (0.332) and the degree of digitization (0.277) have a significant impact on green funds. The increased use of inclusive finance can enable more residents in the sinking market to access green fund products and broaden the financing channels for residents. The level of digitalization will affect the convenience of green fund purchase and redemption, and the speed and reasonableness of market response. The expectations were right and wrong and the product mix was reasonable. It is foreseeable that with the development of digital inclusive finance, green funds will expand the investment pool of private funds and become an important investment asset. Figure (g) shows the impact of carbon finance. The total index (0.265), breadth (0.312) and depth (0.287) are all important impact indicators. The development of the carbon market has a long way to go, and deepening the construction of inclusive finance will help the carbon market cover more small and medium-sized enterprises with carbon reduction and carbon trading needs, and achieve the goal of "double control" of total carbon emissions and intensity. Figure (h) shows the impact of financial inclusion indicators on the overall green finance index. The overall index is relatively average, and the four financial inclusions all account for a large share.

6. Conclusion

Firstly, this paper establishes a comprehensive multi-level index system by carrying on the induction and reorganization to the relevant research at home and abroad. Then, combined with MLP-based neural network technology, the prediction model of the impact of digital inclusive finance on green finance in Guangdong Province is constructed, and the internal nonlinear mapping relationship between digital inclusive finance and green finance in Guangdong Province is revealed. At the same time, the empirical research verifies that the model runs faster and has higher prediction accuracy and validity, which provides a new idea and method for the development of green finance. The results are as follows :

Green finance indicators are most affected by the coverage breadth. In order to further deepen the coordinated development of inclusive finance and green finance, and enhance the role of digital inclusive finance indicators in promoting green finance, efforts should be made to strengthen the construction of digital inclusive finance breadth. Use economies of scale to help green finance.

Depth of use has the greatest impact on government support. In order to ensure that government spending actually falls into the needed investment areas, digital applications in the financial sector should be further deepened and the digital development of finance accelerated. The government should focus on promoting the deep integration of the digital economy and the real economy, enhancing the digital intelligence of public services and social governance to create an internationally competitive digital industry cluster.

The impact of financial inclusion indicators on the overall green finance index is relatively average. This indicates that the government's coordination of the comprehensive and coordinated development of inclusive finance will be conducive to the overall enhancement of green finance, achieving rational allocation and utilization of resources through the regulation of capital flows, and contributing to the sustainable development of society.

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